

# INTERDISCIPLINARY DESCRIPTION OF COMPLEX SYSTEMS

## Scientific Journal

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## INTERDISCIPLINARY DESCRIPTION OF COMPLEX SYSTEMS

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# ROBUST SLIDING MODE CONTROL FOR FLEXIBLE JOINT ROBOTIC MANIPULATOR VIA DISTURBANCE OBSERVER

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## ABSTRACT

In a flexible joint robotic manipulator, parametric variations and external disturbances result in mismatch uncertainties thus posing a great challenge in terms of manipulator's control. This article investigates non-linear control algorithms for desired trajectory tracking of a flexible manipulator subjected to mismatch perturbations. The manipulator's dynamics is derived based on Euler-Lagrange approach followed by the design of nonlinear control laws. The traditional Sliding Mode Control and Integral Sliding Mode Control failed to demonstrate adequate performance due to complex system dynamics. Disturbance Observer-based Sliding Mode Control has been thoroughly examined by defining a novel sliding manifold. The aforementioned control laws are designed and simulated in MATLAB/Simulink environment to characterize the control performance. Results demonstrated that the proposed Disturbance Observer-based Sliding Mode Control scheme over-performed on Sliding Mode Control variants and had three prominent features: robustness against mismatch uncertainty, improved chattering behaviour and ability to sustain nominal control performance of the system.

## KEYWORDS

robotics, automation, modern control, flexible joint manipulator

## CLASSIFICATION

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## INTRODUCTION

In the recent decade, the desired trajectory tracking problem of flexible joint robotic manipulator got considerable attention in the scientific community. Numerous control strategies have been investigated to address the aforementioned problem, most of which assume torque as an input to the system, thus excluding actuator dynamics. However, the actuator dynamics is an essential component of an electromechanical system which must be considered in system modelling [1, 2].

Spong in [3], presented a dynamic model of a flexible joint manipulator, which instigated many researchers to carry out studies on its desired trajectory tracking problem. Various reported control methods to address this tracking problem are based on both linear and nonlinear control laws. In [4], the effects of joint flexibility on the dynamic response of flexible joint manipulator are studied. In [5], the trajectory tracking control of the manipulator is presented using Proportional Integral Derivative (PID) Controller with state feedback control law. Sliding Mode Control (SMC) based adaptive law for a flexible joint manipulator with parametric uncertainty is presented in [6]. Nguyen et al. [7] designed a robust position and vibration control approach for an elastic manipulator with actuator perturbation. Some prominent laws explored in literature to control the manipulator include; Integral control approach [8], adaptive feedback linearization methodology [9], the singular perturbation scheme [10], fuzzy error governing approach for counteracting the actuator saturation [11] and Proportional Derivative (PD) based control method [12]. In [13, 14], adaptive backstepping based control algorithms are designed for a flexible joint manipulator with varying parameters to control the desired trajectory. In [15], adaptation based controller is designed for the trajectory tracking problem of a flexible joint manipulator with varying parameters. Iterative regulation of an electrically driven manipulator with unknown payload and parametric model variation is developed in [16].

To the best of authors' knowledge, little attention has been paid in the literature towards the inclusion of actuator dynamics and designing of observer-based control scheme for a flexible joint manipulator with mismatch perturbations. Thus instigated by the literature, the SMC based non-linear control approaches with Disturbance Observer (DO) are presented in this article for desired trajectory tracking of the manipulator with the inclusion of actuator dynamics as well as mismatch perturbations. The mismatch perturbations must be non-vanishing and are not necessarily  $H_2$  norm bounded.

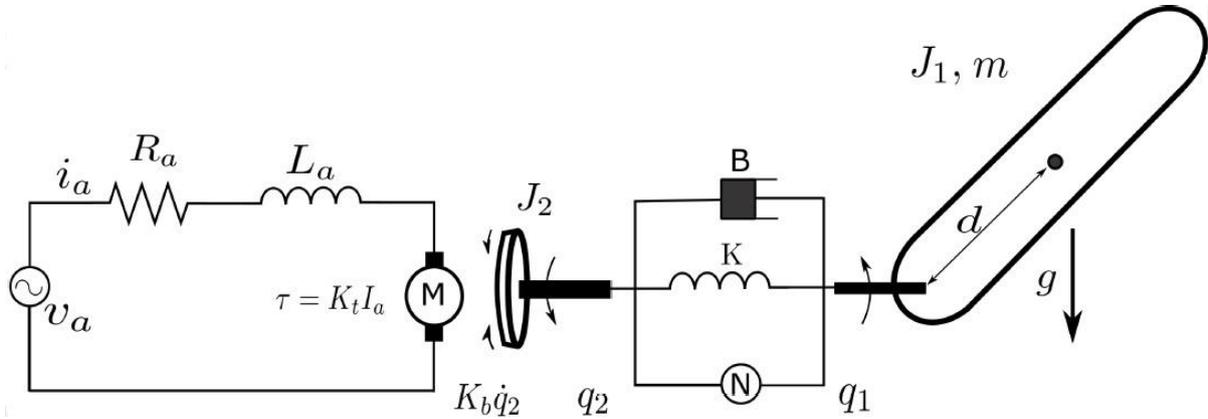
SMC is gaining popularity in various scientific applications owing to its computational simplicity and excellent robust nature [17-20]. However, the sliding manifold in SMC is only focused on the alleviation of match uncertainties. Thus, the matching condition may not be satisfied by certain uncertainties present in the practical systems and hence the traditional SMC would not work anymore [21]. In SMC, the chattering problem is still a concerning issue which needs to be handled. For this reason, an Integral SMC is preferred. It is verified that Integral SMC is more practical and robust as compared to SMC [22]. However, in Integral SMC, integral action in the sliding surface brings some adverse effects such as high overshoot and degradation of nominal control performance. It means that Integral SMC scheme counteracts mismatch perturbations by compromising on system control performance.

To tackle the situation, a state of the art non-linear disturbance observer based SMC algorithm is developed for the trajectory tracking problem of the manipulator. By investigating a novel sliding manifold based on estimated disturbance, the system trajectory can be asymptotically driven to the desired equilibrium point, while counteracting the mismatch perturbations. The novelty of the proposed control scheme lies in its excellent robust nature to handle the mismatch uncertainty while retaining good nominal control performance and the capability to substantially mitigate the undesirable chattering problem.

This article is organized into following sections: In section II, mathematical modelling of a flexible joint manipulator is presented. Control strategies with stability analysis are developed in section III. Section IV covers simulation results and discussion. Finally, section V comments on the conclusion.

## MATHEMATICAL MODELLING

A flexible joint manipulator is an electromechanical system in which the manipulator's link is connected to the actuator's shaft. The system is actuated with a DC motor with voltage as the input. The output is the position of the manipulator's end effector which can freely move around its x-axis. At the joint, the actuator's shaft is connected to the manipulator's link through a chain of gears which possess flexibility. Due to this flexibility at the joint, undesirable oscillations are produced which prevent the end-effector from precisely tracking the desirable position. The flexibility is portrayed as a linear torsion spring which is depicted as the combined effect of damping factor, spring constant and opposing force [3]. The graphical view of a flexible joint manipulator is shown in Figure 1.



**Figure 1.** Block diagram of the flexible joint manipulator.

Dynamics of the electromechanical system is modelled using Euler-Lagrange equation in [23, 24], which are as follows:

$$J_1 \ddot{q}_1 + mgh \sin(q_1) + k(q_1 - q_2) = 0 \quad (1)$$

$$J_2 \ddot{q}_2 - k(q_1 - q_2) + B_d \dot{q}_2 = k_t I_a \quad (2)$$

$$u = R_a I_a + L_a \frac{dI_a}{dt} + K_b \dot{q}_2 \quad (3)$$

The description of the system parameters is listed in Table 1.

**Table 1.** System parameters and values.

Parameter	Symbol	Value	Unit	Parameter	Symbol	Value	Unit
Mass of link	$m$	1	kg	Length of link	$h$	0,5	m
Gears ratio	$N$	1	-	Gravitational acceleration	$g$	10	m/s <sup>2</sup>
Armature resistance	$R_a$	1.6	$\Omega$	Link moment of inertia	$J_1$	1	kg·m <sup>2</sup>
Motor torque constant	$k_t$	0,2	N·m/A	Motor shaft moment of inertia	$J_2$	0,3	kg·m <sup>2</sup>
Back EMF constant	$B$	0,001	N·m·s/rad	Armature inductance	$L_a$	0,001	H
Stiffness of joint	$K$	14	N·m/rad	Control input	$u$	-	V

**ASSUMPTION 1.** Certain parameters in (1), (2) and (3) are assumed to be time variant and can be written as  $J_{2,d}(\cdot) = J_2 + \Delta J_2(t)$ ,  $B_{-d}(\cdot) = B + \Delta B(t)$  and  $k_{t,d}(\cdot) = k_t + \Delta k_t(t)$ .

**REMARK 1.** The system parameters, described in assumption 1, are the combination of nominal and uncertain parts. The assumption made is pretty reasonable in case of practical applications. The parameters show uncertain behaviour around their nominal values due to the external environmental impacts. This is the reason that dynamics of the system (1), (2) and (3) is incorporated with such assumption.

The non-linear dynamical equations of the flexible joint manipulator can be represented in state space form as:

$$\dot{x}_1 = x_2 \quad (4)$$

$$\dot{x}_2 = -\frac{mgh}{J_1} \sin(x_1) - \frac{k}{J_1} (x_1 - x_3) \quad (5)$$

$$\dot{x}_3 = x_4 \quad (6)$$

$$\dot{x}_4 = \frac{k}{J_2} (x_1 - x_3) - \frac{B}{J_2} x_4 + \frac{k_t}{J_2} x_5 + \zeta(x, t) \quad (7)$$

$$\dot{x}_5 = -\frac{R_a}{L_a} x_5 - \frac{k_b}{L_a} x_4 + \frac{1}{L_a} u \quad (8)$$

$$y = x_1 \quad (9)$$

where  $[x_1, x_2, x_3, x_4, x_5, ] = [q_1, \dot{q}_1, q_2, \dot{q}_2, I_a]$ , which represent angular position and angular velocity of manipulator's link, angular position and angular velocity of motor's shaft and the motor armature current respectively.  $y$  is the system output, while  $\zeta(x, t)$  represents the mismatch perturbation caused due to parametric variation, un-modelled dynamics and external disturbances.

**ASSUMPTION 2.** The mismatch perturbation in the system (4) – (9) is norm bounded and must satisfy  $\zeta^* = \lim_{t \rightarrow \infty} |\zeta(x, t)|$ , where  $\zeta^*$  is the upper bound of the mismatch uncertainty.

## SMC BASED NONLINEAR CONTROL APPROACHES

The SMC based nonlinear control approaches are discussed as follows:

### CONVENTIONAL SLIDING MODE CONTROL

SMC plays a vital role in the theory of variable structure system. It is a non-linear robust control algorithm, which has significant advantages in the field of control engineering [25]. The most prominent feature of SMC is the enforcement of the system's trajectories onto a defined switching manifold which is called a sliding or switching surface. Once the system trajectories reach the defined manifold, the configuration of the controller is then altered continuously to keep the states on the switching surface. SMC scheme exhibits insensitivity to parametric variations, un-modelled system dynamics and external disturbances. Besides offering the salient features, the high frequency switching along a sliding manifold results in the so-called chattering phenomena, which is the inherent property and is thus considered as the main limitation of SMC [26].

Sliding manifold for the system (1)-(3) is given as;

$$s = \left(\frac{d}{dt} + c\right)^{n-1} z \quad (10)$$

where  $c$  is a constant switching parameter i.e.,  $c > 0$ .  $n$  is the system relative degree and  $z$  is the error variable, which can be expressed as,

$$z = y - x_d = x_1 - x_d \quad (11)$$

As the system has full relative degree i.e. = 5, so the sliding manifold (10) can be expressed as,

$$s = \frac{d^5 z}{dt^5} + 4c \frac{d^4 z}{dt^4} + 6c^2 \frac{d^3 z}{dt^3} + 4c^3 \frac{d^2 z}{dt^2} + zc^4 \quad (12)$$

Taking derivatives of (12) and substituting (4)-(9) in (12), the surface manifold can be expressed as,

$$\dot{s} = \psi + \frac{kk_t}{J_1 J_2 L} u + \left( \frac{4ck}{J_1} - \frac{Bk}{J_1 J_2} \right) \zeta(x, t) \quad (13)$$

where the notation  $\psi$  is used for the sake of brevity and can be expressed as,

$$\begin{aligned} \psi = & c^4 x_2 + 4c^3 \dot{x}_2 + 6c^2 \ddot{x}_2 + 4c - c^4 \dot{x}_d - 4c^3 \ddot{x}_d + 6c^2 \ddot{\ddot{x}}_d - 4c \frac{d\ddot{x}_d}{dt} - \\ & \frac{d\ddot{x}_d}{dt} \left( -\frac{mgd}{J_1} \cos(x_1) \dot{x}_2 + \frac{mgd}{J_1} \sin(x_1) x_2^2 + \frac{2mghk}{J_1^2} \sin(x_1) + \frac{k^2}{J_1^2} (x_1 - x_3) + \right. \\ & \left. \frac{k^2}{J_1 J_2} (x_1 - x_3) - \frac{Bk}{J_1 J_2} x_4 + \frac{k_t k}{J_1 J_2} x_5 \right) - \frac{mgh}{J_1} \dot{x}_2 \cos(x_1) + \frac{mgh}{J_1} \sin(x_1) x_2 \dot{x}_2 + \\ & \frac{2mgh}{J_1} \sin(x_1) x_2 \dot{x}_2 + \frac{mgh}{J_1} x_2^3 \cos(x_1) + \frac{mghk}{J_1^2} \cos(x_1) x_2 + \frac{k^2}{J_1^2} (x_2 - x_4) + \\ & \left. \frac{k^2}{J_1 J_2} (x_2 - x_4) - \frac{Bk}{J_1 J_2} \left( \frac{k}{J_2} (x_1 - x_3) - \frac{B}{J_2} x_4 + \frac{k_t}{J_2} x_5 \right) + \frac{k_t k}{J_1 J_2} \left( \frac{-R}{L} x_5 - \frac{k_b}{L} x_4 \right). \end{aligned} \quad (14)$$

The designed control input i.e.  $u$ , obtained using exponential reaching law is given as

$$u = \frac{L J_1 J_2}{kk_t} (-\psi - k_1 \text{sign}(s) - k_2 s) \quad (15)$$

where  $k_1$  and  $k_2$  are switching gain parameters. Substituting (15) in (14) results in new surface dynamics, which can be expressed as

$$\dot{s} = -k_1 \text{sign}(s) - k_2 s + \left( \frac{4ck}{J_1} - \frac{Bk}{J_1 J_2} \right) \zeta(x, t) \quad (16)$$

### Stability Analysis

To examine the stability of the proposed control scheme, Lyapunov candidate function is considered, which can be expressed as;

$$V = \frac{1}{2} s^2 \quad (17)$$

To ensure asymptotic stability, the derivative of Lyapunov function must be negative definite for  $s \neq 0$  i.e.  $\dot{V} < 0$ . The derivative of the Lyapunov candidate function (17) can be expressed as;

$$\dot{V} \leq -k_2 |s|^2 - |s| \left\{ k_1 - \left| \left( \frac{4ck}{J_1} - \frac{Bk}{J_1 J_2} \right) \right| |\zeta(x, t)| \right\} \quad (18)$$

This proves the asymptotic stability of the system trajectory to the desired equilibrium point. The asymptotic stability  $\dot{V} < 0$  holds if the gains in the control input hold the condition

$$k_2 > 0, \quad k_1 > \left| \left( \frac{4ck}{J_1} - \frac{Bk}{J_1 J_2} \right) \right| \zeta^*(x, t) \quad (19)$$

where  $\zeta^*(x, t)$  represents the maximum value of the mismatch perturbations. At  $s = 0$  the solution of differential equation (12) can be given by,

$$z(t) = \left( e^{-ct} + \frac{c^2 t^2 e^{-ct}}{2} + \frac{c^3 t^3 e^{-ct}}{6} + c t e^{-ct} \right) z(0) + \zeta(x, t) \left\{ \frac{1}{c^4} - e^{-ct} \left( \frac{1}{c^4} + \frac{t}{c^3} + \frac{t^2}{2c^2} + \frac{t^3}{6c} \right) \right\} \quad (20)$$

where  $z(t)$  is the tracking error with convergence rate given in (20). It is evident from the equation that despite of using the control law, tracking error does not converge to zero i.e.  $\lim_{t \rightarrow \infty} z(t) \neq 0$ . This is because of the fact, that traditional SMC scheme is highly sensitive to mismatched perturbations.

### INTEGRAL SLIDING MODE CONTROL

Integral SMC is proposed to overcome the limitations found in traditional SMC strategy. It is well established that Integral SMC is an effective control approach for compensation of mismatched uncertainty [27]. It concentrates on the system to be insensitive in the entire state space to any perturbation. Furthermore, it significantly alleviates the chattering problem.

The integral sliding manifold for the system (1)-(3) is defined as

$$s = \int (c + \frac{d}{dt})^n z, \quad (21)$$

where  $c$  is a constant parameter,  $n$  represents system relative degree and  $z$  is the difference between the desired and actual trajectory, which can be expressed as

$$z = y - x_d = x_1 - x_d. \quad (22)$$

Taking time derivative and substituting (22) in (21), the integral sliding manifold is formulated as

$$\dot{s} = \vartheta + \frac{kk_t}{J_1 J_2 L} u + \left( \frac{5ck}{J_1} - \frac{Bk}{J_1 J_2} \right) \zeta(x, t), \quad (23)$$

where

$$\begin{aligned} \vartheta = & c^5 z + 5c^4 \dot{z} + 10c^3 (\dot{x}_2 - \dot{x}_d) + 10c^2 \left( -\frac{mgh}{J_1} \cos(x_1) x_2 - \frac{k}{J_1} (x_2 + x_4) - \ddot{x}_d \right) + \\ & 5c \left( -\frac{mgh}{J_1} \cos(x_1) \dot{x}_2 + \frac{mgh}{J_1} \sin(x_1) x_2^2 - \frac{k}{J_1} \dot{x}_2 + \frac{k}{J_1} \dot{x}_4 \frac{d\ddot{x}_d}{dt} \right) - \frac{mgh}{J_1} \cos(x_1) \ddot{x}_2 + \\ & \frac{mgh}{J_1} \sin(x_1) x_2 \dot{x}_2 + \frac{2mgh}{J_1} \sin(x_1) x_2 \dot{x}_2 + \frac{mgh}{J_1} \cos(x_1) x_2^3 - \frac{k}{J_1} \ddot{x}_2 + \frac{k^2}{J_1 J_2} (x_2 - x_4) - \\ & \frac{Bk}{J_1 J_2} \left( \frac{k}{J_2} (x_1 - x_3) - \frac{B}{J_2} x^4 + \frac{k_t}{J_2} x_5 \right) + \frac{kk_t}{J_1 J_2} \left( -\frac{R}{L} x_5 - \frac{k_b}{L} x_4 \right) - \frac{d\ddot{x}_d}{dt} \end{aligned} \quad (24)$$

To stabilize the manipulator's link position under the influence of mismatch uncertainty, the control input can be designed as

$$u = \frac{LJ_1 J_2}{kk_t} (-\vartheta - k_1 \text{sign}(s) - k_2 s) \quad (25)$$

where  $k_1$  and  $k_2$  are the switching gain parameters. Substituting the designed control law (25) in (24), we get

$$\dot{s} = -k_1 \text{sign}(s) - k_2 s + \left( \frac{5ck}{J_1} - \frac{Bk}{J_1 J_2} \right) \zeta(x, t) \quad (26)$$

### Stability Analysis

To analyze the stability of the close loop system using integral SMC approach, Lyapunov candidate function is considered, which can be expressed as

$$V = \frac{1}{2} s^2 \quad (27)$$

Taking derivative of Lyapunov function and putting (26) in (27), we get,

$$\dot{V} \leq -k_2 |s|^2 - |s| \left\{ k_1 - \left| \left( \frac{5ck}{J_1} - \frac{Bk}{J_1 J_2} \right) \right| |\zeta(x, t)| \right\}. \quad (28)$$

Hence, the negative definiteness of the Lyapunov candidate function is proved i.e.  $\dot{V} < 0$  which guarantees the asymptotic stability of the system trajectories in the presence of mismatch perturbations. In (28), the condition for asymptotic stability i.e.  $\dot{V} < 0$  holds, if the switching gains in the designed control input satisfy the condition.

$$k_2 > 0, \quad k_1 > \left| \left( \frac{5ck}{J_1} - \frac{Bk}{J_1 J_2} \right) \right| \zeta^*(x, t). \quad (29)$$

To work out the convergence rate of the steady state error, the integral sliding manifold with incorporated mismatch uncertainty is given as

$$s = \int (c^5 z + 5c^4 \dot{z} + 10c^3 \ddot{z} + 10c^2 \ddot{\dot{z}} + 5c \ddot{\ddot{z}} + \frac{d}{dt} \ddot{\ddot{z}} + \zeta(x, t)) dt. \quad (30)$$

At sliding mode i.e.  $s = 0$ , the solution of differential equation (30) becomes;

$$z(t) = e^{-ct} \left( 1 + \frac{c^2 t^2}{2} + \frac{c^3 t^3}{6} - \frac{c^4 t^4}{6} + ct \right) z(0) + \zeta(x, t) \left( \frac{e^{-ct} t^4}{24} \right), \quad (31)$$

where  $z(t)$  is the steady-state error, whose convergence rate is given by (31). It is an exponentially decaying function i.e.  $\lim_{t \rightarrow \infty} z(t) = 0$ .

## DISTURBANCE OBSERVER-BASED SMC APPROACH

The numerical analysis reported in the literature validates that traditional SMC has the most sensitive nature to mismatched uncertainty and results in a severe steady-state error, thus enforcing the system trajectories to deviate from the desired one. Contrary to this, Integral SMC counteract mismatched uncertainty in a robust way, but on the price of sacrificing nominal control performance of a system. DO-based SMC is a non-linear control technique, which acts in a robust fashion to counteract any perturbations while sustaining the nominal control performance of a system. In DO-based SMC, the internal state observer estimates the instantaneous value of mismatched uncertainty and updates the parameters in the control law.

The system formulated in (4)-(9) can be generally expressed as;

$$\dot{x} = f(x) + g_1(x)u + g_2\zeta(x, t), \quad (32)$$

$$y = h(x), \quad (33)$$

where  $x \in \mathfrak{R}^n$  is the states matrix,  $\zeta(x, t)$  is an unknown bounded uncertainty vector,  $u$  and  $y$  are input and output variables respectively, while  $f(x)$ ,  $g(x)$  and  $h(x)$  are nonlinear smooth functions. To nullify the effect of the disturbance, the estimated version of disturbance is required, which is done with disturbance observer expressed as [28] and [29],

$$\dot{p} = -lg_2p - l(g_2lx + f(x) + g_1(x)u), \quad (34)$$

$$\hat{\zeta} = p + lx, \quad (35)$$

where  $p$  is the internal state of the observer,  $l$  is the observer gain and  $\hat{\zeta}$  is the estimated disturbance. A novel sliding manifold for the system (20) can be expressed as,

$$s = 4\ddot{z}c + 6\dot{z}c^2 + 4\dot{z}c^3 + zc^4 - \frac{mgh}{J_1} \cos(x_1)x_2 + \frac{mgh}{J_1} \sin(x_1)x_2^2 + \frac{mghk}{J_1^2} \sin(x_1) + \frac{k^2}{J_1^2}(x_1 - x_3) + \frac{k^2}{J_1J_2}(x_1 - x_3) - \frac{Bk}{J_1J_2}x^4 + \frac{kk_t}{J_1J_2}x_5 + \frac{k}{J_1}\hat{\zeta}(x, t). \quad (36)$$

Taking derivative of (36) and substituting error dynamics, we obtain,

$$\dot{s} = v + \frac{kk_t}{J_1J_2L}u + \left(\frac{4ck}{J_1} - \frac{Bk}{J_1J_2}\right)\zeta(x, t) + \frac{k}{J_1}\dot{\hat{\zeta}}(x, t), \quad (37)$$

where  $v$  is introduced for the sake of simplicity and can be expressed as,

$$v = c^4x_2 + 4c^3\dot{x}_2 + 6c^2\ddot{x}_2 + 4c\left(\frac{mgh}{J_1} \sin(x_1)x_2^2 - \frac{mgh}{J_1} \cos(x_1)x_2 + \frac{mghk}{J_1^2} \sin(x_1) + \frac{k^2}{J_1^2}(x_1 - x_3) + \frac{k^2}{J_1J_2}(x_1 - x_3) - \frac{Bk}{J_1J_2}x^4 + \frac{kk_t}{J_1J_2}x_5\right) - \frac{mgh}{J_1} \cos(x_1)x_2 + \frac{mgh}{J_1} \sin(x_1)x_2\dot{x}_2 + \frac{2mgh}{J_1} \sin(x_1)x_2\dot{x}_2 + \frac{mgh}{J_1} \cos(x_1)x_2^3 + \frac{mghk}{J_1^2} \cos(x_1)x_2 + \frac{k^2}{J_1^2}(x_2 - x_4) + \frac{k^2}{J_1J_2}(x_2 - x_4) - \frac{Bk}{J_1J_2}\left(\frac{k}{J_2}(x_1 - x_3) - \frac{B}{J_2}x_4 + \frac{k_t}{J_2}x_5\right) + \frac{kk_t}{J_1J_2}\left(-\frac{R}{L}x_5 - \frac{k_b}{L}x_4\right) - c^4\dot{x}_d - 4c^3\ddot{x}_d + 6c^2\ddot{x}_d - 4c\frac{d}{dt}\ddot{x}_d - \frac{d}{dt}\ddot{x}_d \quad (38)$$

The control law required to track the system's desired trajectory under the influence of mismatch uncertainty can be formulated as,

$$u = \frac{LJ_1J_2}{kk_t}(-v - k_1\text{sign}(s) - k_2s + \left(\frac{4ck}{J_1} - \frac{Bk}{J_1J_2}\right)\hat{\zeta}(x, t)), \quad (39)$$

where  $k_1$  and  $k_2$  are the switching gain parameters. Back substitution of (39) in (37) gives,

$$\dot{s} = -k_1 \text{sign}(s) - k_2 s + \left( \frac{4ck}{J_1} - \frac{Bk}{J_1 J_2} \right) \tilde{\zeta}(x, t) + \frac{k}{J_1} \dot{\tilde{\zeta}}(x, t), \quad (40)$$

where  $\tilde{\zeta}(x, t)$  is the difference between the estimated and original disturbances i.e.  $\tilde{\zeta}(x, t) = \hat{\zeta}(x, t) - \zeta(x, t)$ .

**Assumption 3.** The derivative of disturbance is bounded and must satisfy the condition  $\lim_{t \rightarrow \infty} \dot{\zeta}(z, t) = 0$ .

**Assumption 4.** The estimated disturbance error  $\tilde{\zeta}(x, t)$  is norm bounded and is given by  $\tilde{\zeta}^*(x, t) = \lim_{t \rightarrow \infty} \sup |\tilde{\zeta}(x, t)|$ .

**Lemma 1.** Suppose the system (32) and (33) satisfies both the assumptions 3 and 4. In that case the disturbance estimation error  $\tilde{\zeta}(x, t)$  will converge to zero asymptotically i.e.

$$\dot{\tilde{\zeta}}(x, t) + lg_2 \tilde{\zeta}(x, t) = 0 \quad (41)$$

This condition holds if the observer gain  $l$  is selected such that  $lg_2 > 0$ .

To design a disturbance observer, (34) and (35) can be expressed as

$$\tilde{\zeta} = p + lx \quad (42)$$

Taking time derivative of (42) and substituting (32) - (35), we get

$$\dot{\tilde{\zeta}} = -lg_2 p - l(g_2(x)lx + f(x) + g_1(x)u) + l(f(x) + g_1(x)u + g_2(x)\zeta(x, t)). \quad (43)$$

Since  $\dot{\tilde{\zeta}} = \dot{\zeta}$ , the solution of (43) can be expressed as,

$$\tilde{\zeta}(t) = \tilde{\zeta}(0)e^{-lg_2 t}. \quad (44)$$

It is well established in (44) that the observer gain  $l$ , if chosen such that  $lg_2 > 0$ , the disturbance estimation error would converge to zero asymptotically. To analyse the stability of a close-loop control system, Lyapunov candidate function is considered, which is as follows:

$$V = \frac{1}{2} s^2 \quad (45)$$

Taking time derivative of Lyapunov candidate function and substituting (40) and (41), we get

$$\dot{V} \leq -k_2 |s|^2 - |s| \left( k_1 - \left| \left( \frac{4ck}{J_1} - \frac{Bk}{J_1 J_2} - \frac{lg_2 k}{J_1} \right) \right| |\tilde{\zeta}(x, t)| \right), \quad (46)$$

where  $k_1$  and  $k_2$  are tuning parameters and can be expressed as,

$$k_2 > 0, k_1 > \left| \left( \frac{4ck}{J_1} - \frac{Bk}{J_1 J_2} - \frac{lg_2 k}{J_1} \right) \right| |\tilde{\zeta}^*(t)| \quad (47)$$

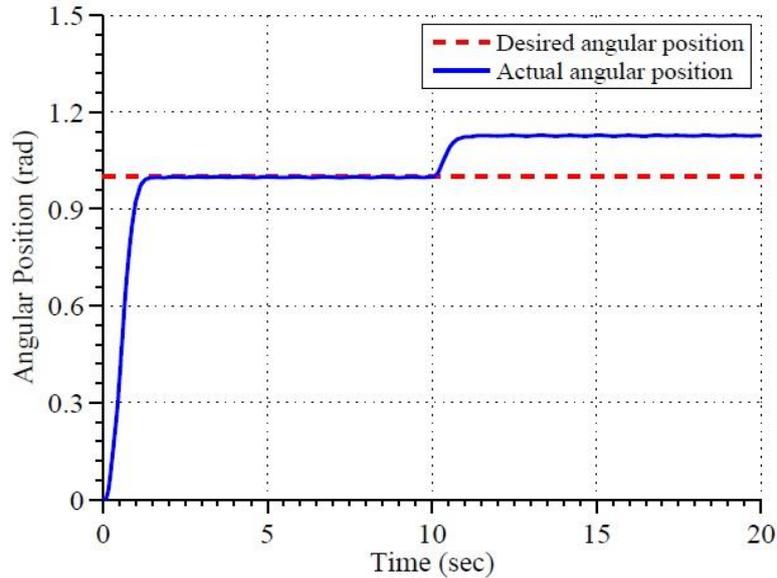
It is clearly validated that the designed control law ensures the asymptotic stability of the system's trajectory as long as the gains in the control law and internal observer  $l$  satisfy their respective conditions.

## SIMULATION RESULTS AND DISCUSSION

The aforementioned non-linear control approaches have been simulated in the MATLAB/Simulink environment. The key objective of the designed control algorithms is the tracking of the desired trajectory along with the stabilization of closed-loop system under the influence of a non-vanishing mismatch perturbation. The desired trajectory to be tracked is of constant amplitude.

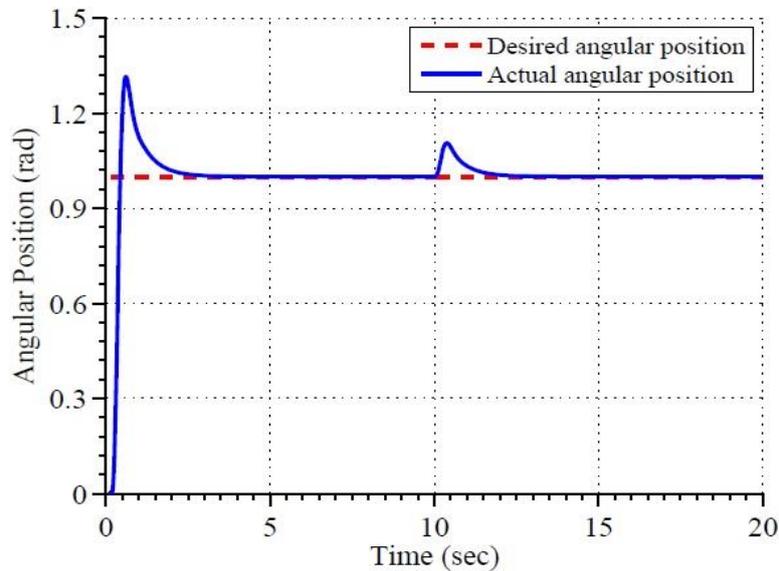
Figure 2. depicts the performance of traditional SMC for desired trajectory tracking of the flexible joint manipulator. It can be seen that initially the system is relaxed and is perfectly

tracking the desired trajectory. However, at  $t = 10$  s when the disturbance is injected into the system, the system trajectory deviates from the desired one and causes a constant steady state error. The steady state error is non-vanishing and exists till infinity.



**Figure 2.** Desired trajectory tracking of the flexible joint manipulator by SMC law.

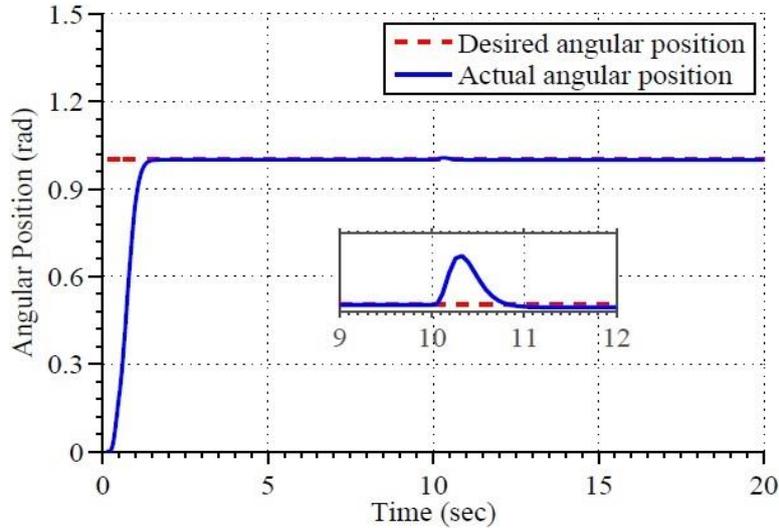
Figure 3. illustrates the effectiveness of integral SMC for the desired trajectory tracking by the flexible joint manipulator. The system is exposed to mismatched disturbances at  $t = 10$  s. It is well established from the results that integral SMC shows excellent robustness property and eradicates the mismatch disturbance effectively but on the price of sacrificing nominal control performance, such as introducing an overshoot of high amplitude and suffering from long settling time.



**Figure 3.** Desired trajectory tracking for flexible joint manipulator by integral SMC law.

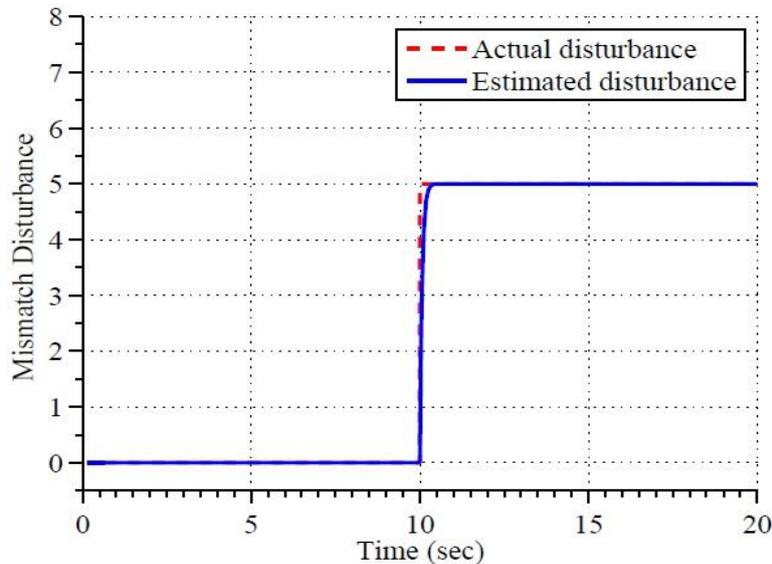
Figure 4. demonstrates the control performance of nonlinear DO-based SMC. The proposed control method acts as traditional SMC in the absence of any perturbations. However, when a disturbance is introduced in the system at  $t = 10$  s it counteracts the effect of disturbance. This is primarily possible due to the excellent sharp update law of the internal observer, which estimates the disturbance at each instant and thus nullifies its effects. It is pretty unambiguous

that the DO based SMC algorithm accurately compensates the mismatch disturbances, thus enabling the system to track the desired trajectory accurately with a negligible amount of steady-state error.



**Figure 4.** Desired trajectory tracking for flexible joint manipulator by DO based SMC law.

In Figure 5., the profile of estimation error between actual and estimated disturbance is presented. It is clearly evident that the estimation error approaches to zero because of the excellent update law of the proposed control scheme.



**Figure 5.** Profile of actual and estimated disturbance.

Figure 6. presents the comparative results of the three control strategies under investigation. The comparison is based on transient parameters like settling time and overshoot as well as steady state error. The comparative results justify the effectiveness of nonlinear DO-based SMC scheme.

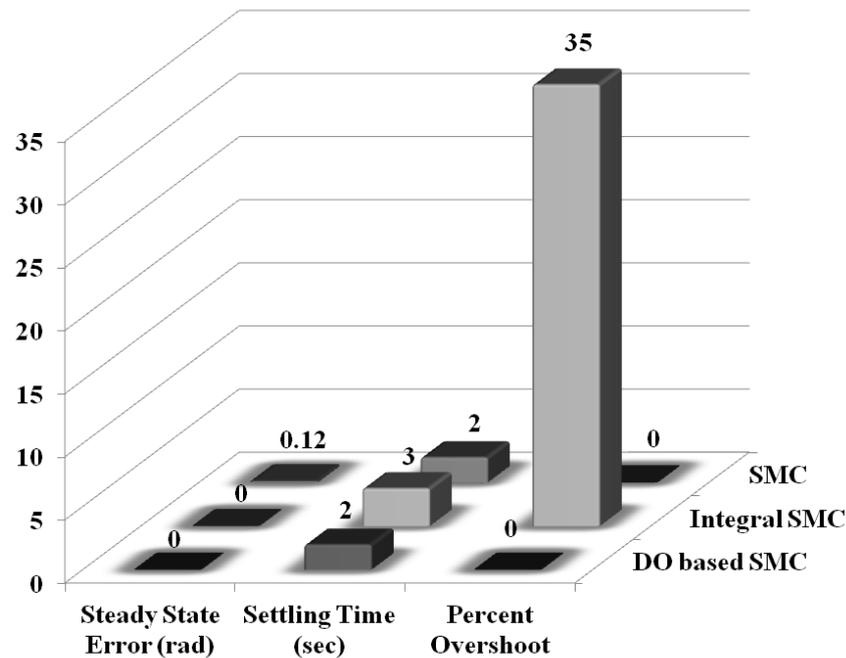


Figure 6. Performance comparison of proposed control strategies.

## CONCLUSION

In this article, a robust sliding mode control approach, via a nonlinear DO, is designed for the desired trajectory tracking of a flexible joint manipulator with mismatch perturbations. The novelty exists in the sliding manifold, which is based on the estimated version of disturbance. Once the disturbance is estimated, the system trajectory converges onto the desired equilibrium point asymptotically. Furthermore, the comparison between traditional and integral SMC is carried out. It is verified from both the numerical and simulation results that traditional SMC and integral SMC schemes face degradation of nominal control performance in the presence of mismatched perturbations, while the DO-based SMC technique showed remarkable advantages including sustainability of control performance and alleviation of chattering problem. The aforementioned control schemes have been simulated in MATLAB environment to validate the effectiveness and analysis of the proposed control law. The results dictate that DO-based control algorithm accurately counteracts the mismatched disturbances while retaining the system nominal control performance.

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# ECONOMIC HYSTERESIS WITH MULTIPLE INPUTS – A SIMPLIFIED TREATMENT

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## ABSTRACT

Hysteresis in economics has so far usually been based on a representation of a system with only a single input variable, which has a persistent effect on an economic outcome (i.e. the output variable). However, in general there is more than one factor influencing economic decision problems. As a result, the description of the path-dependency in relation to only one input variable may (possibly) be insufficient. The multidimensional path-dependence phenomenon is addressed (in mathematics and physics) by a vector-hysteresis system, with an input vector of two or more variables. Unfortunately, for practical purposes, these models are quite complicated in economics. However, since standard economic decisions are based on comparing economic values of alternatives (e.g. present values of investments), such models can be used to reduce the dimensions of the hysteresis system. This article outlines how the influence of several original input variables (e.g. price level and interest rate) is captured by the resulting variations of the present value of an investment. This economic value then can be used as a single signal/input variable of a modified hysteresis system. Since this system is dimensionally reduced to the standard hysteresis case with only a single input variable, the standard aggregation procedure for a situation with heterogeneous agents can be applied again.

## KEYWORDS

vector-hysteresis, sunk-cost hysteresis, path-dependence, non-ideal relay, Mayergoyz/Preisach-model

## CLASSIFICATION

JEL: C61

## INTRODUCTION

‘Hysteresis’ – originally stemming from physics (magnetism) – describes a permanent effect of a temporary stimulus, i.e. the dependence of the state of a system on its history. The phenomenon of hysteresis can be found in several areas like mechanics (elastics), chemistry (liquid–solid-phase transitions), engineering (thermostats, mechanical backlash), biology (e.g. bi-stable systems), and economics (see the edition [1] for examples from various sciences).

Relations between economic variables are often characterized by circumstances where initial conditions and the past realizations of economic variables matter. I.e. past (transient) disturbances of the relevant economic determinants (technically: the input or forcing variables) and past states of the economic system do often have a permanent influence on the current economic outcome (the output or dependent variable)<sup>1</sup>. Hysteresis in economics is typically based on sunk adjustment costs, which may occur either on the demand (as in the case of hiring and firing costs affecting labour demand) or on the supply side of the market (as e.g. entry or exit costs on international export markets)<sup>2</sup>.

An example of a supply side reason for hysteresis is learning-by-doing, since gaining skills via past production activity results in a higher productivity and lower costs. On the demand side, positive consumers experience with a firm’s product may lead to demand-carry over effects; i.e. a temporary price decrease, inducing additional sales may result in a permanently higher demand. However, all these factors are only a transient: The costs due to capacity adjustments, or training costs resulting in skills, or temporary price reductions in order to open a market can be interpreted as “investments” in future profits. Since these investments can not be regained, they can be considered as sunk costs. The consequence is a divergence between the ex-ante decision (before the sunk costs are spent) and the ex-post situation (after these sunk investments were carried out). As the relevant marginal costs or revenues were changed, temporary exogenous disturbances can have permanent effects on (economic) equilibria – what is the constituting feature of hysteresis.

Analyzing hysteresis usually starts with describing the path-dependent behavioural pattern at the micro level of a single unit: e.g. the hysteretic supply-pattern of a single firm, being active on a market or not – under consideration of having spent sunk costs in the past. At the micro level the path-dependent switching of the activity status occurs at firm-specific triggers. However, aggregation over a multiplicity of heterogeneous agents/firms is not straightforward. The path-dependent pattern of the aggregate economic system (as may be known from the magnetic hysteresis-loop of an entire piece of iron compared to single iron crystals) is not characterised by discontinuous switches (between activity and inactivity), but by a smooth/continuous transition between different “branches” of the input-output-relation, which occurs every time the direction of the movement of the forcing variable alters.

The standard model representation of hysteresis in economics is based on a system with one input and one output variable, e.g. price level as an input and production activity as the output variable to describe supply hysteresis. However, the standard situation in economic relations is based on a multitude of input factors having an influence on the output – which may be path-dependent. Thus, being able to model only path-dependent hysteretic relations related to a single (one-dimensional) input variable, applying 2D-representations if the output variable is included, restricts the application of the concept of hysteresis to more general economic problems. Modelling vector-hysteresis based on more-dimensional inputs was already addressed in the mathematics and physics (see e.g. [2]). Especially the properties of the non-ideal relay with 2 inputs and the consequences for the aggregation procedure were analyzed by [3]. While the application of multidimensional vector-hysteresis is quite tractable for single agents on a microeconomic level – since it shows a simple pattern of a non-ideal relay– the application of an adequate aggregation procedure becomes complicated if the agents are heterogeneous.

The aim of this article is to show, that this complex multi-dimensional aggregation procedure can be avoided in a standard situation of hysteresis in economics. This is due to the fact, that for economic problems typically – in order to decide about the optimal strategy – a comparison of the *economic values* of feasible alternatives is executed. And the economic value is a scalar (generally measured in currency units)! Thus, even though there is more than one determinant behind the optimal decision, the effects of this multitude of inputs/determinants can be described by the consequences on the relevant economic value – as a single variable! E.g. this article presents an example where the *present value* of an investment as a function of two inputs, the future revenue/price level ( $p_t$ ) and the interest rate ( $i_t$ ), is used as a “reduced” single signal capturing the effects of both original input variables on the economic decision problem. And referring to the present value as a single (one-dimensional) signal, a modified version of the standard aggregation procedure can be applied.

The structure of the article is as follows. In the next section a simple model of microeconomic sunk cost hysteresis is presented to show the non-ideal relay property of the supply of a single firm. This path-dependent pattern is explicitly outlined in relation to price level and to the interest rate as different factors having an influence on this decision. The third section gives an intuition of the problems coming about via a vector-hysteresis situation with more than one input variable, resulting in (for practical purposes too) complicated aggregation procedures if the firms are heterogeneous. The following two chapters present a simplification of the problem by using the present value as a scalar signal instead of the two-dimensional input vector comprising the price level and the interest rate. Moreover, in a second step a procedure based on the so called ‘*play-operator*’ is presented in order to filter out a third factor of influence, the option value effect caused by stochastic uncertainty about future profits. The modified version of the standard aggregation procedure based on the (filtered) present value as a single input signal related to the aggregate output is outlined in the following section. The last section concludes.

## **SUNK COST HYSTERESIS AND NON-IDEAL RELAYS WITH A ONE-DIMENSIONAL INPUT**

### **SUNK COST HYSTERESIS IN SITUATIONS WITH NO UNCERTAINTY**

A change in the level of the relevant forcing variables typically induces a change of the economic behaviour/outcome. However, a change back to the initial levels of the forcing variables does in the case of hysteresis not induce a complete change back to the initial outcome. A typical mechanism behind this path-dependency is driven by *sunk adjustment costs* [4, 5]. A firm which is previously not selling on a market and intends to enter has to bear market entry costs, e.g. for setting up distribution networks or for advertising. These costs are firm and market specific and cannot be regained after market entry. Ex-post, these market entry ‘investments’ are sunk. A market entry is only profitable, if both, variable costs and sunk entry costs, are covered by revenues. If a temporary high market price in the past has led to a market entry, a subsequent price decrease back to the initial level will not induce a market exit – as long as the variable costs are covered. Summarizing, the same price level may result in different states of the firm’s activity, depending on the history of its activity. In the following a simple model of this microeconomic supply pattern is presented (see e.g. [6] or [7] for this type of micro hysteresis model).

A price-taking firm  $j$  decides in period  $t$  whether or not to supply one unit of a product ( $x_{j,t} \in \{0,1\}$ ). Selling the product, the firm receives the market price  $p_t$  as a unit revenue. Three different components of costs have to be paid. One component  $c_j$  of variable costs is

not affected by the interest rate, and represents e.g. labour/wage costs and/or material costs per unit. Based on using capital as an input factor, the interest rate  $i_t$  has to be paid on the firm's capital stock  $K_j$  ( $\geq 0$ ). Additionally, if the firm has not produced in the preceding period, it has to pay the starting costs  $H_j$  ( $\geq 0$ ). The value created by  $H_j$  is completely firm specific and decays immediately as soon as the firm does not produce and sell. Thus,  $H_j$  represents the adjustment sunk costs. If the firm was inactive in the preceding period ( $x_{j,t-1}=0$ ) it has to pay all components including sunk costs. If it has been active in the preceding period ( $x_{j,t-1}=1$ ) only the two components of variable costs, interest costs on  $K_j$  plus "other" variable costs  $c_j$ , are relevant. In the case of a market entry in period  $t$ , the profit  $R_{j,t}$  in  $t$  and in the subsequent periods  $t + \tau$  is given by:

$$R_{j,t} = p_t - c_j - i_t \cdot K_j - H_j \quad \text{and} \quad R_{j,t+\tau} = p_{t+\tau} - c_j - i_{t+\tau} \cdot K_j, \quad (\tau > 0) \quad (1)$$

As a simple example we assume the firm is expecting a constant level of the price and the interest rate for the whole *infinite future* ( $p_t = p_{t+\tau}$  and  $i_t = i_{t+\tau}$ , for all  $\tau > 0$ ), that is anticipated with certainty. Thus, in the case of activity the (expected) present value of future revenues (corrected by "other" variable costs  $c_j$ ) as an annuity is:

$$V_t := \frac{p_t - c_j}{i_t}. \quad (2)$$

Under certainty the present value of revenues has to cover (at least) the value of the capital stock  $K_j$  plus the sunk entry costs ( $V_t > K_j + H_j$ ) to make an entry a profitable investment. Solving ( $V_t = K_j + H_j$ ) leads to the firm's entry trigger price  $\alpha_j$  under certainty:

$$\alpha_j = c_j + i_t \cdot (K_j + H_j) \quad \text{entry if } p_t > \alpha. \quad (3)$$

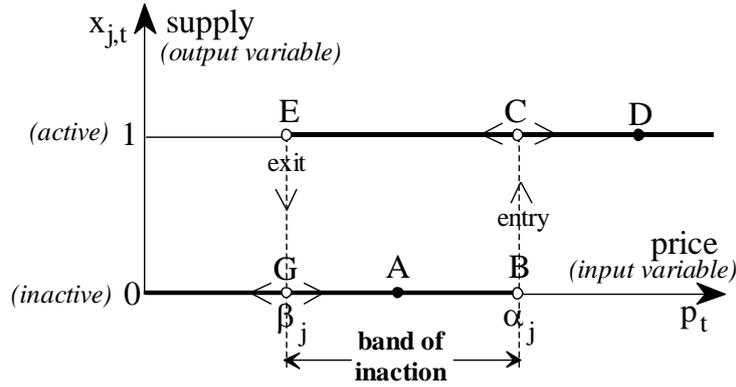
Therefore, the price has to cover at least (the variable costs  $c_j$  plus) the interest costs on both, capital stock  $K_j$  and sunk entry costs  $H_j$ .

If the firm was active in the preceding period ( $x_{j,t-1} = 1$ ) it will leave the market and sell the production capital  $K_j$ , if the price is too low. However, it has to pay sunk exit cost  $F_j$  ( $\geq 0$ ), e.g. for writing off firm-specific parts of the capital stock, or for severance payments. Thus, an exit of the firm is optimal if ( $V_t < K_j - F_j$ ), and the exit trigger price  $\beta_j$  is:

$$\beta_j = c_j + i_t \cdot (K_j - F_j), \quad \text{exit if } p_t < \beta_j \quad (4)$$

In the following (for reasons of a simple graphical representation) we assume ( $K_j \geq F_j$ ), so that the exit trigger price is non-negative. For a constant interest rate, an (unexpected) change in the (current and future) price  $p_t$  results in a supply-pattern of the price-taking firm  $j$  which is described by a so called 'non-ideal relay'<sup>3</sup>:

$$x_{j,t} = \begin{cases} 1 & \text{if } (x_{j,t-1} = 0 \wedge p_t > \alpha_j) \\ 1 & \text{if } (x_{j,t-1} = 1 \wedge p_t \geq \beta_j) \\ 0 & \text{if } (x_{j,t-1} = 0 \wedge p_t \leq \alpha_j) \\ 0 & \text{if } (x_{j,t-1} = 1 \wedge p_t < \beta_j) \end{cases} \quad \text{with } \alpha_j \geq \beta_j \quad (5)$$



**Figure 1.** Supply according to a ‘non-ideal relay’ related to the price as the input variable.

A non-ideal relay describes a path-dependent multiple-equilibria characteristic. E.g., starting in an inactivity situation at point A (Fig. 1) a price increase exceeding the trigger  $\alpha_j$  induces a market entry, i.e. a “jump” from the ( $x_j=0$ )-inactivity-line to the ( $x_j=1$ )-activity-line (point C). A later price decrease is resulting in a market exit (point E), only if the price falls below the exit trigger  $\beta_j$ . A switch from one equilibrium-branch to the other takes place when the triggers are passed – otherwise the activity status remains the same. Therefore, the area GB (or CE) can be described as a ‘band of inaction’ or ‘hysteresis-band’ [4; p.7f., 8; p.11]. Dependent on the past, two different equilibria are possible: The current level of the input variable (price) does not unambiguously determine the current state of the output/dependent variable (firm’s activity). If a *temporary* change of the input variable results in a switch between these equilibria, a *permanent* effect on the output variable remains (called ‘*remanence*’). This after-effect is the constituting feature of hysteresis.

Up to now, the price level was implicitly assumed as the single input variable of the system, and the entry trigger condition ( $V_t = K_j + H_j$ ) was solved for the price in order to derive price triggers. However, if alternatively the interest rate is assumed to be the single input variable, the entry condition can be solved for the interest rate, and an entry trigger interest rate  $A_j$  can be calculated:

$$A_j = \frac{p_t - c_j}{K_j + H_j}, \quad \text{entry if } i_t < A_j. \quad (6)$$

A low interest rate results in low capital costs for  $K_j$  and  $H_j$  and in a high present value of future profits making an entry profitable. A similar calculation could be done for the exit condition, determining the exit trigger rate  $B_j$  for a situation with a high interest rate:

$$B_j = \frac{p_t - c_j}{K_j - F_j}, \quad \text{exit if } i_t > B_j \quad (7)$$

Thus, for a constant price level, an (unexpected) change of the interest rate  $i_t$  analogously results in a ‘non-ideal relay’, however, now with respect to the interest rate as the (single) input variable:

$$x_{j,t} = \begin{cases} 1 & \text{if } (x_{j,t-1} = 0 \wedge i_t < A_j) \\ 1 & \text{if } (x_{j,t-1} = 1 \wedge i_t \leq B_j) \\ 0 & \text{if } (x_{j,t-1} = 0 \wedge i_t \geq A_j) \\ 0 & \text{if } (x_{j,t-1} = 1 \wedge i_t > B_j) \end{cases} \quad \text{with } A_j \leq B_j \quad (8)$$



The entry-trigger price level  $\alpha_j$  in the case of uncertainty is determined by a situation of indifference between immediate entry and wait-and-see, i.e if  $E(WN_{j,t})=E(N_{j,t})$ :

$$\alpha_j = c_j + i_t \cdot (K_j + H_j) + \frac{\varepsilon}{1 + 2 \cdot i_t} \quad \text{in period } t: \text{ entry if } p_t > \alpha_j \quad (10)$$

The decision problem of a currently active firm, deciding to leave the market now or to stay active, with an option to exit later if an unfavourable ( $-\varepsilon$ ) price change will occur, is analogous. Here, the option value of waiting is based on avoiding sunk exit costs if the future price level turns out to be better. To remain active and to wait in period  $t$  results in a current profit of  $(p_t - c_j - i_t \cdot K_j)$ . Conditional on a ( $-\varepsilon$ )-realisation, the firm will use its option to exit in  $t+1$  causing discounted exit costs. For a ( $+\varepsilon$ )-realisation the firm will continue to stay in the market with a future annuity of  $(p_t + \varepsilon - c_j - i_t \cdot K_j)$ . The resulting expected present value of the wait-and-see strategy is  $E(WX_{j,t})$ , and the expected present value of an immediate exit (without a re-entry) is  $E(X_{j,t})$ :

$$E(WX_{j,t}) = \frac{1}{1 + i_t} \cdot \left( p_t - c_j - i_t \cdot K_j + \frac{p_t + \varepsilon - c_j - i_t \cdot K_j}{2 \cdot i_t} - \frac{F_j}{2} \right) \quad \text{and} \quad E(X_{j,t}) = -F_j \quad (11)$$

The exit-trigger price level  $\beta_j$  in the case of uncertainty can be calculated for a situation of indifference between immediate exit in  $t$  and wait-and-see, i.e  $E(WX_{j,t})=E(X_{j,t})$ :

$$\beta_j = c_j + i_t \cdot (K_j - F_j) - \frac{\varepsilon}{1 + 2 \cdot i_t} \quad \text{in period } t: \text{ exit if } p_t < \beta_j \quad (12)$$

Thus, the entry trigger price  $\alpha_j$  is under uncertainty augmented by the term  $[\varepsilon/(1 + 2 \cdot i_t)]$ , and the option value effect for the exit trigger price  $\beta_j$  is of the same size, but negative. As a consequence, the ('band-of-inaction')-range between both triggers  $\beta_j$  and  $\alpha_j$  where two path-dependent equilibria are possible is widened by uncertainty. However, when considering a situation with uncertainty, the qualitative non-ideal-relay property of microeconomic hysteresis has not changed.

A qualitatively similar widening effect on the 'band of inaction' would result, if uncertainty is not based on stochastic price changes, but on stochastic future changes of the interest rate. Moreover, the same consequence of widening the ('band-of-inaction')-range results due to uncertainty induced option value effects for the distance between the entry and exit trigger interest rate  $A_j$  and  $B_j$ . We refrain from presenting the explicit calculations for all these analogous cases, as explicitly modelling option value effects on the width of the non-ideal relay is not the focus of this article<sup>4</sup>.

## CONSEQUENCES FOR THE CASE OF A NON-IDEAL RELAY WITH TWO INPUTS

Up to now, the non-ideal relay characteristic was derived for only one-dimensional changes of the inputs – of either the price or the interest rate. However, both input variables may alter at the same time. Actually, the decision of the firm is simultaneously depending on both of the two input variables, price and interest rate. Thus, we have an example of so called '*vector hysteresis*' with a two-dimensional input vector, i.e. the non-ideal relay is actually two-dimensional with respect to the inputs (or even 3D, if the output dimension is included).

Since more than one factor of influence is standard in economic relations, being able to model only path-dependent hysteretic relations related to a one-dimensional input variable

(and if output is included, only applying 2D-representations of the entire input-output system) would be a severe restriction, even in a simple standard case of sunk cost hysteresis as outlined above. Modelling vector-hysteresis based on more-dimensional input-vectors was already done in the theory of mathematics and physics (see e.g. [2]). Especially the properties of the non-ideal relay with a 2-dimensional input-vector and the resulting consequences for the aggregation procedure were analyzed by [3]. In the simple case of a single scalar-valued input, the value of the output variable is switched when the input signal crosses one or the other of two threshold values (e.g. for the price-based relay,  $\alpha_j$  and  $\beta_j$ ). The adequate aggregation procedure for a multitude of heterogeneous individual non-ideal relays  $j$ , each relay having a different pair of threshold parameters  $(\alpha_j, \beta_j)$  is done by a continuous superposition of this collection of relays: i.e. the so-called ‘Mayergoyz/Preisach’-procedure, which will be explicitly outlined later in this article.

In the single input case the two thresholds  $(\alpha_j, \beta_j)$  are scalars. However, in the generalized situation with two simultaneous inputs, the  $(\alpha_j, \beta_j)$ -triggers are replaced by a pair of two threshold-*curves* on the two-variable-plane of both inputs. Analogous to an exit trigger scalar  $\alpha_j$  in the 2-dimensional input-vector case there is a entry trigger curve  $\gamma_{0,j}(p_t, i_t)$  and another curve  $\gamma_{1,j}(p_t, i_t)$  as an analogy/generalisation of the exit trigger  $\beta_j$ . Having to deal with (heterogeneous) individual pairs of trigger curves instead of heterogeneous trigger scalars makes the aggregation procedure more complicated compared to the single input situation. As it is shown later on, an aggregated system has a different hysteresis pattern. For the single-input case the aggregate system shows a permanent (‘remanence’) effect resulting for every extremum of this input variable, via smooth/continuous switches between different branches [and not by a discontinuous (0-1)-“jump” as for relay-hysteresis]. Of course, it is not straightforward to identify an “extremum” for a pair of curves in the two-inputs-case. Moreover, the memory characteristics of the aggregate system (e.g. the so called ‘wiping-out’ property of subsequent even “more extreme” inputs) is different, as it is shown by [3] for the two-inputs-generalisation of the Mayergoyz/Preisach-model.

Indeed, in the following we will outline that the complex aggregation procedure for two-dimensional input-vector could be avoided in a typical economic situation. This is due to the fact, that comparing the *economic values* of feasible alternatives typically enables the decision about the optimal strategy for economic problems. Thus, even if there is more than one determinant affecting the optimal decision, the effects of this multitude of inputs can be described by the consequences on the economic value (measured in units of currency). In the following the *present value* – as a function of revenues ( $p_t$ ) and interest rate ( $i_t$ ) – works as “reduced” single signal capturing the effects of both original input variables on the economic decision problem. And with reference to this single signal a modified version of the standard aggregation procedure can be applied. In the next two chapters the “reduced” non-ideal relay system with the present value as the only input variable is presented. Moreover, in a second step, a filtering procedure based on the so called ‘play-operator’ is presented for capturing a third factor of influence, the option value effect caused by stochastic uncertainty about future profits.

## **NON-IDEAL RELAY RELATED TO THE PRESENT VALUE AS A SIGNAL**

As usual in economic problems, values are compared in order to receive an optimal decision (in our example the present value of the annuity of profits compared with sunk entry or exit costs), the relevant signal function in many (sunk cost) investment decisions can be the same single (!) present value function, though two (!) trigger functions are addressed.

The immediate entry trigger condition  $[E(WN_{j,t}) = E_t(N_{j,t})]$  can be rearranged to receive:

$$\frac{p_t - c_j}{i_t} = K_j + H_j + \frac{\varepsilon}{i_t \cdot (1 + 2 \cdot i_t)}, \quad (13)$$

with  $V_t := \frac{p_t - c_j}{i_t}$  and  $OE := \frac{\varepsilon}{i_t \cdot (1 + 2 \cdot i_t)}$  in period  $t$ : entry if  $V_t > K_j + H_j + OE$ .

An entry in the current period is profitable if the present value of the revenues  $V_{j,t}$  covers the capital  $K_j$ , plus sunk entry costs  $H_j$ , plus an option value effect  $OE$ . Analogously, the immediate exit trigger condition [ $E(WX_{j,t}) = -F_j$ ] is:

$$V_t = K_j - F_j - \frac{\varepsilon}{i_t \cdot (1 + 2 \cdot i_t)} \text{ in period } t: \text{ exit if } V_t < K_j - F_j - OE. \quad (14)$$

Using the present value as a function of price  $p_t$  and interest rate  $i_t$ , the two dimensional input problem is simplified and reduced to a one-dimensional non-ideal relay, again (see Fig. 3).

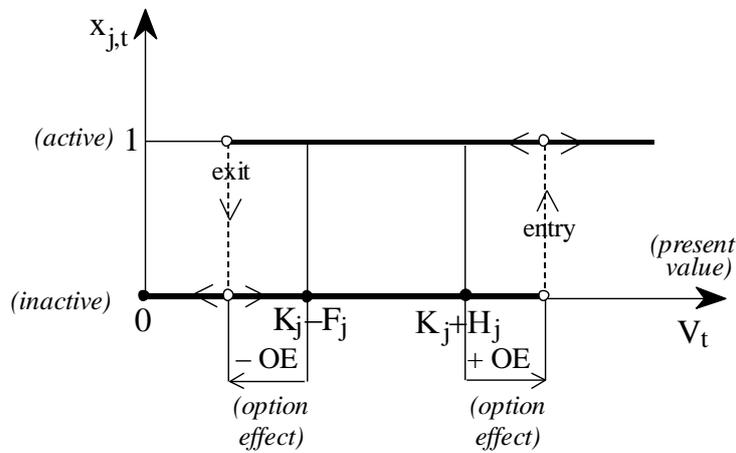


Figure 3. ‘Non-ideal relay’ related to the present value of revenues.

## PLAY-OPERATOR APPLIED TO RECEIVE A SIMPLE SINGLE SIGNAL FUNCTION

Previously was shown how the present value as a single variable is able to represent both trigger functions, for the entry and the exit trigger. However, the option value effect  $OE$  is still obstructing a simple representation, since there is still an interest rate effect on the RHS of eqs. (13) and (14) included in  $OE$ . These immediate entry/exit trigger conditions can be rearranged:

$$\begin{aligned} V_t - OE &= K_j + H_j \quad \text{entry in } t \text{ if } V_t - OE > K_j + H_j, \\ V_t + OE &= K_j - F_j \quad \text{exit in } t \text{ if } V_t + OE < K_j - F_j. \end{aligned} \quad (15)$$

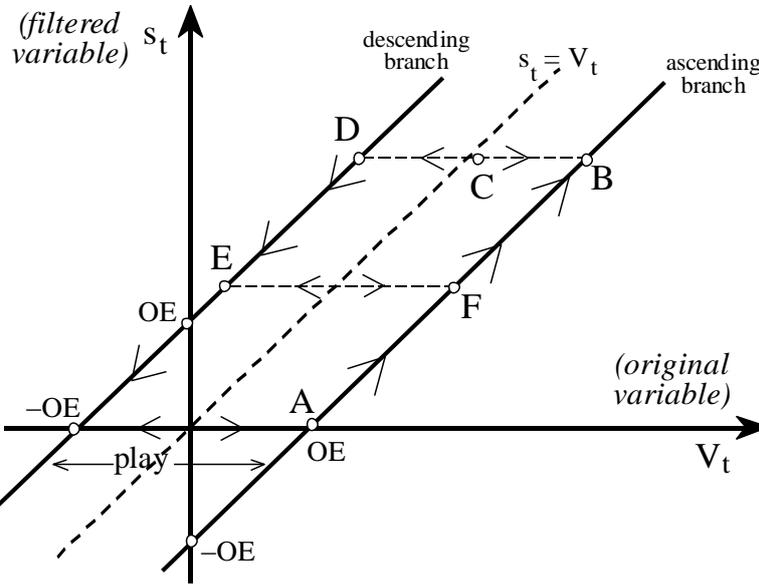
The band of inaction related to the present value is:

$$-F_j + K_j < V_t - OE \leq V_t + OE < K_j + H_j. \quad (16)$$

Thus in the case of a decreasing present value the relevant signal function comprising price and interest rate effects is  $(V_t + OE)$ , while it is  $(V_t - OE)$  in the case of an increasing present value. Actually this signal function can be interpreted as a *play-(hysteresis-)operator* procedure on  $V_t$  with a play-width of  $(2 \cdot OE)$ <sup>5</sup>. The play-operator is filtering out small changes in the original variable  $V_t$ , and only large changes exceeding the play area are transmitted to the resulting filtered variable  $s_t$ . The signal function  $s_t$  is derived from the present value  $V_t$  by the following play-operator:

$$s_t = \begin{cases} V_t - OE & \text{if } (V_t \geq V_{t-1} \wedge V_t > s_{t-1} + OE) & \text{(ascending branch)} \\ s_{t-1} & \text{if } (s_{t-1} - OE \leq V_t \leq s_{t-1} + OE) & \text{(play area)} \\ V_t + OE & \text{if } (V_t \leq V_{t-1} \wedge V_t < s_{t-1} - OE) & \text{(descending branch)} \end{cases} \quad (17)$$

For changes in the current present value  $V_t$  the ‘play-hysteresis’ loop of the signal  $s_t$  as depicted in Fig. 4 results. If – starting from the origin – the present value  $V_t$  increases, the signal  $s_t$  at first does not react due to the option value effect  $OE$ . If a threshold is exceeded ( $OE$  at point A), the signal reacts according to line AFB along the ‘ascending branch’. If  $V_t$ , and thus  $s_t$ , rises up to point B and falls later on, again the signal shows no reaction, but ‘play’ occurs along the line BCD. Only when a threshold is passed in point D, the signal decreases (to point E) with a lower  $V_t$ . As in the case of a non-ideal relay, for a particular input area no reaction of the output variable occurs.

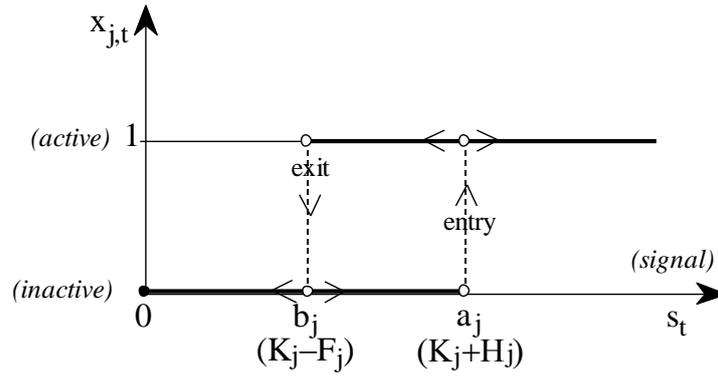


**Figure 4.** Play-operator deriving the filtered signal  $s_t$  from the original  $V_t$ .

To be more precise, the option effect  $OE := \varepsilon / [i_t \cdot (1 + 2 \cdot i_t)]$  varies if the interest rate  $i_t$  is changing. If, e.g., the interest rate is increasing,  $OE$  is decreasing. This ceteris paribus results in a narrowing of the play-width, with a move of the ‘ascending branch’ to the left (closer to the  $(s_t = V_t)$ -line, and of the ‘descending branch’ to the right. If a position on the ascending branch was pre-existing, the narrowing effect on the signal c.p. results in an increase of  $s_t$ , since the ascending branch moves to the left. If a position on the descending branch was pre-existing, the narrowing effect is c.p. moving  $s_t$  downwards. However, in addition to the narrowing effect, an increase of the interest rate is ceteris paribus diminishing the present value  $V_t$  by nearly the same proportion<sup>6</sup>.

Using the filtered signal  $s_t$  instead of the original present value  $V_t$  eliminates the option value effect from the non-ideal relay representation of the firm’s optimal decision (see Fig. 5). These trigger signals are defined as:

$$\begin{aligned} a_j &:= K_j + H_j & \text{entry in } t & \text{if } s_t > a_j, \\ b_j &:= K_j - F_j & \text{exit in } t & \text{if } s_t < b_j. \end{aligned} \quad (18)$$



**Figure 5.** ‘Non-ideal relay’ related to the signal (where  $OE$  is filtered out).

In the simple case of no (anticipated) uncertainty (i.e.  $\varepsilon=0 \Rightarrow OE=0$ ), with a zero “play-width” the signal  $s_t$  is similar to the original variable  $V_t$ . Thus, the simple case without uncertainty is in the following implicitly included as a special/border case of the more general presentation.

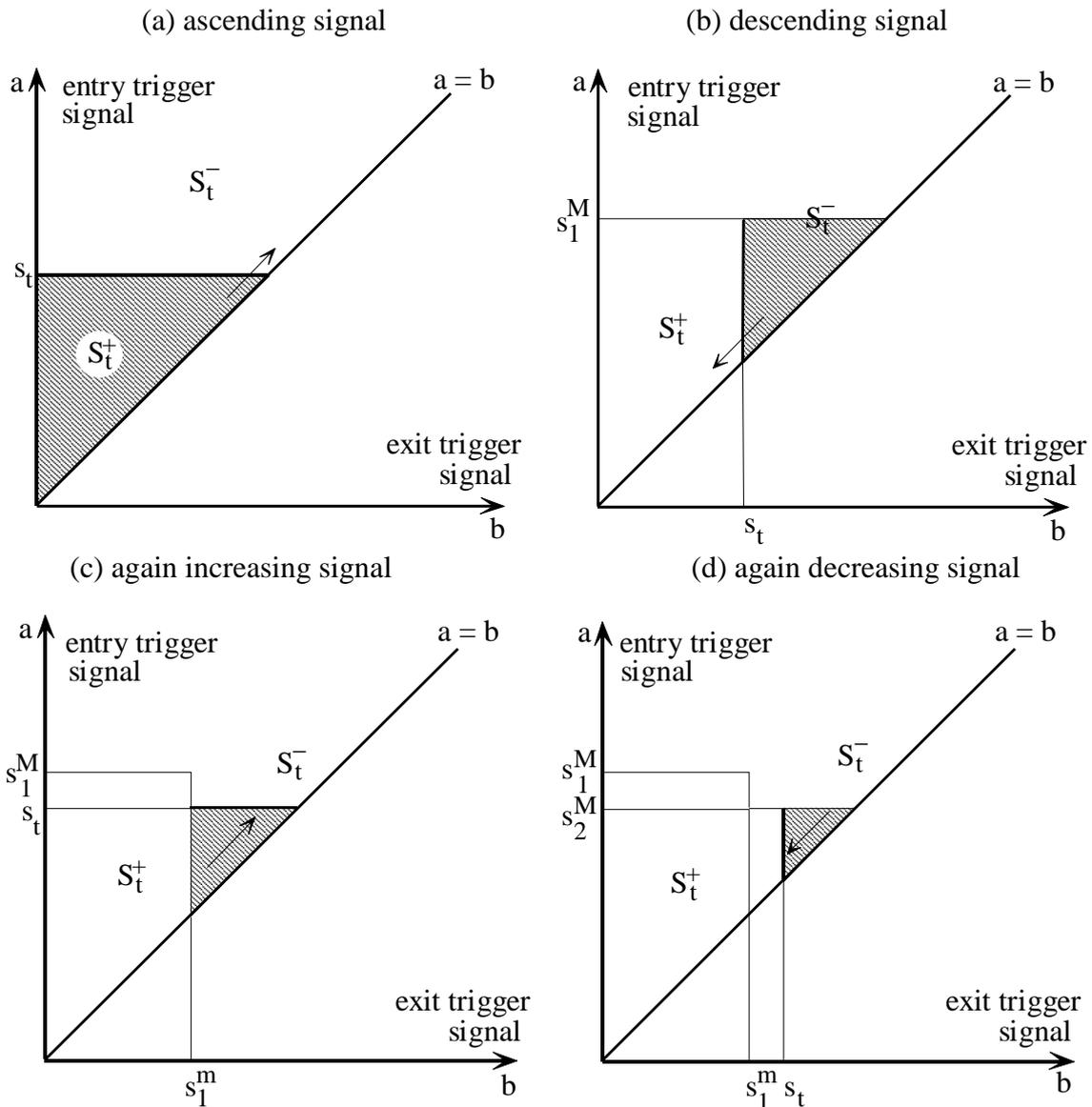
## AGGREGATION AND MACROECONOMIC HYSTERESIS

Though the Mayergoyz [14]-Preisach [15]-procedure is standard in the literature and can be applied straightforward based on the signal variable  $s_t$ , in order to complete the presentation of the simplified model, the aggregation procedure is outlined in this section. This procedure is based on the explicit aggregation of non-ideal relay agents ( $j = 1, \dots, n; n \gg 0$ ) each of them having different entry/exit triggers due to a heterogeneity in the firms’ cost structure<sup>7</sup>.

Every potentially active firm  $j$  is characterized by a set of entry/exit triggers ( $a_j/b_j$ ). In an  $a_j/b_j$ -diagram (see Fig. 6), the firms are represented by points in a triangle area above the  $45^\circ$ -line (since  $a_j \geq b_j$ ). The aggregation procedure can be performed without any serious restriction of the heterogeneity of the distribution of the firms over the triangle area (i.e. of the cost structure of the firms). Points on the  $45^\circ$ -line describe non-hysteretic firms ( $H_j=0 \wedge F_j=0 \Rightarrow a_j=b_j$ ) – the horizontal distance from the origin given by  $K_j$ . Firms with a position above the  $45^\circ$ -( $a=b$ )-line are characterized by a non-ideal relay supply – the distance from the ( $a=b$ )-line measured in vertical direction determined by ( $+H_j$ ), and in horizontal direction by ( $-F_j$ ).

To avoid a long description of the past development, a situation with a zero initial signal level ( $s_t=0$ ) is assumed, implying no firm is initially active. Now, a rising signal results in market entries by firms with the lowest costs – i.e. the lowest entry triggers  $a_j$ . Aggregate supply increases, as traced in Fig. 6 (a), with a growing space of the hatched triangle  $S_t^+$  representing the active firms which have entered the market (and  $S_t^-$  representing the inactive firms). For a rising signal level, the  $S_t^+$ -expansion is indicated by an upward shift of the horizontal borderline. The corresponding aggregate macro reaction is depicted by the path OAB in Fig. 7.

In Fig. 6 (b) a subsequent decrease of the signal is traced:  $s_t$  falls from the highest value, the (local) maximum  $s_t^M$ . Therefore, area  $S_t^+$ , representing active firms, now shrinks, since firms that have recently entered, leave the market as the signal falls below their exit trigger  $b_j$ . For a decreasing signal, the activity changes (hatched area) are illustrated by a left vertical shift of the  $S_t^-$ - $S_t^+$ -borderline. In Fig. 7 the corresponding path is BC.

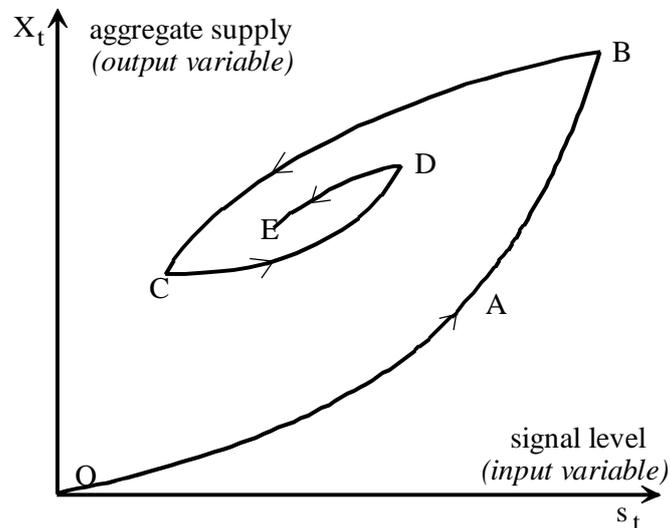


**Figure 6.** Application of the Mayergoyz/Preisach procedure – active firms under a volatile signal.

If, after reaching the local minimum  $s_1^m$  the signal rises again, area  $S_t^+$  again expands, depicted in Fig. 6 (c) by an upward shift of the right-horizontal part of the borderline. The corresponding macro reaction is path CD in Fig. 7. The result of the subsequent shifts is a “staircase-shape” of the border between the two parts of the triangle. If the recently reached (local) maximum is lower than the highest maximum  $s_1^M$ , a staircase step in the borderline remains – characterised by the coordinates  $(a = s_1^M / b = s_1^m)$ . If the signal level had continued to increase and had passed the original maximum, the a-coordinate of the “ $s_1^M$ -step” would have been “wiped out” and replaced [14; p.605]. However, if (as traced in Fig. 6 (c)) the new local maximum is lower than the “old”  $s_1^M$ , this “old” maximum remains and the new local maximum becomes the second highest, labelled  $s_2^M$ .

Fig. 6 (d) illustrates a subsequent decrease in the signal. The borderline is changed by a shift to the left of the lower vertical part (path DE in Fig. 7). If  $s_t$  does not fall below  $s_1^m$  the new local minimum  $s_2^m$  is now the second lowest minimum. If the input were to fall under the

“old”  $s_I^m$ , the b-coordinate of the corresponding staircase-step would be eliminated. If subsequent local maxima and minima are not as “extreme” as the preceding extrema, a new corner in the staircase border is created. However, local maxima which are higher than preceding maxima will erase the a-coordinate of the corresponding corners; subsequent local minima will ‘wipe-out’ the b-coordinate of corners corresponding to higher preceding minima [16; p.11ff.].



**Figure 7.** The continuous macroeconomic hysteresis loop.

Summarizing, the aggregate system shows a memory of non-erased (*‘non-dominated’*) past input signal extrema – graphically represented by the “staircases” in the borderline of the area  $S_t^+$  of active firms. Aggregation leads to a stronger pattern of hysteresis: For the aggregate loop a branch-to-branch transition occurs with *every local extremum* in the path of the input variable, while at the micro/firm level a passing of triggers is necessary, in order to induce permanent remanence effect. Therefore, this type of macro-hysteresis is called *‘strong’* hysteresis (e.g. [16, 17], see [18; p.22ff.], for typical characteristics of the macro hysteresis-loop). The *distribution* of the heterogeneous firms in the  $(a_j \geq b_j)$ -triangle is important for the results. A continuous distribution of the firms in the  $(a_j \geq b_j)$ -triangle implies a *continuous* macro loop as depicted in Fig.7. The exact density of the  $(a_j, b_j)$ -distribution determines the curvature of the macro loop branches: the more they are clustered in a specific area (i.e. the less heterogeneous the firms), the more “curved” are the macro branches. In the borderline case of a multiplicity of similar/homogenous firms the macro loop degenerates to a non-ideal relay.

## CONCLUSION

The purpose of this article was to show how an economic hysteresis system based on persistence effects related to more than one input variable (i.e. a vector-hysteresis system), can be reduced to a simple system based on present values as the single input variable. This was shown for a standard example of sunk-cost hysteresis, where the firm’s investment decision is based on (expected) future revenues. On a microeconomic level of a single firm, it was shown that (non-ideal relay) hysteresis can be derived related to the price level, but in an analogous way related to the interest rate as well. However, the present value – as a function based on the (future) levels of the price level and the interest rate – captures the effects of both original input variables on the decision problem. For a situation with uncertainty (due to the stochastic nature of future revenues), option value effects of waiting have additionally to

be considered: These option value effects are widening the ‘band-of-inaction’ area of path-dependent multiple equilibria. However, if the present value is filtered by a play-operator procedure, these option value effects can be filtered out in order to derive a single signal/input variable capturing the dynamic effects of the present value. In a last step it is shown, how the usual Mayergoyz/Preisach single-input-procedure for heterogeneous agents could be applied again, based on this reduced and filtered present value signal. Thus, for a typical economic decision situation, a case with multiple input (vector-)hysteresis was simplified to the standard single input variable case again.

## REMARKS

<sup>1</sup>The terms ‘input’ and ‘output’ are used to address the processing of the system and *not* used in a narrow economic sense (as e.g. factor input and production output) [19; p.26].

<sup>2</sup>In labour economics hysteresis was introduced by [20-23], and in foreign trade theory by [4, 1124, 24, 25]. For an overview of applications and different concepts of hysteresis in economics see the surveys [6, 26-28]. See [29; p.638] for factors generating hysteresis differentiated in supply and in demand side determinants.

<sup>3</sup>See [30; p.263 & p.271] and [18; pp.23f.] for a general description of relay-hysteresis.

<sup>4</sup>For a comprehensive analysis of option effects see [31].

<sup>5</sup>A play-operator describes an effect which is well known as mechanical play or ‘backlash’. Car drivers know this if the steering wheel has to be turned by a small angle before the tires actually respond. In fact, play is another type of hysteresis, generalising the non-ideal-relay, since for play a continuous loop is resulting, while the non-ideal relay is based on discontinuous “jumps”. See [30; pp.6ff.] and [18; p.24 & p.42] for a general presentation of the play-operator.

<sup>6</sup>For a more elaborated treatment of a situation with a variable play-width, e.g. due to changes of the size  $\varepsilon$  of uncertainty, see [32, 33].

<sup>7</sup>This procedure was introduced to economics by [16] and [26]. See e.g. [34-36] for applications of the Preisach-Mayergoyz-model in foreign trade and in labour market economics.

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# ACCUMULATIVE POLLUTION, ENVIRONMENTAL REGULATION AND ENVIRONMENTAL COSTS: DYNAMIC APPROACH

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## ABSTRACT

This article analyses how social preference towards environmental costs for addressing environmental concerns can have an impact on the steady state solution concerning the stock of accumulative pollutants and the optimal environmental regulatory stringency as well as on the initial value of the optimal environmental regulatory stringency that leads to the steady state solution. The results found that the steady state value of the optimal environmental regulatory stringency was higher, and the steady-state value of the stock of accumulative pollutants was lower in the case where sufficient liability costs for environmental damages were estimated, compared with the case where the estimation of liability costs was insufficient. In addition, the results showed that the steady-state value of optimal environmental regulatory stringency was higher and the value of the stock of accumulative pollutants was lower in the case where the discount rate provided sufficient consideration for future generations, than when the discount rate provided insufficient consideration. Moreover, the study also indicated that, where the initial value of the stock of accumulative pollutants was within a given range, in the cases where sufficient liability costs for environmental damages were estimated and where the discount rate provided sufficient consideration for future generations, the initial value of the optimal environmental regulatory stringency was found to be at a higher level, compared to the initial value of the optimal environmental regulatory stringency for the cases where there was insufficient estimation of liability costs and when the discount rate provided insufficient consideration.

## KEYWORDS

accumulative pollution, environmental regulatory stringency, liability cost for environmental damage, discount rate

## CLASSIFICATION

JEL: Q52, Q53, Q54

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## **INTRODUCTION**

The pollution from various toxic substances which is often a by-product of production and industrialization can be a threat to the environment. Heavy metals such as mercury and cadmium; radioactive contamination caused by accidents or wastes from nuclear power stations; dioxins which is considered to impact endocrine disruptors; and global warming by greenhouse gases, are all growing social concerns. These pollutants which accumulate over time are referred to be the main causes of environmental degradation [1, 2]. In recent years, providing for both intergenerational and intra-generational equity which are vital principles of sustainability and taking into consideration the trend of environmentalism, the effects of such accumulative pollutants on the environment cannot be ignored. Accordingly, it would be necessary to appropriately understand how these accumulative pollutants and environmental policies which could be related to these pollutants change over time. Environmental costs which could affect accumulative pollutants would be important to examine along with how social planners consider the social preference towards environmental costs. The reason is that under a competitive market, it is considered that the social benefit is larger when social costs related to environmental issues are internalized compared to when the costs are ignored [3]. It is also considered that firms could receive benefits such as maintaining a strong brand image, enhance productivity and profitability and establish stronger social/stakeholders relationships when they have appropriate consideration for environmental costs and there are previous researches supporting this [4-6].

The environmental costs, here, are composed of liability costs for environmental damages and abatement costs. As for the abatement costs, it can be regarded as ex-ante costs that prevent pollution. These are costs necessary to reduce the volume of residuals emitted into the environment or to reduce the ambient concentrations [7]. They also include costs for pollution prevention, environmental preservation and the investment, administration, and transaction to support this. For example, activities such as changes in production technologies, input switching, recycling and treatment are covered in these costs [7]. With regards to the liability costs for environmental damages, they include environmental loss costs, environmental loss mitigation costs, environmental restoration costs, related administration costs and transaction costs. Concerning the estimation of liability costs, this will be regarded as “sufficient liability costs for environmental damages” when the private interests, which contain both rights to live and property rights; and the public interests from living organisms and their surrounding; and the intrinsic values of the environment are included. However, only a portion of the “sufficient liability costs for environmental damages” are usually covered. Holl and Howarth [8] identify a number of cases where environmental restoration costs were not adequately covered. Yoshimura [9] identified the lack of a system for administrators and citizens to play a role in the restoration of the environment, which implies that environmental restoration costs have not been adequately considered [9]. Moreover, there are cases where the compensation costs for environmental losses were not adequately paid [10, 11]. According to Otsuka [12], the effectiveness of the conciliation is limited to the settlement agreement and it does not impact the proceedings of the trial, which could be considered that the compensation fees were insufficient. Furthermore, with regards to laws related to environmental compensation, it is recognised that there are challenges for the compensation to cover the public interests which include living organisms and their surroundings and the intrinsic value of the environment [9]. When such liability costs for environmental damages are not sufficiently covered, we will consider this as “insufficient liability costs for environmental damages.” In this research we will examine both the cases of sufficient and insufficient coverage of liability costs for environmental damages.

It is necessary to estimate environmental costs which are composed of abatement costs and liability costs for environmental damages from the viewpoint of not only the present generation but also with consideration for future generations. This leads to the important consideration of the discount rates adopted when estimating environmental costs. Therefore, in this article, we will analyse the discount rates adopted for both insufficient and sufficient consideration of future generations. In the former case where there is insufficient consideration, there is the tendency to estimate lower environmental costs compared to the latter where the discount rate takes sufficient consideration for future generations and estimates higher environmental costs. Accordingly, the discount rate of the former case will be higher than the discount rate for the latter case [13-15].

Concerning the above, it is considered to be effective to examine the accumulative pollution where time proceeds are taken into account, that is, through a dynamic analysis. Numerous literature that examine pollutants including accumulative pollutants using the dynamic approach exists. For instance, there is literature on the examination of the relationship between pollutants and the economy such as economic growth, capital accumulation and consumption [16, 17]. There are also past research which study the relationship between pollution and the assimilative capacity and the degradation of this capacity under pollution excess [18-20]. Moreover, there are large amounts of past literature on the relationship between pollution and environmental policies in a dynamic setting. For example, there is a study that examine the relationship between tax and subsidy; and pollution flow and stock [17]. There are also studies which analyse the relationship between emissions quotas or permit and pollution flow and stock [21-23]. Furthermore, Saltari and Travaglini [24] question whether there is an intermediate phase where consumers, firms and society anticipate the effects of environmental constraints in planning their current economic-ecological decisions and so they examine if even an unconstrained regime can have an impact on pollution, by anticipating the latent constraint.

As seen previously, we know that dynamic analysis concerning pollution have been conducted from various aspects. The main purpose of this article is to examine the differences in the steady state solution and initial values for both the stock of accumulative pollutants and the stringency of environmental policies, affected by social preference towards environmental costs if a steady state solution exists. Therefore, our analysis will extend the study of Chukwuemeka [25] which focuses on both the stock of accumulative pollutants and emission tax from a dynamic approach. The study analyses the existence of a steady state solution for both the stock of accumulative pollutants and emission tax, their paths in the phase diagram, the set of initial values of emission tax, under the framework to minimize environmental costs which include liability costs for environmental damages and abatement costs. As emphasized before, this article will introduce the aspects of social preference towards environmental costs. First, it will examine the differences of the steady state solution in the case of sufficient estimation of liability costs for environmental damages and then the case of insufficient estimation of liability costs for both the stock of accumulative pollutants and the optimal environmental regulatory stringency. Second, similar to the first analysis, this article will observe the differences in the steady state solution in the case where the discount rate takes sufficient consideration for future generations and in the case where the consideration is insufficient for both the stock of accumulative pollutants and the optimal environmental regulatory stringency. Third, this article also examines, under a given range of initial stock of accumulative pollutants, how the initial value of the optimal environmental regulatory stringency is decided, depending on the social preference towards environmental costs as studied in the first and second analysis.

## ACCUMULATIVE POLLUTION AND OPTIMAL GROWTH MODEL

### EXPLANATION OF THE BASIC MODEL

In this section, based on Chukwuemeka [25], we will introduce the framework applied in this study. At first, we will confirm the existence of the steady state solution for the stock of accumulative pollutants and the optimal environmental regulatory stringency and the possible region to be able to move into a steady state solution. To more be specific, given the initial value of the stock of accumulative pollutants, and under the condition that abatement activities are being conducted, in order to manage environmental costs efficiently, that is, when minimizing the total environmental costs which include the liability costs for environmental damages and abatement costs, we will identify the existence of the steady state solution for the stock of accumulative pollutants and the optimal environmental regulatory stringency and the path to the steady state solution. Hence, the objective function and the constraint equations are as follows.

$$\min_A \int_0^{\infty} [D_p(S) + A(M)] e^{-r_q t} dt,$$

subject to

$$\begin{aligned} \dot{S} &= W - M - dS, \\ S(0) &= S_0. \end{aligned} \quad (1)$$

Here,  $S$  represents the stock of accumulative pollutants,  $W$  is the amount of the pollutants under the uncontrolled regime,  $M$  denote the amount of abatement activities. Quantity  $d$  ( $0 \leq d \leq 1$ ) is the rate of decay for the accumulative pollutants. The functional relationship between the stocks of pollutants and the rate of decay is little known [20]. Hence, this article adopts a constant proportionate rate of decay, which is often used in previous literatures concerning pollution stock [20, 25].  $D_p(S)$  is the liability costs for environmental damages. As identified by many economists and environmentalists, it assumes that  $D'_p > 0, D''_p > 0$ . It also assumes that  $D'''_p = 0, D_p(0) = 0$ . The  $p$  denotes the sufficiency of the consideration for the liability costs of environmental damages, which will be explained in the next section.  $A(M)$  represents abatement costs. According to Field and Field [7], it is assumed that  $A' > 0, A'' > 0$  since they increase and the marginal costs also increase as the reduction of emissions increase.  $S_0$  is the initial value of the stock of accumulative pollutants.  $r_q$  denotes the discount rate. The  $q$  represents the sufficiency concerning future generation consideration. It will be explained in a later section.  $t$  means time and the dot on top of the letter (e.g.  $\dot{S}$ ) represents the differential with respect to  $t$ .

From the previously stated, the present value Hamiltonian is as follows.

$$H = [D_p(S) + A(M)] e^{-r_q t} + \delta(W - M - dS). \quad (2)$$

Here, using the definition  $\varepsilon = \delta \cdot e^{r_q t}$ , the current value Hamiltonian is as follows:

$$H^C = D_p(S) + A(M) + \varepsilon(W - M - dS). \quad (3)$$

Since  $D_p$  and  $A$  are strictly convex, the current value Hamiltonian is also strictly convex in  $S$  and  $M$ . Accordingly, the following necessary conditions are sufficient.

$$\partial H^C / \partial M = 0, \quad \therefore \varepsilon = A'(M), \quad (4)$$

$$-(\partial H^C / \partial S) e^{-r_q t} = \partial(\varepsilon e^{-r_q t}) / \partial t, \quad \therefore \dot{\varepsilon} = -D'_p(S) + \varepsilon(r_q + d), \quad (5)$$

$$\partial H^C / \partial \varepsilon = \dot{S}, \quad \therefore \dot{S} = W - M - dS, \quad (6)$$

Here,  $\varepsilon$  indicates the shadow value of abating one unit of emissions. Since it can be interpreted that society will pay for the amount corresponding to the value of abating one unit

of emissions, it could be regarded as the optimal environmental regulatory stringency, assuming that it could be estimated. Hence, (4) suggests that the increase of marginal cost of abating the accumulative pollution represents the increase of the optimal environmental regulatory stringency.

Here, in order to find the steady state, making use of (4), (5), (6),  $\dot{S} = \dot{\varepsilon} = 0$ . At first, substitute  $\dot{\varepsilon} = 0$  into (5). As a result, we obtain the following:

$$\varepsilon = \frac{D_p'}{r_q + d}. \quad (7)$$

Here, differentiate (7) with respect to  $S$ , the following equation can be introduced:

$$\frac{\partial \varepsilon}{\partial S} = \frac{D_p''}{r_q + d} > 0. \quad (8)$$

From  $D_p''(S) > 0, r_q > 0, d > 0$ , we can find the sign of (8). Next, substitute  $\dot{S} = 0$  into (6),

$$W - M - dS = 0. \quad (9)$$

Rewrite (9),

$$M = W - dS. \quad (10)$$

Here, substitute (10) into (4),

$$\varepsilon = A'(W - dS). \quad (11)$$

Differentiate (11) with respect to  $S$ , we can obtain:

$$\frac{\partial \varepsilon}{\partial S} = -dA''(W - dS) < 0. \quad (12)$$

From  $A''(M) > 0$ , i.e.  $A''(W - dS) > 0, d > 0$ , we can confirm the sign of (12). From (4), (7) and (9), we can get  $(S^S, M^S, \varepsilon^S)$  as the steady state solution of  $(S, M, \varepsilon)$ .

Since this article aims to focus on the stock of accumulative pollutants and the optimal environmental regulatory stringency, and to illustrate them in two dimensions, we will focus on  $(S, \varepsilon)$ . Therefore, with regards to the path to a steady state solution, we will proceed as follows. In order to do so, first, we will set  $(\bar{S}, \bar{\varepsilon})$  such as  $\dot{\varepsilon} = 0$ . That is, from (5),  $\dot{\varepsilon} = \dot{\varepsilon}(\bar{S}, \bar{\varepsilon}) = -D_p'(\bar{S}) + \bar{\varepsilon}(r_q + d) = 0$ .

Fixing  $\varepsilon = \bar{\varepsilon}$ , if it assumes that  $S_a < \bar{S}$ , from (5), we obtain  $\partial \varepsilon / \partial S < 0$ . With  $\dot{\varepsilon}(\bar{S}, \bar{\varepsilon}) = 0$ , we can introduce  $\dot{\varepsilon}(S_a, \bar{\varepsilon}) > 0$ . On the other hand, keeping  $\varepsilon = \bar{\varepsilon}$ , assuming that  $S_b > \bar{S}$ , we attain  $\partial \varepsilon / \partial S < 0$ . With  $\dot{\varepsilon}(\bar{S}, \bar{\varepsilon}) = 0$ , we can make sure  $\dot{\varepsilon}(\bar{S}, \bar{\varepsilon}) = 0$ . From these results, in the region above  $\dot{\varepsilon} = 0$ , we can confirm  $\dot{\varepsilon}(S, \varepsilon) > 0$ , while in the region below  $\dot{\varepsilon} = 0$ , we can find  $\dot{\varepsilon}(S, \varepsilon) < 0$ .

Next, we set  $(\hat{S}, \hat{\varepsilon})$  such as  $\dot{S} = 0$ . That is, from (6),  $\dot{S} = \dot{S}(\hat{S}, \hat{\varepsilon}) = W - M - dS = 0$ . Here, as  $A'(M)$  is strictly increasing, its inverse is also strictly increasing. Let  $(A')^{-1} = v$ . By making use of (4) and (6),  $\dot{S} = \dot{S}(\hat{S}, \hat{\varepsilon}) = W - v(\varepsilon) - dS$ . Hence,  $\partial \dot{S} / \partial \varepsilon = v'(\varepsilon) < 0$ .

Keeping  $S = \hat{S}$  and supposing that  $\varepsilon_a < \hat{\varepsilon}$ , from  $\partial \dot{S} / \partial \varepsilon < 0$  and  $\dot{S}(\hat{S}, \hat{\varepsilon}) = 0$ ,  $\dot{S}(\hat{S}, \varepsilon_a) > 0$ . On the other hand, leaving  $S = \hat{S}$  and supposing that  $\varepsilon_b > \hat{\varepsilon}$ , from  $\partial \dot{S} / \partial \varepsilon < 0$  and  $\dot{S}(\hat{S}, \hat{\varepsilon}) = 0$ ,  $\dot{S}(\hat{S}, \varepsilon_b) < 0$ . From these results, we can identify that, in the region above  $\dot{S} = 0$ ,  $\dot{S}(S, \varepsilon) < 0$ . On the other hand we can confirm that, in the region below  $\dot{S} = 0$ ,  $\dot{S}(S, \varepsilon) > 0$ .

By summarizing these results, we can obtain the direction of the paths in each region as follows:

1) in the region which is below  $\dot{S} = 0$  and above  $\dot{\varepsilon} = 0$ , the stock of accumulative pollutants

- increases and the optimal environmental regulatory stringency also increases as time proceeds. Hence, the paths composed of the stock of accumulative pollutants and the optimal environmental regulatory stringency move towards the upper right direction in the region;
- 2) in the region which is below  $\dot{S} = 0$  and below  $\dot{\varepsilon} = 0$ , the stock of accumulative pollutants increases and the optimal environmental regulatory stringency also increases as time proceeds. Accordingly, the paths composed of the stock of accumulative pollutants and the optimal environmental regulatory stringency move towards the lower right direction in the region;
  - 3) in the region which is above  $\dot{S} = 0$  and below  $\dot{\varepsilon} = 0$ , the stock of accumulative pollutants increases and the optimal environmental regulatory stringency also increases as time proceeds. Hence, the paths composed of the stock of accumulative pollutants and the optimal environmental regulatory stringency move towards the lower left direction in the region.
  - 4) in the region which is above  $\dot{S} = 0$  and above  $\dot{\varepsilon} = 0$ , the stock of accumulative pollutants increases and the optimal environmental regulatory stringency also increases as time proceeds. Therefore, the stock of accumulative pollutants and the optimal environmental regulatory stringency move towards the upper left direction in the region.

### **STEADY STATE COMPARION BETWEEN SUFFICIENT AND INSUFFICIENT LIABILITY COSTS ESTIMATIONS**

Based on the previous results, this section will examine the difference that can occur in terms of the steady state solution of the stock of accumulative pollutants and the optimal environmental regulatory stringency for the case where the liability costs for environmental damages estimated are sufficient and the case where those estimates are insufficient. As mentioned before, in the case of liability costs for environmental damages through sufficient consideration, the estimation includes costs corresponding to not only the private interests such as rights to live and property rights but also covers the public interests from living organisms and their surrounding and the intrinsic values of the environment. In this case, we will define that  $D_p = D_h$  (when the liability costs for environmental damages are sufficiently estimated). On the other hand, in the case of the liability costs for environmental damages estimated through insufficient consideration, it can be considered that the costs representing both the private and public interests may not be sufficiently covered. This will be defined as  $D_p = D_l$  (when the liability costs for environmental damages are insufficiently estimated). Taking into consideration the above and past literature that find that only a portion of the sufficient liability costs for environmental damages are usually covered and compensation costs for environmental losses are not adequately paid [8-12], the estimation of the liability costs for the case of sufficient estimation will be larger than those in the case of insufficient estimation. Hence, it assumes that the estimation of the liability costs for environmental damages in the former case are larger than those in the latter case with any amount of stock of accumulative pollutants. i.e.  $D_h(S) > D_l(S)$  for  $0 < S$ . It also assumes that  $D_h(0) = D_l(0) = 0$ .

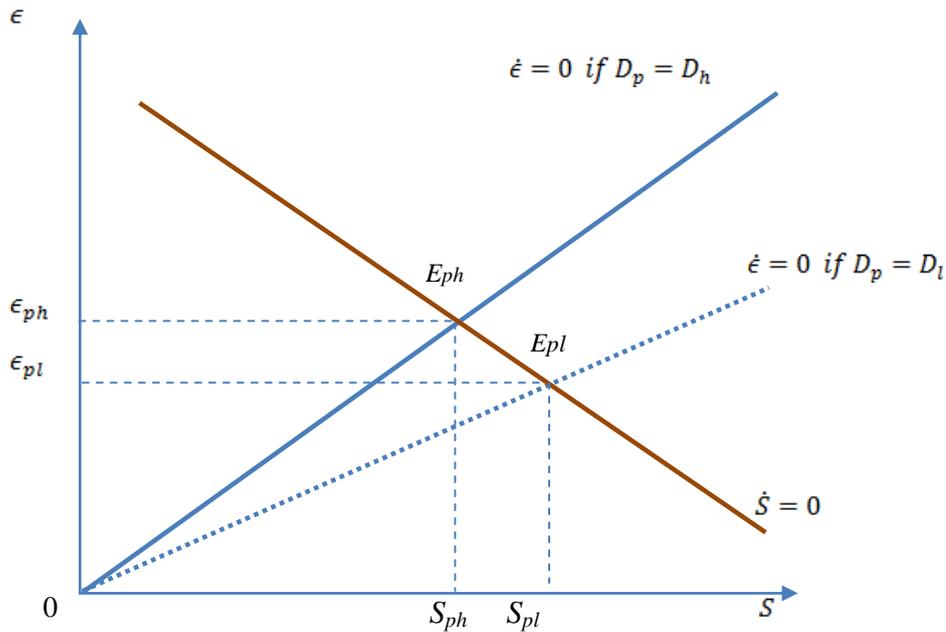
Accordingly,

$$D_h''(S) > D_l''(S). \quad (13)$$

Substitute (13) into (8), we can obtain:

$$\frac{D_h''(S)}{r_q + d} > \frac{D_l''(S)}{r_q + d} > 0. \quad (14)$$

Since this section and the next section only focuses on the differences between the case of sufficient estimations of liability costs for environmental damages and the case of insufficient estimations, for convenience, it assumes that the discount rates are identical in both cases. Hence, from (12) and (14), we can draw Figure 1.  $\dot{\varepsilon} = 0$  refers to the stock of accumulative



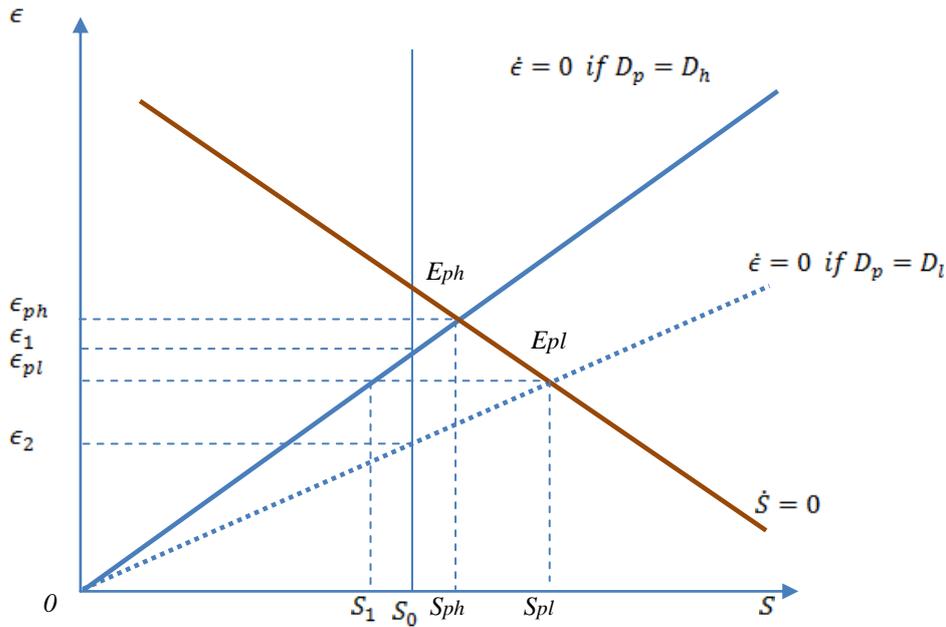
**Figure 1.** Steady state solutions in the case of sufficient estimation of liability costs for environmental damages and in the case of insufficient estimation of liability costs for environmental damages.

pollutants under the steady state;  $S_{ph}$  indicates the stock of accumulative pollutants at the steady state when the estimations of liability costs are sufficient; and  $S_{pl}$  indicates the stock of accumulative pollutants at the steady state when the estimations of liability costs are insufficient.

As seen in Figure 1, we can find that in the case where liability costs for environmental damages are sufficiently estimated, which include both costs covering the public and private interests, the steady state value of the optimal environmental regulatory stringency are higher and the stock of accumulative pollutants are lower, than compared with the case of insufficient estimation of liability costs for environmental damages. That is, this steady state could be regarded as the steady state solution of high environmental consideration. On the contrary, in the case of insufficient estimation of liability costs for environmental damages, the steady state value of the optimal environmental regulatory stringency are lower, and the stock of accumulative pollutants are higher, than compared with the case of sufficient estimation of liability costs. Hence, this state could be interpreted as the steady state solution of low environmental consideration.

### **DIFFERENCE IN THE INITIAL VALUE OF THE ENVIRONMENTAL REGULATIONS – COMPARING SUFFICIENT AND INSUFFICIENT LIABILITY COSTS ESTIMATIONS**

Next, in this section, we will examine, under the condition that the initial value of the stock of accumulative pollutants is within a given range, how the initial value of the optimal environmental regulatory stringency in the case of sufficient estimation of liability costs for environmental damages differs from the case of insufficient estimation of liability costs for environmental damages. To describe more precisely, under the condition that the initial value of the stock of accumulative pollutants is within a given range, this section will analyse how the initial value of the optimal environmental regulatory stringency which leads to the steady state solution of high environmental consideration differs from one which leads to the steady state solution of low environmental consideration. The reason for analysing this is that we can observe how the initial value of the optimal environmental regulatory stringency is set in order to converge into a steady state solution of higher environmental consideration compared to the

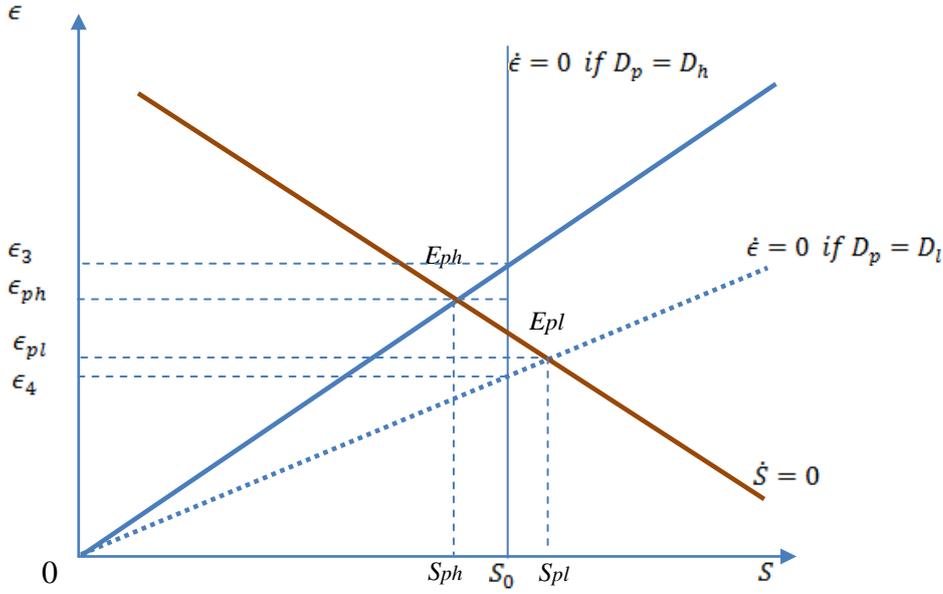


**Figure 2.** Initial values of the optimal environmental regulatory stringency under  $S_1 < S_0 < S_{ph}$  for both sufficient and insufficient estimations of liability costs for environmental damages.

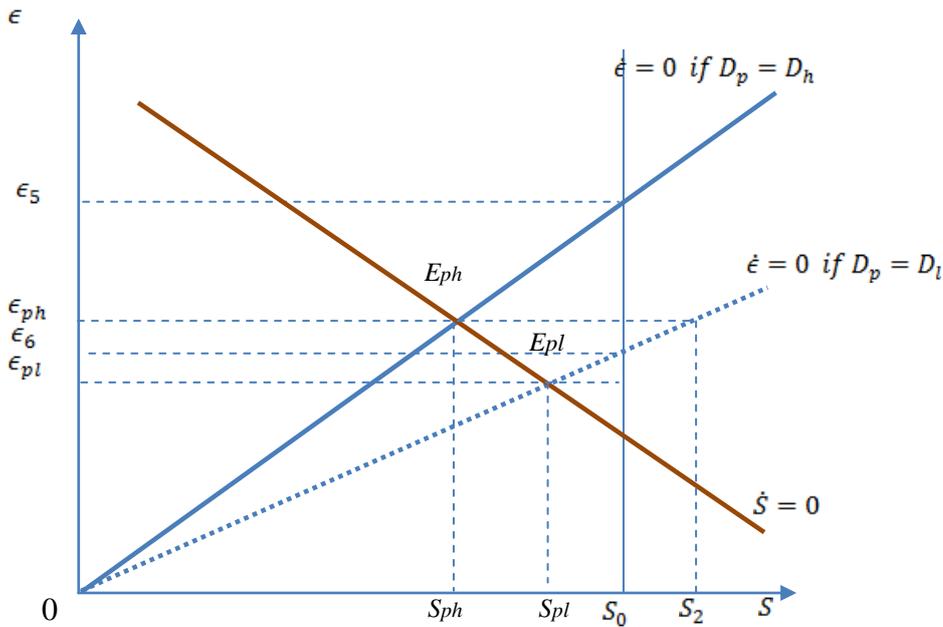
compared to the steady state solution of lower environmental consideration, given that the initial value of the stock of accumulative pollutants is within a given range and under the condition that the social preference towards the consideration of liability costs for environmental damages does not change over time in each of the cases.

In Figure 2,  $S_1$  represents the stock of accumulative pollutants at the steady state with sufficient estimation of liability cost ( $D_p = D_h$ ) and at the level of environmental regulations stringency ( $\varepsilon_{pl}$ ) obtained under the steady state of the stock of accumulative pollutants ( $\dot{S} = 0$ ) and the steady state with insufficient estimation of liability costs ( $D_p = D_l$ ). As seen in Figure 2, given  $S_1 < S_0 < S_{ph}$ , concerning the case of sufficient estimation of liability costs for environmental damages, from the result of 1), the initial value of the optimal environmental regulatory stringency which leads to the steady state solution can be set within the range of  $\varepsilon_1 < \tilde{\varepsilon}_{0h} < \varepsilon_{ph}$ . On the other hand, given  $S_1 < S_0 < S_{ph}$ , concerning the case of insufficient estimation of liability costs, from the result of 1), the initial value of the optimal environmental regulatory stringency which leads to the steady state solution can be set within the range of  $\varepsilon_2 < \tilde{\varepsilon}_{0l} < \varepsilon_{pl}$ . From Figure 2, we can identify  $\varepsilon_2 < \tilde{\varepsilon}_{0l} < \varepsilon_{pl} < \varepsilon_1 < \tilde{\varepsilon}_{0h} < \varepsilon_{ph}$ . From transitivity,  $\tilde{\varepsilon}_{0l} < \tilde{\varepsilon}_{0h}$ . That is, when sufficient liability costs for environmental damages are covered, the initial optimal environmental regulatory stringency that leads to the steady state of high environmental consideration, is at a higher level than the initial optimal environmental regulatory stringency when the estimation of the liability costs are insufficient and leads to a steady state of low environmental consideration. Accordingly, when insufficient liability costs for environmental damages are covered, the initial optimal environmental regulatory stringency that leads to the steady state of low environmental consideration, is at a lower level than the initial optimal environmental regulatory stringency when the liability costs are sufficiently estimated and leads to a steady state of high environmental consideration.

As indicated in Figure 3, given  $S_{ph} < S_0 < S_{pl}$ , with regard to the case of sufficient estimation of liability costs for environmental damages, from the result of 3), the initial value of the optimal environmental regulatory stringency which leads to the steady state solution can be



**Figure 3.** Initial values of the optimal environmental regulatory stringency under  $S_{ph} < S_0 < S_{pl}$  for both sufficient and insufficient estimations of liability costs for environmental damages.



**Figure 4.** Initial values of the optimal environmental regulatory stringency under  $S_{pl} < S_0 < S_2$  for both sufficient and insufficient estimations of liability costs for environmental damages.

set within the range of  $\varepsilon_{ph} < \tilde{\varepsilon}_{0h} < \varepsilon_3$ . On the other hand, given  $S_{ph} < S_0 < S_{pl}$ , concerning the case of insufficient estimation of liability costs, from the result of (i), the initial value of the optimal environmental regulatory stringency which leads to the steady state solution can be set within the range of  $\varepsilon_4 < \tilde{\varepsilon}_{0l} < \varepsilon_{pl}$ . As seen in Figure 3, we can identify  $\varepsilon_4 < \tilde{\varepsilon}_{0l} < \varepsilon_{pl} < \varepsilon_{ph} < \tilde{\varepsilon}_{0h} < \varepsilon_3$ . From transitivity,  $\tilde{\varepsilon}_{0l} < \varepsilon_{0h}$ . That is to say, when sufficient liability costs for environmental damages are covered, the initial optimal environmental regulatory stringency that leads to the steady state of high environmental consideration, is at a higher level than the initial optimal environmental regulatory stringency when the liability costs are insufficiently estimated which leads to a steady state of low environmental consideration.

In Figure 4,  $S_2$  represents the stock of accumulative pollutants at the steady state with insufficient estimation of liability cost ( $D_p = D_l$ ) and at the level of environmental regulation stringency ( $\varepsilon_{ph}$ ) obtained under the steady state of the stock of accumulative pollutants ( $\dot{S} = 0$ ) and the steady state with sufficient estimation of liability costs ( $D_p = D_h$ ).

As shown in Figure 4, given  $S_{pl} < S_0 < S_2$ , as for the case of sufficient estimation of liability costs for environmental damages, from the result of (iii), the initial value of the optimal environmental regulatory stringency which leads to the steady state solution can be set within the range of  $\varepsilon_{ph} < \tilde{\varepsilon}_{0h} < \varepsilon_5$ . On the other hand, given  $S_{pl} < S_0 < S_2$ , concerning the case of insufficient estimation of liability costs, from the result of (iii), the initial value of the optimal environmental regulatory stringency which leads to the steady state solution can be set within the range of  $\varepsilon_{pl} < \tilde{\varepsilon}_{0l} < \varepsilon_6$ . As indicated in Figure 4, we are able to identify  $\varepsilon_{pl} < \tilde{\varepsilon}_{0l} < \varepsilon_6 < \varepsilon_{ph} < \tilde{\varepsilon}_{0h} < \varepsilon_5$ . From transitivity,  $\tilde{\varepsilon}_{0l} < \tilde{\varepsilon}_{0h}$ . In other words, when sufficient liability costs for environmental damages are covered, the initial optimal environmental regulatory stringency that leads to the steady state of high environmental consideration, is at a higher level than the initial optimal environmental regulatory stringency when the liability cost is insufficiently estimated which leads to a steady state of low environmental consideration.

To summarize these results, given  $S_1 < S_0 < S_2$ , when sufficient liability costs for environmental damages are covered, the initial optimal environmental regulatory stringency that leads to the steady state of high environmental consideration, is at a higher level than the initial optimal environmental regulatory stringency when the liability cost is insufficiently estimated which leads to a steady state of low environmental consideration. Accordingly, when insufficient liability cost for environmental damages are covered, the initial optimal environmental regulatory stringency that leads to the steady state of low environmental consideration, is at a lower level than the initial optimal environmental regulatory stringency when the liability cost is sufficiently estimated which leads to a steady state of high environmental consideration.

### **STEADY STATE COMPARISON BETWEEN SUFFICIENT AND INSUFFICIENT DISCOUNT RATES FOR FUTURE GENERATIONS**

Next, in this section, we will compare the steady state in the case of a discount rate with sufficient consideration for future generations with the steady state in the case of a discount rate with insufficient consideration. Here, with respect to the discount rate with insufficient consideration for future generations, we define it as  $r_q = r_h$ . On the other hand, with regards to the discount rate with sufficient consideration for future generations, we define it as  $r_q = r_l$ . When future generations are not adequately considered, there is the tendency that environmental costs along with human activities including economic activities are not sufficiently estimated and the discount rate is relatively high. On the other hand, when future generations are adequately considered, there is the tendency that environmental costs along with human activities including economic activities are sufficiently estimated and the discount rate is low. Hence,

$$r_h > r_l. \quad (15)$$

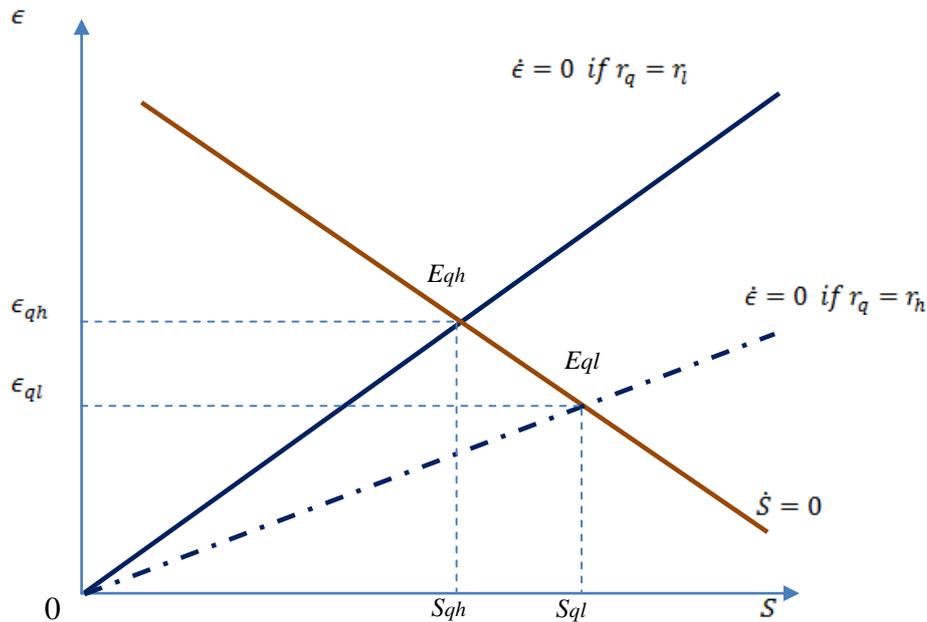
Substitute (15) into (8), we can attain:

$$\frac{D_p''(S)}{r_l + d} > \frac{D_p''(S)}{r_h + d} > 0. \quad (16)$$

Since this section and the next section only focuses on the differences between the cases with discount rates with sufficient consideration for future generation and the discount rate with insufficient consideration, for convenience, it assumes that the function concerning the

estimation of liability costs for environmental damages are identical for both cases. Hence, from (12) and (16), we can draw Figure 5.

In Figure 5,  $S_{qh}$  represents the stock of accumulative pollutants at the steady state when the discount rate for future generations is sufficient and  $S_{ql}$  indicates the stock of accumulative pollutants at the steady state when the discount rate for future generations is insufficient. As seen in Figure 5, we can find that in the case of environmental costs estimated adopting a discount rate with sufficient consideration for future generations, the steady state value of the optimal environmental regulatory stringency are higher, and the stock of accumulative pollutants are lower, than compared with the case of environmental costs estimated adopting a discount rate with insufficient consideration for future generations. That is, this could be regarded as the steady state solution of high environmental consideration. Accordingly, in the case of a discount rate with insufficient consideration for future generations, the steady state value of the optimal environmental regulatory stringency are lower, and the stock of accumulative pollutants are higher, than compared with the case of a discount rate with sufficient consideration for future generations. Hence, they could be interpreted as the steady state solution of low environmental consideration.



**Figure 5.** Steady state solutions in the case of a discount rate with sufficient consideration for future generations and in the case of a discount rate with insufficient consideration.

From the previous results, we can find that the results of the case of sufficient estimation of liability costs for environmental damages is similar to the results of the case of a discount rate with sufficient consideration of future generations. We can also find that the results of the case of insufficient estimation of liability costs for environmental damages is similar to the results of the case of a discount rate with insufficient consideration for future generations.

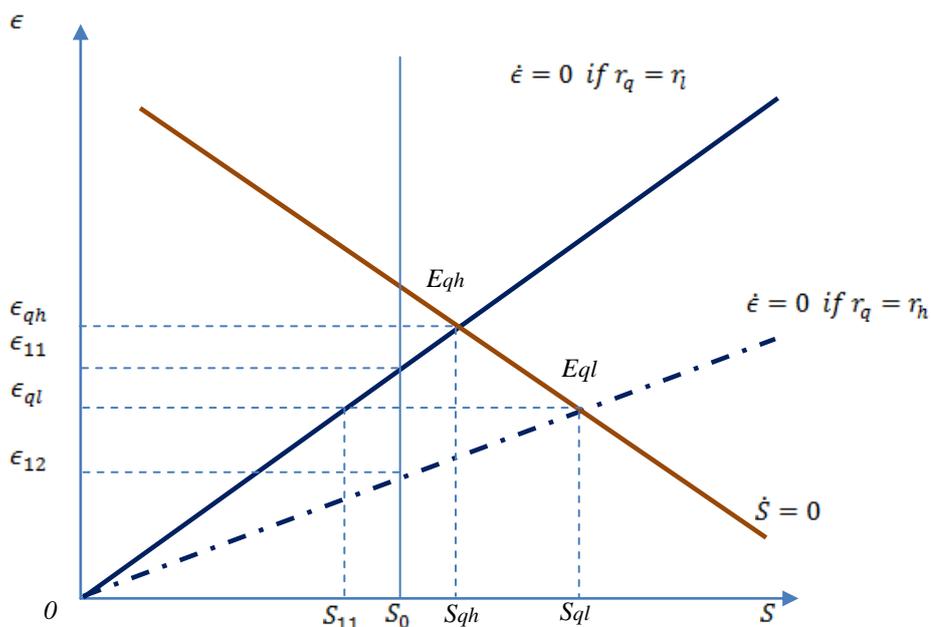
### **DIFFERENCE IN THE INITIAL VALUE OF THE ENVIRONMENTAL REGULATIONS – COMPARING SUFFICIENT AND INSUFFICIENT DISCOUNT RATES FOR FUTURE GENERATIONS**

Next, in this section, similar to analysis on the consideration of liability costs for environmental damages, under the condition that the initial value of the stock of accumulative pollutants is within a given range, we will examine, how the initial value of the optimal

environmental regulatory stringency in the case of a discount rate with sufficient consideration for future generations differs from the initial value of optimal environmental regulatory stringency in the case of a discount rate with insufficient consideration.

In Figure 6,  $S_{11}$  represents the stock of accumulative pollutants at the steady state with sufficient consideration for future generations ( $r_q = r_l$ ) and at the level of environmental regulations stringency ( $\varepsilon_{ql}$ ) obtained under the steady state of the stock of accumulative pollutants ( $\dot{S} = 0$ ) and the steady state with insufficient consideration for future generations ( $r_q = r_h$ ). As seen in Figure 6, given  $S_{11} < S_0 < S_{qh}$ , concerning the case of a discount rate with sufficient consideration for future generations, from the result of 1), the initial value of the optimal environmental regulatory stringency which leads to the steady state solution can be set within the range of  $\varepsilon_{11} < \hat{\varepsilon}_{0h} < \varepsilon_{qh}$ . On the other hand, given  $S_{11} < S_0 < S_{qh}$ , concerning the case of a discount rate with insufficient consideration for future generations, from the result of 1), the initial value of the optimal environmental regulatory stringency which leads to the steady state solution can be set within the range of  $\varepsilon_{12} < \hat{\varepsilon}_{0l} < \varepsilon_{ql}$ . From Figure 6, we can confirm  $\varepsilon_{12} < \hat{\varepsilon}_{0l} < \varepsilon_{ql} < \varepsilon_{11} < \hat{\varepsilon}_{0h} < \varepsilon_{qh}$ . From transitivity,  $\hat{\varepsilon}_{0l} < \hat{\varepsilon}_{0h}$ . That is, when the discount rate is adopted, sufficiently considering future generations, the initial optimal environmental regulatory stringency that leads to the steady state of high environmental consideration, is at a higher level than the initial optimal environmental regulatory stringency when the discount rate is adopted with insufficient consideration of future generations and leads to a steady state of low environmental consideration.

From these results, the initial value of the optimal environmental regulatory stringency in the case of a discount rate with sufficient consideration of future generations and in the case of a discount rate with insufficient consideration under  $S_{11} < S_0 < S_{qh}$ , corresponds with the trend of the initial value of the optimal environmental regulatory stringency in the case of sufficient liability for environmental damages and in the case of insufficient liability costs for environmental damages under  $S_1 < S_0 < S_{ph}$ .



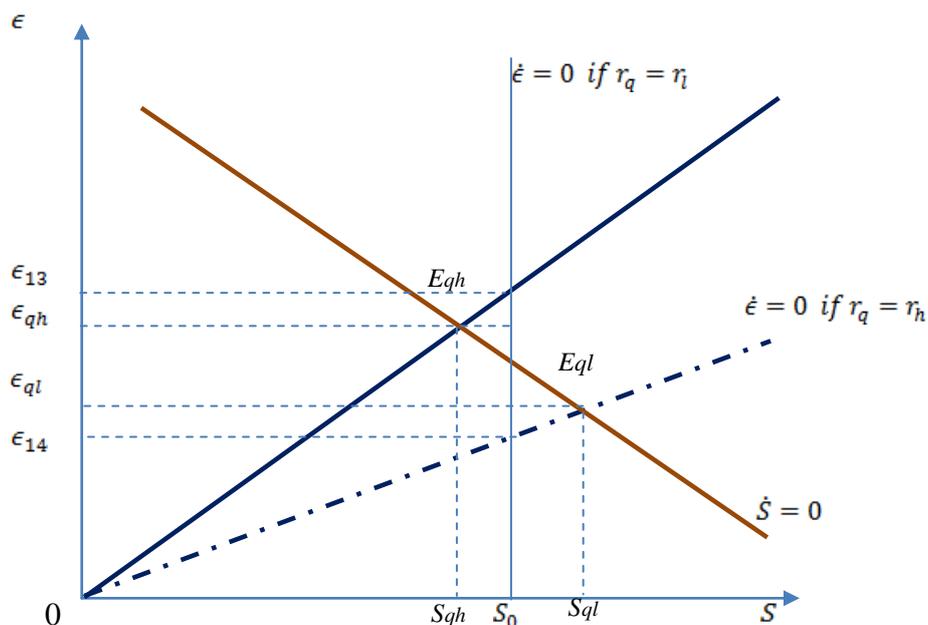
**Figure 6.** Initial values of the optimal environmental regulatory stringency under  $S_{11} < S_0 < S_{qh}$  for both discount rates with sufficient and insufficient consideration for future generations.

As indicated in Figure 7, given  $S_{qh} < S_0 < S_{ql}$ , with respect to the case of a discount rate with sufficient consideration of future generations, from the result of 3), the initial value of the optimal environmental regulatory stringency which leads to the steady state solution can be set within the range of  $\varepsilon_{qh} < \hat{\varepsilon}_{0h} < \varepsilon_{13}$ . On the other hand, given  $S_{qh} < S_0 < S_{ql}$ , concerning the case of a discount rate with insufficient consideration of future generations, from the result of 1), the initial value of the optimal environmental regulatory stringency which leads to the steady state solution can be set within the range of  $\varepsilon_{14} < \hat{\varepsilon}_{0l} < \varepsilon_{ql}$ . As found in Figure 7, we are able to see  $\varepsilon_{14} < \hat{\varepsilon}_{0l} < \varepsilon_{ql} < \varepsilon_{qh} < \hat{\varepsilon}_{0h} < \varepsilon_{13}$ . From transitivity,  $\hat{\varepsilon}_{0l} < \hat{\varepsilon}_{0h}$ . That is to say, when discount rate is adopted, sufficiently considering future generations, the initial optimal environmental regulatory stringency that leads to the steady state of high environmental consideration, is at a higher level than the initial optimal environmental regulatory stringency when the discount rate is adopted with insufficient consideration for future generations which leads to a steady state of low environmental consideration.

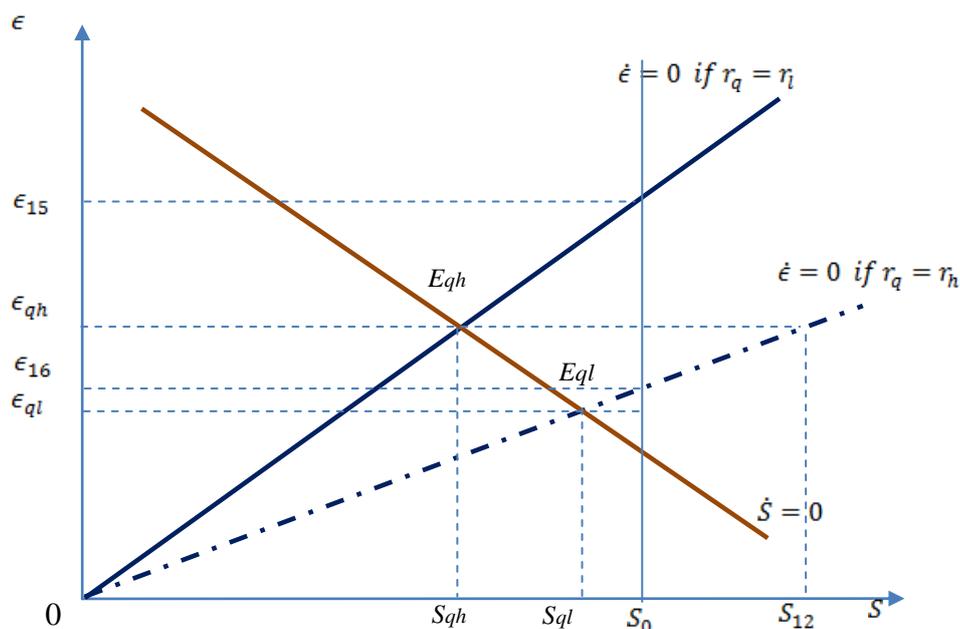
From these results, the initial values of the optimal environmental regulatory stringency in the case of a discount rate with sufficient consideration of future generations and in the case of a discount rate with insufficient consideration under  $S_{qh} < S_0 < S_{ql}$ , corresponds to the initial values of the optimal environmental regulatory stringency in the case of a sufficient estimation of liability costs for environmental damages and in the case of an insufficient estimation under  $S_{ph} < S_0 < S_{pl}$ .

In Figure 8,  $S_{12}$  represents the stock of accumulative pollutants at the steady state with insufficient consideration for future generations ( $r_q = r_h$ ) and at the level of environmental regulations stringency ( $\varepsilon_{qh}$ ) obtained under the steady state of the stock of accumulative pollutants ( $\dot{S} = 0$ ) and the steady state with sufficient consideration for future generations ( $r_q = r_l$ ). As shown in Figure 8, given  $S_{ql} < S_0 < S_{12}$ , as for the case of a discount rate with sufficient consideration for future generations, from the result of 3), the initial value of the optimal environmental regulatory stringency which leads to the steady state solution can be set within the range of  $\varepsilon_{qh} < \hat{\varepsilon}_{0h} < \varepsilon_{15}$ . On the other hand, given  $S_{ql} < S_0 < S_{12}$ , concerning the case of a discount rate with insufficient consideration of future generations, from the result of 3), the initial value of the optimal environmental regulatory stringency which leads to the steady state solution can be set within the range of  $\varepsilon_{ql} < \hat{\varepsilon}_{0l} < \varepsilon_{16}$ . Through Figure 8, we can find out  $\varepsilon_{ql} < \hat{\varepsilon}_{0l} < \varepsilon_{16} < \varepsilon_{qh} < \hat{\varepsilon}_{0h} < \varepsilon_{15}$ . From transitivity,  $\hat{\varepsilon}_{0l} < \hat{\varepsilon}_{0h}$ . In other words, when the discount rate is adopted, sufficiently considering future generations, the initial optimal environmental regulatory stringency that leads to the steady state of high environmental consideration, is at a higher level than the initial optimal environmental regulatory stringency when the discount rate is adopted with insufficient consideration of future generations which leads to a steady state of low environmental consideration.

From these results, the initial values of the optimal environmental regulatory stringency in the case of a discount rate with sufficient consideration of future generations and in the case of a discount rate with insufficient consideration under  $S_{ql} < S_0 < S_{12}$ , corresponds to the initial values of the optimal environmental regulatory stringency in the case of a sufficient estimation of liability costs for environmental damages and in the case of an insufficient estimation under  $S_{pl} < S_0 < S_2$ . To summarize the results, given  $S_{11} < S_0 < S_{12}$  when the discount rate with sufficient consideration of future generations is adopted, the initial optimal environmental regulatory stringency that leads to the steady state of high environmental consideration, is at a higher level than the initial optimal environmental regulatory stringency when the adopted discount rate is high and leads to a steady state of low environmental consideration.



**Figure 7.** Initial values of the optimal environmental regulatory stringency under  $S_{qh} < S_0 < S_{ql}$  for both discount rates with sufficient and insufficient consideration for future generations.



**Figure 8.** Initial values of the optimal environmental regulatory stringency under  $S_{ql} < S_0 < S_{12}$  for both discount rates with sufficient and insufficient consideration for future generations.

From the results described, the case of a discount rate with sufficient consideration of future generations is similar to the case of sufficient estimation of liability costs for environmental damages. Accordingly, the case of a discount rate with insufficient consideration of future generations corresponds to the case of insufficient estimation of liability costs for environmental damages.

## CONCLUSIONS

Along with the expansion of economic activities, accumulative pollution such as global warming, radioactive contamination, and dioxins is a growing concern. In order to tackle this

concern, environmental costs which include the liability costs of environmental damages and abatement costs will be required and it will be important to understand the social preference towards such environmental costs.

Therefore, this article examines the impacts the difference in social preference towards environmental costs have on the steady state solution of the stock of accumulative pollutants and the optimal environmental regulatory stringency. Furthermore, this article analyses the difference in terms of the initial value of the optimal environmental regulatory stringency, depending on the social preference towards environmental costs.

The results find that the steady state value of the optimal environmental regulatory stringency was higher, and the steady state value of the stock of the accumulative pollutants was lower in the case when the estimation of the liability costs for environmental damages was sufficient, compared to when the estimation was insufficient. This article also finds that the steady state value of the optimal environmental regulatory stringency was higher, and the steady state value of the stock of accumulative pollutants was lower in the case when the discount rate adopted took sufficient consideration for future generations, than compared to the adoption of a discount rate with insufficient consideration. These results indicate that in the case of high social preference towards addressing environmental issues accepting environmental costs, we can find the convergence of the steady state solution with high environmental consideration where the optimal environmental regulatory stringency is higher and the stock of accumulative pollutants is lower, than compared with the case of low social preference towards costs concerning environmental issues. Accordingly, as in the case of insufficient estimation of the liability for environmental damages and the case with the adoption of a discount rate with insufficient consideration for future generations where there is low social preference towards costs concerning environmental issues, we find the convergence of the steady state solution with low environmental consideration where the optimal environmental regulatory stringency is lower and the stock of accumulative pollutants is higher, than compared with the case of high social preference towards costs to address environmental issues. Therefore, it is desirable to conduct policies to encourage a shift towards the social preference to address environmental issues and accepting the environmental costs. For example, it would be necessary to promote educational activities to penetrate the concept of intergenerational equity and the intrinsic values of the environment, and promote the concept and measures of environmental accounting to companies and public organizations.

The results indicate that the steady state solution converges at a higher state of environmental consideration if society sufficiently estimates the liability costs for environmental damages, and/or adopts discount rates with sufficient consideration of future generations. When aiming to achieve such a steady state of high environmental consideration and the initial value of the stock of accumulative pollutants are within a given range, the initial value of the stringency of environmental regulations are set much higher than when society is not aiming for such a high environmental consideration and converges to a steady state of low consideration. Hence, in order to support the convergence it would be necessary to establish appropriate systems and/or institutions. For instance, the gathering and accessibility of information and an objective monitoring system would be required to support society to make well informed decisions. Here, we will refer to the shortcoming of this study. Given that  $S_0 < S_1$  and  $S_2 < S_0$ , the possible range of the initial value of the optimal environmental regulatory stringency that converges to a steady state solution for the case of a sufficient estimate of liability costs for environmental damages, partially overlaps with the possible range of the initial value of the optimal environmental regulatory stringency for the case of an insufficient estimation of liability costs. Hence, it would be uncertain if the initial value of the optimal environmental regulatory stringency in the case of a sufficient estimation of liability costs is higher than that

in the case of an insufficient estimation. It would depend on the function of abatement costs and/or of liability costs for environmental damages in the case of those sufficiently estimated and in the case of those insufficiently estimated. Given that  $S_0 < S_{11}$  and  $S_{12} < S_0$  the possible range of the initial value of the optimal environmental regulatory stringency that converges to a steady state solution in the case of the adoption of a discount rate with sufficient consideration of future generations partially overlaps with the possible range of the initial value of the optimal environmental regulatory stringency when a discount rate with insufficient consideration is adopted. Hence, it would be uncertain if the initial value of the optimal environmental regulatory stringency in the case of a discount rate with sufficient consideration for future generations is higher than that of the case of a discount rate with insufficient consideration. It would depend on the difference between the discount rate of sufficient and insufficient consideration of future generations, or the function of the abatement costs and/or of liability costs for environmental damage. Hence, this would be a possible area for future studies.

From the previous results, the steady state solution of the stock of accumulative pollutants and the optimal environmental regulatory stringency, and the initial value of the optimal environmental regulatory stringency depend on social preference toward environmental costs to address environmental issues. Therefore, it could lead to the establishment of a more sustainable society, by conducting the appropriate policies based on these results.

## APPENDIX

Explanation concerning equation (4)

$$\frac{\partial H^C}{\partial M} = 0.$$

Therefore,

$$A'(M) - \varepsilon = 0.$$

$$\therefore \varepsilon = A'(M).$$

With respect to equation (5),

$$-\frac{\partial H^C}{\partial S} e^{-r_q t} = \frac{\partial(\varepsilon e^{-r_q t})}{\partial t}.$$

Therefore,

$$-\left[D'_p(S) - \varepsilon d\right] e^{-r_q t} = \dot{\varepsilon} e^{-r_q t} - r_q \varepsilon e^{-r_q t}.$$

Divide both sides of the above equation by  $e^{-r_q t}$ , then we can obtain:

$$\dot{\varepsilon} - r_q \varepsilon = -D'_p(S) + \varepsilon d,$$

$$\therefore \dot{\varepsilon} = -D'_p(S) + \varepsilon(r_q + d).$$

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# ACCOMPLISHING THE SUSTAINABLE DEVELOPMENT GOAL 13 – CLIMATE ACTION AND THE ROLE OF THE EUROPEAN UNION

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## ABSTRACT

One of the key aspects of Sustainable Development Goals is the difference in awareness of various societies regarding the need to protect the environment and transform economies and societies, so they rely more on renewable energy sources. As an initiative, it should represent a commitment that should be in focus of the international agreements, especially the Paris Climate Treaty. Whilst the Sustainable Development Goals as a totality comprise serious implementation limits, the Paris Climate Treaty should be considered necessary to implement the Sustainable Development Goal 13: Climate Action. Implementing the Sustainable Development Goals would perhaps allow a holistic framework in combating climate change. Nevertheless, for the immediate future, there should be no delays in implementing a certain form of international effort to combat climate change. Therefore, the role of the European Union's climate policy was studied in this article, mainly its effectiveness in the reduction of emissions, as a crucial aspect of implementing one of the crucial Sustainable Development Goals, Goal 13, especially in the context of the Paris Climate Treaty and carbon taxes. The EU sees its vital interest in the fulfilment of the Sustainable Development Goal 13, and in successful action that would enable it to comply with the Paris Climate Treaty. The quantitative analysis in this article, based on an Autoregressive Distributed Lags approach, finds that the most effective way of reducing carbon dioxide emissions in the European Union would be to continue the shift towards more dependency on renewable sources of energy sources while maintaining current or slightly higher levels of taxation on energy consumption. The revenue should be directed towards subsidizing research and development of renewable energy sources.

## KEYWORDS

sustainable development goals, Paris climate treaty, the European Union, environmental tax, renewable energy sources

## CLASSIFICATION

JEL: E60, O13, Q28

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## **INTRODUCTION**

With the signing of the Paris Climate Treaty (also known as the Paris Climate Agreement, the Paris Agreement or Accord; hereafter: the Paris Climate Treaty) and its ratification, the focus of the international debate once again slowly shifted back towards sustainable development.

Mitigating, as well as adapting to climate change [1] and its impacts, will require building on the momentum achieved by the Paris Climate Treaty on Climate Change, which entered into force on 4 November 2016 [2]. The Paris Climate Treaty's central aim is "to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below two °C above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1,5 °C"<sup>1</sup>. The goals set forth in Paris do not aim to ensure long-term sustainable development. As part of the Paris Climate Treaty, each country put forward a "nationally determined contribution" (NDC) towards the common goal of limiting global warming. This will likely shift the focus away from international mitigation policies, such as the Kyoto Protocol, to policies on national level [3].

Pacala and Socolow [4] warned that "mitigating climate change will require substantial abatement of greenhouse gas emissions from all core economic sectors", whilst Martin et al. [5] pointed out that "the choice of appropriate policy instruments for each of these sectors is essential for minimizing the overall economic costs of mitigation with given technologies (static efficiency), and for stimulating technological innovations that will further reduce mitigation costs in the future (dynamic efficiency)."

Europe's transition to a low carbon economy is "a work in progress, now hampered by internal stresses and foot-dragging by some laggard member states." China has also already managed to influence the international markets of renewable energy products, its production mainly responsible for the decrease of price of solar panels for about 80 percent in a short period<sup>2</sup>. The European Union (hereafter: the EU) sees its vital interest in the fulfilment of the Sustainable Development Goal 13 (hereafter: the SDG 13), and in a successful action that would enable it to comply with the Paris Climate Treaty. The framework was adopted by EU leaders in October 2014. It builds on the 2020 climate and energy package. The framework contains a binding target to cut emissions in EU territory by at least 40 percent below 1990 levels by 2030. This will enable the EU to take cost-effective steps towards its long-term objective of cutting emissions by 80-95 percent by 2050 in the context of necessary reductions by developed countries as a group, as well as make a fair and ambitious contribution to the Paris Climate Treaty [6]. The article aims to empirically assess the relevance of several key variables from an econometric perspective to test the impact key variables in the discussion of the Paris Climate Treaty may have on CO<sub>2</sub> emissions. It primarily aims to review whether subsidizing renewable energy or implementing carbon taxing is more effective as a means of curbing CO<sub>2</sub> emissions as these are the two most common theoretical recommendations for this issue.

This article will primarily try to provide one of the possible answers on how the EU climate policy is to be further pursued in the context of the Paris Climate Treaty, by conducting an analysis of the selected literature on both qualitative and quantitative papers and studies concerning the SDG13, limiting the emissions, as well as the relationship between economic growth and carbon dioxide (hereafter: CO<sub>2</sub>) emissions. After a short discussion, the article presents the quantitative approach used. The methodological section is followed by the presentation of results and discussion, while policy recommendations are provided in the conclusion.

## **LITERATURE REVIEW**

In the literature review, we address relevant sources on carbon taxation and SDG13. Carbon taxes are "expected to stimulate the production of clean technology, hence they modify the

price differential between the use of high-carbon and low-carbon technologies” – according to the “Porter Hypothesis”. Additionally, carbon taxes “stimulate country’s economic growth more than harming it, by stimulating technological innovation” [7]. Baranzini and Carattini [8], however, warn about are significant downsides to carbon taxation: “the difficulty of their implementation, administrative burdens, exemptions for many carbon emitting intensive industries<sup>3</sup> and potential damages that may be caused to the competitiveness of key industries”. Despite these issues, already mentioned carbon taxation is perhaps the most direct path to decreasing harmful emissions. Davis and Kilian [9] use a range of econometric techniques to “assess the potential impact that a carbon tax could have in the United States, by estimating the impact of past variations in gasoline tax” [8], while Baranzini and Weber [10] find that in Switzerland “an increase in the existing mineral oil tax decreased gasoline demand by about 3.5 percent”. Concurrently, the consumers are aware that the price increase is not a product of market forces. So, while still a highly debated issue, studies like the one from [3], who used the unit without carbon taxes implemented as studied unit and “synthetic Sweden” as control unit, proved that the carbon taxes can be efficient in reducing CO<sub>2</sub> emissions, contrary to the earlier studies of carbon taxes implementation performed by Bohlin [11], Bruvold and Larsen [12], as well as Lin and Li [13].

Different from the G7’s development agenda, which still primarily focuses on aid–recipient relationships as “dynamically defined by the OECD through the Development Assistance Committee (DAC), the G20 may be better placed to facilitate the implementation of the SDGs” [14]. It may be complex to understand the link between the Paris Climate Treaty and the SDGs. While we agree that the SDGs as a whole have serious limitations in their implementation, the Paris Climate Treaty should be considered necessary to implement the SDG 13. Implementing the SDGs as a whole would perhaps allow a holistic framework in combating climate change, but for the immediate future, there can be no delay in implementing some form of international effort to combat climate change. This is further emphasized in the study of von Stechow et al. [15] in determining that there is an inescapable link between the Paris Climate Treaty and implementing the SDGs. These goals attempt to combat climate change, inequality, hunger, discrimination, conflict, and all other essential concerns of the modern world. These goals are described in detail in Le Blanc [16], who emphasizes that it is sometimes difficult to transform these 13 goals into exact policy proposals and that is why it is so significant that the Paris Climate Treaty – as a bare minimum of what could be achieved on climate change, should be implemented without delay and with the participation of all of the key global actors.

Donald and Way [17] point out: “Although the SDGs are not legally binding, in some contexts it may be possible to make claims within national judicial mechanisms to hold governments accountable for the 2030 Agenda commitments, particularly where commitments to goals and targets overlap with existing legal or constitutional guarantees”, whilst Elder et al. [18] accentuate the real cost of SDGs’ implementation, which is actually not too high: “About 2.5–3.8 percent of the world GDP, and 0.7–1.1 percent of global financial assets.”

Figueres [19] points out that “even the basic approach to decreasing CO<sub>2</sub> and other greenhouse gas emissions, as required by the Paris Climate Treaty, would require a significant change.” This is the reason why many have been sceptic of the SDGs and believe that these goals did not go far enough in ensuring the sustainability of our world.

Leismann et al. [20] emphasize the task that lies in front of Western societies, if they want to preserve the habitat, and “ensure basic access to resources for developing and emerging economies and for the future generations: Western industrial societies must reduce their absolute resource consumption by a factor of 10 by 2050” [20]. Germany, as the largest

economy of the EU, must now become one of the leaders in the fight against excessive greenhouse gas emission. While the EU has limited hard power in order to implement such a goal, its soft power has never been as important as it is today. The soft and normative power of the EU, or “leading by example”, has now become one of the key elements in ensuring the sustainability of the global economy. Policy-makers of the world’s large powers are currently focused on numerous conflicts that prevent a stronger focus on sustainable development.

Moore [21], on the other hand points out: “China, the biggest emitter of greenhouse gases in the world, already agreed to cap its output by 2030 or earlier if possible. Previously, China had only ever pledged to reduce the rapid rate of growth in its emissions, but it has now also promised to increase its use of energy from zero-emission sources to 20 percent by 2030. The USA pledged to cut its emissions to 26-28 percent below 2005 levels by 2025.” Incremental transition from coal-dependent to low carbon economy has started everywhere – as Figueres [19] states: “Emissions from the USA decreased the most: by 3 percent last year, while the GDP grew by 1,6 percent. In China, CO<sub>2</sub> emissions fell by 1 percent in 2016, and its economy expanded by 6,7 percent. In 2016, two-thirds of China’s 5,4 percent extra demand for electricity was supplied by carbon-free energy resources, mostly hydropower and wind”.

The environmental policy of the EU has progressed with time and positioning itself in such a manner may be vital to the long-term soft-power approach adopted by the EU. Therefore, the EU is “the only international actor that has been dedicated to sustainable development and has been continuously dedicated to such an effort in the past two decades” [22]. It is nevertheless interesting to take note of the fact that, despite the EU’s declarative international stance towards climate change, there have been long-standing inconsistencies in the domestic stance of its member-states [23]. Michaelowa’s concerns regarding the influence of interest groups remains significant to this day, but relevant steps have since been taken to ensure the further development of EU environmental policy [23].

The EU has certainly built on its original strategy to combat excessive greenhouse gas emissions that was originally built upon voluntary cuts by members of the corporate sector, subsidies for “producing electricity from renewable energy sources” and a proposal to implement a tax on energy products [24]. The EU has continuously built upon this original framework and has contributed to the first strategy with a second strategy launched in 2005, and it EU remains the most up-to-date relevant leader in dealing with the issues of climate change, acknowledging and covering topics such as carbon capture and geological storage [25]. It is for this reason that we conduct an empirical assessment of key traits that determine the EU’s emissions.

Altieri and Rojas [26] as well as Renfrew [27] point out: “It is visible that environmental costs are unequally distributed as the burdens of air and water pollution, degraded soils and defoliated lands to a large extent rest disproportionately on the poor”. Bakker [28] emphasizes that it is argued that “this will help preserve the environment because of the internalisation of externalities and private property rights by recognising environmental resources as economic goods”, while Goldman [29] states that this way of thinking has been known as “green neoliberalism”.

Han and Lee [30] conducted a generalized method of moments (GMM) analysis on a panel of 19 OECD countries that have ratified the Kyoto protocol. They have concluded “the effect of CO<sub>2</sub> emission on economic growth is declining at a statistically significant trend.”

Blanco et al. [31] conducted panel Granger causality tests on 18 Latin American countries and found empirical evidence of causality between FDI in pollution-intensive industries and CO<sub>2</sub> emission per capita.

Shaari et al. [32] made a Vector Error Correction Model (VECM) for Malaysia and emphasize that “increasing energy consumption in order to increase economic growth may also result in increased CO<sub>2</sub> emission”. The authors suggest that “a statistically significant relationship between CO<sub>2</sub> emission and several macroeconomic variables is present”.

Srinivasan [33] used several quantitative analysis methods, including a VECM, impulse response functions and cointegration tests on the available data for India and concluded that there is “a short-run relationship from CO<sub>2</sub> emission to economic growth.” He further concludes that there is also “a long-term relationship between GDP and energy consumption.”

Lutz and Meyer [34] suggest a positive effect could be expected from a rising environmental tax in Europe. This will be highly relevant in regards to the empirical framework of the article, which also examines the impact of “carbon taxing” on CO<sub>2</sub> emissions.

Martin et al. [5] analysed the Climate Change Levy (CCL) package - “the single most important climate change policy that the UK government has unilaterally imposed on the business sector so far (HM Government, 2006), which consists of “a carbon tax and a scheme of voluntary agreements available to plants in selected energy intensive industries.”

Muhyidin et al. [35] analysed the long-run relationship between environment degradation, economic growth, total energy consumption and industrial production index growth in Malaysia (1970 to 2012). The authors used Johansen and Julies Cointegration test and VECM Granger causality test to estimate time series data were. The empirical analysis suggested “a long-run cointegration relationship between all series, while the orientation towards renewable energy sources (higher investment to control CO<sub>2</sub> emission) should jeopardize economic growth”, the authors concluded.

In their study, Wagner et al. [36] conducted Ordinary Least Squares (OLS) regression, with the adequate number of lags, the coefficients, constant, and error term. The authors concluded that “a switch to renewable energy is needed as soon as possible.”

Obradović and Lojanica [37] analysed the “causal relations among economic growth, energy consumption and carbon-dioxide emissions in Greece and Bulgaria by multivariate analysis”. The authors took into consideration two more variables – gross fixed capital formation, and export as an indicator of trade openness (both countries are included into integration flows and represent open economies), and used the VECM model in order to determine long and short run causal relations among the variables.

Andersson [3] analysed the environmental efficiency of a specific measure, in reducing greenhouse gas emissions – carbon tax and a value-added tax (VAT) on transport fuels, by using the example of Sweden, one of the first countries in the world to implement a carbon tax in 1991. It was introduced at the level of US\$30 per ton of CO<sub>2</sub> and then successively increased to today's rate of US\$132, currently the highest carbon tax in the world [38]. The author uses the data for CO<sub>2</sub> emissions of the transport sector (as the biggest emitter) and empirically analyzes the reduction of CO<sub>2</sub> emissions using panel data and two separate identification strategies: a differences-in-differences (DiD) approach and the synthetic control method, giving however the advantage to the latter.

As can be seen from the conducted literature review, several papers find empirical evidence that a shift to renewable energy sources can endanger economic growth [35], while others [36, 37] emphasize the long-term economic drawbacks of dependency on renewable energy sources and the costs that are associated with such a dependency. Similar disagreements can be found in the afore-mentioned studies that discuss the effects of carbon tax introduction. However, it has to be emphasized that the short-term impact of switching to renewable energy sources may be negative, but it decreases the dependency on foreign sources of energy and stimulates economic growth in the long run.

## DATA AND METHODOLOGY

The data used in analysis is covering a time span from 1995 to 2015, and was extracted from the Eurostat database in 2017. The data is aggregated at the level of the EU, because, as mentioned earlier – one of the primary goals of this article was to study the EU’s climate policies mainly through reducing their emissions. This article prefers the methodology of individual time series analysis; hence the key reason is the understanding of the impact of various variables on the emission levels of the EU. All of the variables, with brief descriptions and the period for which they were available, are presented in Table 1.

**Table 1.** Variables considered. Source: the Eurostat database 2017.

Variable	Abbreviated	Measurement
Gross Domestic Product	GDP	Gross domestic product at market prices – Euros
Exports of goods and services	Export	Export of goods and services at current prices – Euros
Unemployment rate - annual average	Unemp	Percentage rate
Carbon Dioxide emission	CO <sub>2</sub>	Carbon dioxide in tons
Implicit tax rate on energy	Tax	EUR per ton of oil equivalent
Gross inland consumption of coal	Coal	Gross inland consumption of coal in TJ
Energy dependency	EnergyDep	Percentage rate
Share of renewable energy in gross final energy consumption (as in ec.europa.eu)	ShareofRE	Percentage rate

Before performing any further analysis, we will conduct a stepwise regression to determine which variable has the highest significance for our dependent variable, CO<sub>2</sub> emissions. Log transformations will be used for several variables in order to avoid concerns regarding heteroscedasticity.

The next step in our empirical approach is conducting an Autoregressive Distributed Lags (ARDL) regression model, introduced in literature in Pesaran and Shin [39]. This approach can be used to estimate both the short-term dynamics, as well as the long-term coefficients for the independent variables. Upon determining which variables are most significant, we will use up to three variables in order to determine the impact on greenhouse gas emission. All of the variables considered can be seen in Table 1. The general equation that will be used for the ARDL model is as follows:

$$CO2_t = \alpha_0 + \sum_{i=1}^p \beta_i CO2_{t-i} + \sum_{j=0}^q \gamma_j X_{t-j} + \sum_{j=0}^q \delta_j Z_{t-j} + \sum_{j=0}^q \theta_j Q_{t-j} + \epsilon_t \quad (1)$$

where CO<sub>2</sub> is the dependent variable with the number of lags determined by the Akaike information criterion, and X, Z, and Q are the independent variables that will be determined through stepwise regression from the possible variables in Table 1. The tests were performed using the specified ( $p$ ,  $q$ ) optimum lag lengths determined by “proper model order selection criteria” [40]. A restricted constant and the error term are included in the equation. As the ARDL approach is only suitable if variables are “stationary or are stationary in their first difference”, we used the stationarity test [41] to confirm that the model is properly specified. It is not relevant whether the variables are stationary or stationary in their first differences for the ARDL approach [39]. After ensuring that the models are adequate, the Bounds test [42] was used. If based upon the test results evidence of a long-term relationship is detected, the co-integrating equation and long-term coefficients would be analysed. The diagnostic tests employed are the Breusch and Pagan [43] heteroscedasticity test, the autocorrelation LM test [44, 45], as well as the stability of the parameters CUSUM test [46, 47].

## RESULTS AND DISCUSSION

Based on the theoretical evidence present, it is clear that CO<sub>2</sub> emissions are determined by several key factors. Using an ARDL approach, we aim to assess the actual impact of these factors and provide policy recommendations based on these results. Currently, greenhouse gas emissions are strongly impacted by the largest economies of the world – the US and China. As was stated in the theoretical aspect of this article, China plans to become predominantly dependent on renewable energy sources in the near future. This is interesting in the context of Sadorsky's [48] analysis of the G7 countries that pointed out: "GDP per capita and CO<sub>2</sub> per capita are major drivers of increased per capita renewable energy consumption". This suggests that policy-makers of heavily polluted countries are aware of the issue and are moving towards more renewable energy sources. The problem is the link between economic growth and CO<sub>2</sub> emissions that is present in many developed economies. Such a link further serves many who believe that curbing CO<sub>2</sub> emissions swiftly may hamper economic growth and cause stronger unemployment [35]. The reality is that there is no true alternative to preventing the negative consequences of climate change by reducing the impact mankind has on the environment. As has also been noted by Wagner et al. [36], there is also a "cost to not switching to non-renewable energy sources." As the USA plans to opt out of the Paris Climate Treaty and China plans to take a step-by-step approach in curbing its CO<sub>2</sub> emission, it is increasingly relevant for the EU to maintain a strong role in preventing increased emission of greenhouse gases. The stepwise regression has provided that the variables that are most significant to CO<sub>2</sub> emissions are share of renewable energy in gross final energy consumption, the gross domestic product, and gross consumption of coal. Prior to conducting the empirical approach based on the ARDL analysis, unit root tests are used to assert that the variables are stationary in either their level or their first difference. The Augmented Dickey Fuller (ADF) test is used to determine these aspects.

**Table 2.** ADF stationarity test. Source: Authors' calculations and E-Views 9.5 output.

	<b>LGDP</b>	<b>LCOAL</b>	<b>LTAX</b>	<b>Renew</b>
In level	-3,176** (0,0369)	-0,8966 (0,7677)	-3,666** (0,0135)	0,8432 (0,9922)
In first difference	-5,337*** (0,0005)	-4,0673*** (0,0061)	-6,714*** (0,000)	-4,445*** (0,0028)

Note: values in the parentheses represent the *p*-value.

\*\*statistically significant at 5 %

\*\*\*statistically significant at 1%

Based on the results of the ADF test, it is possible to conclude that all the variables are stationary either in level or in their first difference. This allows us to estimate the ARDL model and view whether the variables have a statistically significant long-term relationship. The best fit model that minimized the Akaike information criterion, while also conforming to the stability criteria, was the model with one lag of the dependent variable and one lag of the independent variable (1, 1, 1, and 1). The details concerning the basic regression are included in Table 3.

The first results suggest that the specification of the model is adequate. The R-squared and adjusted R-squared display that the predictability value of the model is very high. This figure, taken into account with the F-statistic and the p-value of the F-statistic, ensures that the model is statistically significant at the 1 percent level. Most of the lags of both the dependent and the independent variables are not statistically significant. Several variables are statistically significant: GDP, renewable energy use, as well as taxation on energy. Interestingly, it would seem that the amount of coal consumed is not one of the key determinants of CO<sub>2</sub> emissions. It is possible to see evidence of a strong short-term impact of economic growth on the growth of

**Table 3.** ARDL model basic regression output. Source: authors' calculations and E-Views 9.5 output.

Variable	Coefficient	Standard error	t-statistic
LCO <sub>2</sub> (-1)	0.079 (0.7306)	0.225	0.354
LGDP	0.448** (0.008)	0.136	3.298
LGDP(-1)	-0.053 (0.7053)	0.135	0.389
RENEW	-0.028** (0.009)	0.006	-4.634
RENEW(-1)	0.002 (0.8235)	0.0088	0.229
LCOAL	0.0389 (0.6229)	0.077	0.507
LCOAL(-1)	-0.004 (0.9581)	0.066	-0.054
LTAX	-0.395*** (0.0007)	0.081	-4.862
LTAX(-1)	0.234** (0.0014)	0.079	2.963
C	14.33** (0.0014)	3.287	4.359
R-squared	0.9921	Mean dependent variable	21.918
Adjusted R-squared	0.985	S.D. dependent variable	0.063
S.E. of regression	0.0077	Akaike information criterion	-6.591
Sum squared residuals	0.0006	Schwarz criterion	-6.092
Log likelihood	75.901	Hannan-Quinn criterion	-6.493
F-statistic	140.262	Durbin-Watson stat	1.792
Probab(F-statistic)	0.000		

Note: values in the parentheses represent the *p*-value.

\*\*statistically significant at 5 %

\*\*\*statistically significant at 1 %

greenhouse gas emission. Taxes and the use of renewable energy seem to have a negative impact on total CO<sub>2</sub> emissions. These findings will be taken into account when estimating the long-term coefficients if there is evidence that the variables have a statistically significant long-term relationship. This will be determined by the Bounds test [42], presented in Table 4, on the basis of which we found a long-term cointegration of the variables, even at the 1 percent level of statistical significance. This allows us to observe the impact of the long-term coefficients in Table 5.

**Table 4.** Bounds test for ARDL model. Source: authors' calculations and E-Views 9.5 output.

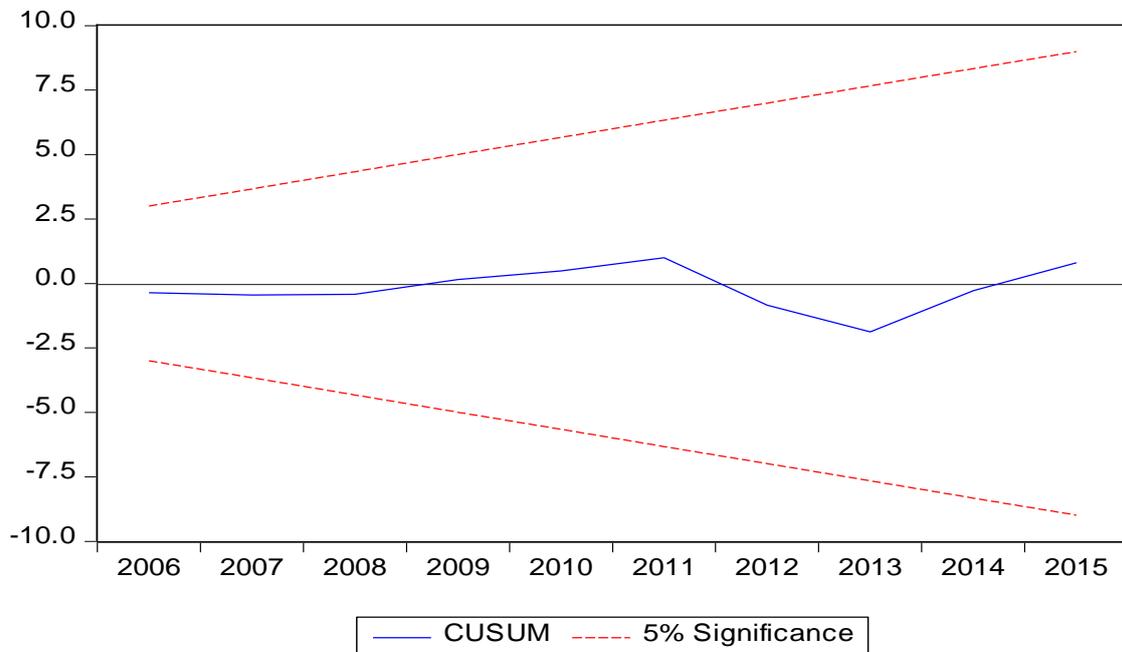
Bounds Test	<i>Null Hypothesis: No levels relationship</i>			
	Value	Significance, %	I(0)	I(1)
F-statistic	5,859	10	2,20	3,09
<i>k</i>	4	5	2,56	3,49
		2,5	2,88	3,87
		1	3,29	4,37

**Table 5.** Long-term coefficients and co-integrating equation. Source: authors' calculations and E-Views 9.5 output.

Variable	Coefficient	Standard error	t-statistic
LGDP	0.4289*** (0.0000)	0.047	9.033
RENEW	-0.028*** (0.0000)	0.0026	-10.844
LTAX	-0.175*** (0.0015)	0.0404	-4.322
LCOAL	0.0383 (0.5397)	0.0605	0.635
C	15.568*** (0.0000)	1.136	13.704

Note: values in the parentheses represent the *p*-value.  
 \*\*\*statistically significant at 1 %

As can be seen in Table 5, all of the coefficients with the exception of coal consumption have long-term statistically significant impact. Prior to conducting a more detailed analysis, the stability of the model is confirmed with the CUSUM test that can be seen in Figure 1.



**Figure 1.** CUSUM test for ARDL model. Source: authors' calculations and E-Views 9.5 output.

Aside from the CUSUM test in Figure 1, Table 6 clearly presents that the ARDL model does not suffer from errors regarding heteroscedasticity, autocorrelation and that the distribution of the residuals is within acceptable parameters.

It is clear that the increase of GDP within the EU is still associated with the increased CO<sub>2</sub> emission. This can be explained through increased industrial investments in times of economic

**Table 6.** The key indicators of used ARDL model specification. Source: Authors' calculations and E-Views 9.5 output.

Indicator	Statistic value	P-value
Serial Correlation LM Test Statistic	1.973	0.2314
Breusch-Pagan-Godfrey F –statistic	0.5296	0.8234
Jarque-Bera	1.629	0.443

prosperity. It would seem that coal consumption does not significantly increase the amount of CO<sub>2</sub> emission within the EU, which is somewhat logical; hence the member-states of the EU are decreasing their dependency on coal on a yearly basis. Environmental taxes seem to have a stronger impact on decreasing the amount of CO<sub>2</sub> emission than investment in renewable energy sources, although both variables are statistically significant at the 1 percent level. Implementing similar environmental taxation and driving the revenue towards investing into renewable energies subsidies may be a significant way of how to effectively decrease the amount of the CO<sub>2</sub> emission. This conforms to the finding of Wagner et al. [36], and emphasizes the need to focus on more renewable energy sources. While coal is not a significant determinant of the increased CO<sub>2</sub> emission in the EU, the case may be completely different in some large emerging economies, such as China for example. However, the idea that leading by example is sufficient is not palpable in the complex geopolitical reality of the 21<sup>st</sup> century and the complex issues faced by China in implementing its new energy policy [49]. With numerous conflicts and competing interests, there needs to be a clear leader in combating excessive emission of greenhouse gases. The EU, although troubled by Brexit, migration and economic crises, and internal disputes amongst its member-states, remains the most dedicated international actor in combating climate change since 1980 [50].

## **CONCLUSION**

The main goal of shift to low carbon economy is decoupling greenhouse gas emissions from GDP and other economic variables. The SDGs remain a key determinant in creating a more sustainable economic approach on a global level and significant progress has been made in their crafting in comparison to the MDGs. However, the Paris Climate Treaty and the SDGs lack a true leader that will implement the needed policy changes, as well as lead by the power of their example. Aside from these problems on a theoretical level, it is clear that many of the global economies are turning less to coal and more to renewable energy sources. This article finds that there is a connection between rising renewable energy use and decreasing levels of CO<sub>2</sub> emissions. The article finds that there is a constant connection between rising economic growth and CO<sub>2</sub> and while switching to renewable sources of energy may slightly decrease CO<sub>2</sub> emission, carbon taxing is a much more effective form of curbing CO<sub>2</sub> emissions.

The quantitative analysis implemented in this article, based on an ARDL approach, finds that the most effective way of reducing CO<sub>2</sub> emissions in the EU would be to continue the shift towards more dependency on renewable energy sources while maintaining current or slightly higher levels of taxation on energy consumption. This form of taxation remains crucial in preventing excessive levels of greenhouse gas emission and revenue should be directed towards subsidizing research and development of renewable energy sources. While we acknowledge the limitations of carbon taxation noted in Baranzini and Carattini [8], we believe that such a policy recommendation is crucial for the long-term sustainability of the planet. Based on these findings, this article finds that developed economies should implement carbon taxing in an effort to reduce CO<sub>2</sub> emissions. Most of the existing research, including that of Baranzini and Carattini [8], does not show that it significantly constrains economic growth, while this article demonstrates that it is highly effective in reducing CO<sub>2</sub> emissions. Ensuring that the Paris Climate Treaty is implemented is an absolute requirement for ensuring that the Goal 13 is implemented. The feasibility of implementing the remaining SDGs lies outside of the scope of this article, but the need to implement coordinated changes based on a coherent strategy should present a logical start to truly global cooperation on many relevant issues.

## REMARKS

<sup>1</sup>[http://unfccc.int/paris\\_agreement/items/9485.php](http://unfccc.int/paris_agreement/items/9485.php).

<sup>2</sup><https://www.greentechmedia.com/articles/read/solar-cost-reduction-drivers-in-2017>.

<sup>3</sup>“The negative impact of exemptions was shown in the study of Bruvoll and Larsen (2004), who analyze the impact of carbon taxes on CO<sub>2</sub> emissions in Norway, over the period 1990-1999. Norway is a country with relatively high carbon tax rates in some specific sectors, but several activities are submitted to lower rates or exempted. Carbon taxes reduce emissions by 2.3 percent, according to the authors, mainly through an increase in energy efficiency and change in energy mix, while impact on scale is negligible, mainly due to tax exemptions” [8].

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# THE DYNAMIC RELATION BETWEEN TECHNOLOGY ADOPTION, TECHNOLOGY INNOVATION, HUMAN CAPITAL AND ECONOMY: COMPARISON OF LOWER-MIDDLE-INCOME COUNTRIES

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## ABSTRACT

The advent of technologies has stimulated the economic growth of western countries, however, some Asian and African countries are among the Lower Middle Income Countries due to lack of technology adoption and digitally skilled human capital. The use of technologies produces digital competent human capital stock that accelerates economic growth. The prime goal of this article is to explore dynamics of technology adoption, technology innovation, human capital and skill development for Lower Middle Income Countries region over the period 2000-2016 by Generalised Method of Moments and cross sectional dependence. New technology adoption, technology innovation and human capital & skill development indices are formulated. The empirical findings indicate that human capital development & skill and investment have positive linkage with Lower Middle Income Countries economic growth while technology adoption and innovation have different linkage across the Lower Middle Income Countries regions. The panel error correction method was applied to estimate short-run dynamics and convergence rate. The fully modified ordinary least square was applied to authenticate whether the long run estimates are consistent and valid for policy implications. The findings propose policy implications for advance technology adoption and innovation with the focus on human capital development & skill and investment in Lower Middle Income Countries region.

## KEYWORDS

technology innovation, technology adoption, human capital, economic growth

## CLASSIFICATION

JEL: E10, E24, O32, O33

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## **INTRODUCTION**

Information era has stimulated the integration of Information and Communication Technologies (ICT) in all facets of life but more importantly in the education sector. Innovation in teaching and learning with the use of technologies results in the digital competent human capital that in turn will accelerate the economic growth of a country. Technology Achievement Index (TAI) is the scale on the basis of utilization of technology. This index was introduced by [1] in 2002. However, it is unable to measure the country's technological development. Industrial Development Scoreboard was started by [2] in 2003 in order to provide information about the industrial performance, technological advancement, use of ICT and technology imports. Industrial-cum-technological advancement (ITA) index was developed by [2] which aim to provide characteristics of a country's economy based on the role of technology and industry [2]. ITA has four indicators for measuring industrial development based on performance. These indicators are; i) contribution of manufacturing in GDP, ii) contribution of manufacturing in exports, iii) contribution of technologies in manufacturing value added (MVA), iv) contribution of technologies in export. High Technology Indicator (HTI) is comprised of national orientation, technological resources, socio-economic infrastructure and productive capacity. Among these indices, Technological Achievement Index (TAI) is based on the capability of creating and utilizing technology and not on the magnitude of technological development [1].

Human ability, capacity, skill and knowledge are required in a home country to adopt foreign technology. Unfortunately, developing countries and especially Muslim developing countries are lagging behind in the field of science, technology, research and development. Therefore, Muslim countries need to focus on capacity building in order to cope well in knowledge society. Human knowledge and skill are imperative for achieving in technological achievement. However, most of the Muslim developing countries do not meet the basic literacy level. Unfortunately, the education system of Muslim countries does not meet the challenges of information era. Therefore, these countries are required to increase their budget for education sector and take immediate necessary steps for the improvement of education system and should focus more on the pedagogy based on the use of technologies [3].

In existing literature, importance of technology adoption (TAD), technology innovation (TIN) and human capital & skill development (HCS) in economic growth has been examined extensively and provide different results in country specific and regional analysis across the globe. As Lower Middle Income Countries (LMICs) need to find the development threshold level for getting TIN, TAD and HCS fruits [4]. The human capital productivity not only depends upon its level but also the composition of skilled human capital as well as the country's position relative to the use of technologies and adapting technologies [5-7]. Endogenous economic growth had positive linkage with TIN and TAD, respectively [8, 9].

Furthermore, [10] elaborated that the stock of human capital based on knowledge skills and attitude positively impact the adoption of technologies in institutions and organizations that are already in practice in other countries. Though, results from preceding literature of single country and region cannot be generalized for LMICs and its sub-regions due to diverse features. To fill aforementioned gap, this study focuses on the development of human capital and skill development for the adoption and innovation of technologies that are necessary to reduce the Digital Divide and to compete successfully in the contemporary societies. We investigate the impact of TAD, TIN and HCS on economic growth in LMICs sub-regions.

The impact of current study to prior literature in the TAD, TIN, HCS and economic growth is elaborated as follows: First, not any of studies obviously examines the HCS importance as

vital driver in enlightening the relationship among TAD, TIN and economic growth. Second, we have developed TAD, TIN and HCS indices because previous studies just incorporated one or two dimensions of TAD, TIN and HCS to investigate the association among TAD, TIN and economic growth. To our best knowledge, this is the first study to measure the effect of HCS, TAD and TIN on the economic growth for LMICs. Third, our article also enhances the existing knowledge by utilizing modern econometric methods as compared to previous studies. As the cross-sectional dependence (CD) test applies to diagnose the concern variable's cross-sectional dependence. The system Generalised Method of Moments (GMM), CD test and Fully Modified Ordinary Least Squares (FMOLS) are used computing relationship among TAD, TIN, HCS and economic growth. Panel Error Correction Method (ECM) is used to compute short run dynamics and convergence rate towards long run equilibrium from short run.

## LITERATURE REVIEW

The progress in human capital is an important factor for the economic development of a country. However, human capital is not effective in the process of development unless and until the economy of a country crosses a threshold level of development [4]. Human capital is multidimensional object that constitutes of language, socio emotional skills, health and cognition. These constituents are important in capacity building and human capital development of a person. These are particularly important in developing countries where children with poverty are exposed to diseases, malnutrition, violence and unproductive environments. These factors are hampering the production function of lifelong outcomes for various dimensions of human capital. Human capital development based on health and cognition factors among young children aged between 1 to15 was studied by [11] and they argued that parental cognition and income accounts a lot for the provision of resources to children with better backgrounds. Moreover, health is important for cognitive development as most of the poor families are unable to invest at an early age of child because of poverty when investments are very important for improved health and cognitive development of a child. Parental investment in early childhood plays a significant role in the human capital development and the economic growth of a country [12].

Human capital affects the economic development by impacting total factor productivity (TFP) as higher level of human capital enhances a country's capability to adapt existing technologies or to introduce new technologies according to the demand of the country. Therefore, differences in the economic growth of various countries arise due to the differences in the level of human capital of these countries [13]. The productivity enhancing impact of human capital not only depends upon its level but also the composition of skilled human capital as well as the country's position relative to the use of technologies. Skilled human capital is important for those countries that are adapting technologies [7]. Various studies found positive results when human capital's impact is measured by literacy rate. However, this association of literacy rate and growth is more prominent in low and middle income countries but nor in rich countries [14, 15]. Similarly, [5] carried out their study in 28 provinces of China and were also of the view that levels of human capital affect the productivity rate, in turn, affecting the economic growth of the country. However, in today's economic scenario, skilled human capital is imperative for using existing technologies or innovating technologies for enhancing the economic growth of the country. Moreover, they suggested that in order to facilitate the alteration and enhancing the economic structure, China should adopt the strategy of changing the human capital structure through the promotion of tertiary education to sustain its future growth. In the information era, while dealing with the economic growth, human capital is taken as a function of education, skills and experience. However, physical and cognitive capacities of a person are also important

while taking human capital as an important factor for the economic growth of a country [16]. In this regard, developing countries need to focus on the development of human capital for the uplift of their economic position [6].

Few studies also focused on the aspect that human capital is also related to organizational aptitude to bring innovation in order to sustain successfully in competitive environment. Bringing innovation in business depends upon the quality of human capital of the workforce [17]. Moreover, the government's capability to create policy measures and the surety for its effective implementation is also dependent upon the eminence of human capital within its enterprises [18]. Human capital had a positive impact on the adoption of technology while its effect on technological innovation is found insignificant in 45 Sub Saharan African countries [19].

Human capital development is allied with family and society and family plays a vital role in financing human capital development. There exists equilibrium between parental disbursement and child's future earning in relation to the building of child's human capital development and this relationship is crucial for family welfare. Positive attitudes of children with their siblings may develop educational aspiration and cooperation among siblings; hence, this will lead to the high level of human capital development. However, non-cooperative attitudes will produce opposite results. In the same way, children's interaction with their friends from other families also shapes the human capital [20].

Economic development of a country is well determined by its human capital. Various human capitals' attributes help in measuring the status of a country's stock of human capital. However various studies across the world emphasized on the school enrollment and educational attainment. School enrollment data of a country provides valuable information about its expansion, development rate and the investment in education system. In this regard, [21] collected data set of 111 countries based on the school enrollment and educational attainment aged 15-64 from 1870 to 2015. Their study reveals that there is an incredible achievement in educational accomplishment in many countries around the world and these countries experienced momentous economic development. Consequently, this economic progression is escorted by the human capital stock and technology progress combined with decreased fertility and mortality rates. This expansion resulted in transition of many countries from uneducated and low income societies combined with their structural change from agricultural to industrial countries.

Human capital stimulates Research and Development (R&D) with the use of technologies and innovative ideas resulting in the creation of new products and increased productivity. Consequently, progress in the economic growth and the innovative products bring the structural change from underdeveloped to developing and developed countries [10, 22]. Many researchers around the world have focused on the relationship between the human capital and the economic growth through the adoption and innovation of technologies [23]. The majority of existing research work has focused on the economies of developed nations with a developed institutional environment; however, this relationship remains unclear in developing countries with a less developed educational environment. The primary objective of this article is to examine the pattern and impact of human capital with respect to technology adoption and technology innovation in the economic growth of less developed countries in particular.

## **TECHNOLOGY INNOVATION AND ECONOMIC GROWTH**

Technological innovation has brought endogenous economic growth in the small and large business activities [8, 9]. Investments in innovative technology and R&D expenditures are premises for the progress, competitiveness and sustainable economic growth [24]. A research

was conducted in developed and developing countries during the period from 2005 to 2007, by [25]. Researchers concluded that technological innovation and skilled labor force has a positive impact on the companies' performance and will boost up the productivity. Implementation of new or improved process, product (goods or services), improved organizational approach or new marketing methods in workplaces or business activities is called as innovation [26]. However, policies, factors and resources of institutions determining the level of productivity are called as competitiveness. Therefore, technological innovation and enhanced competitive strategies are important for countries to sustain successfully in a highly competitive and globalized world economy [27].

## **TECHNOLOGY ADOPTION AND ECONOMIC GROWTH**

The stock of human capital based on knowledge skills and attitude positively impact the adoption of technologies in institutions and organizations that are already in practice in other countries, henceforth, enhance the economic growth of the country [10]. Empirical studies show that technology is invented and adopted first in the countries with advanced economies and later on, it is adopted by the countries with less advanced economies. However, the fact is that all technologies adopted by advanced economies are not appropriate for less advanced economies depending upon the economic structure of these countries [28]. Human capital, R&D resources and the economic status of a country help in the adoption of appropriate technology that will help in the economic development of the country [29]. Political considerations like policy making and decisions about the allocation of capital and human resources for the adoption of technologies in institutions and companies pave the way for towards the economic growth of a country [30]. Consequently, technology adoption for advanced economies demands the educated and digital skilled workforce. Sustainable and innovative economy cannot be achieved without the adoption of technology.

## **HUMAN CAPITAL & SKILL DEVELOPMENT AND ECONOMIC GROWTH**

Education is a vital aspect of all the facets of societies. As knowledge and skills are necessary means for the progress of an institution, organization or a country. Knowledge and skills are combined together as human capital. Investment in education sector (human capital) produces educated workforce that ultimately leads to the increased productivity and economic growth of a country. However, in the Information Era, the use of ICT in education system produces digital workforce that increase the stock of human capital resulting in the increased production and an increased foreign investment [31, 32]. An individual's knowledge, skills and experience is referred to as the human capital [33]. Human capital theory put emphasis on the attainment of knowledge (level of education) and the work experience (training on job) for technology adoption. Consequently, higher the level of education, higher will be the opportunities of bringing innovation in technology to boost up the economic growth. Stock of skilled human capital enhanced growth margins as compared to total human capital [34]. Countries with a small stock of human capital 'school education' may have slower rate of growth rather than developed countries with a large stock of human capital 'tertiary education' [35].

## **MATERIAL AND METHODS**

### **DATA SOURCE**

The current article selected available panel of 48 LMICs from Africa, Asia, Europe, Latin America and South Pacific Ocean region. The study covered time span from 2000 to 2016. The considered LMICs were further categorized into five sub-panels based on

respective continent; 18 countries from Africa, 20 countries from Asia, 2 countries from Europe, 5 countries from Latin America, and 3 countries from South Pacific Ocean region. The sample set of LMICs is presented in Table 1 as follows: Technology innovation, Technology adoption, Human capital and skill development, Investment, Labor force and Economic growth were taken under-consideration to explore the linkages among them. The data description and sources are reported in Table 2.

GDP per capita annual growth is taken as proxy of Economic growth. Whereas, labor force and capital are measured by log of total labor force and gross fix capital formation.

**Table 1.** LMICs countries.

<b>LMICs Regions</b>	<b>Economies</b>
Africa	Angola, Bolivia, Cabo Verde, Cameroon, Congo Rep., Cote d'Ivoire, Djibouti, Egypt Arab Rep., Ghana, Kenya, Lesotho, Mauritania, Morocco, Nigeria, Sudan, Swaziland, Tunisia, Zambia
Asia	Armenia, Bangladesh, Bhutan, Cambodia, India, Indonesia, Jordan, Kyrgyz Republic, Lao PDR, Mongolia, Pakistan, Philippines, Sri Lanka, Syrian Arab Republic, Tajikistan, Timor-Leste, Uzbekistan, Vietnam, West Bank and Gaza, Yemen Republic
Europe	Moldova, Ukraine
Latin America	El Salvador, Georgia, Guatemala, Honduras, Nicaragua
South Pacific	Papua New Guinea, Solomon Islands, Vanuatu

**Table 2.** Variables description. Source; World Development Indicators 2016 and International Telecommunication Union 2016.

<b>Indicator name</b>	<b>Notation</b>	<b>Description</b>	<b>Data source</b>
Economic growth	ECO	GDP per capita growth(% annual)	WDI
Investment	FCF	Gross fix capital formation (% of GDP)	WDI
Labor force	LF	Log of total Labor force	WDI
<b>HCS Dimensions</b>			
<b>Mean years schooling</b>	<b>MYS</b>		
Pre-Primary education	P <sub>1</sub>	Duration (years)	WDI
Primary education	P <sub>2</sub>	Duration (years)	WDI
Secondary education	P <sub>3</sub>	Duration (years)	WDI
<b>Mean school enrollment</b>	<b>MSE</b>		
Primary enrollment	SE <sub>1</sub>	% of gross enrollment	WDI
Secondary enrollment	SE <sub>2</sub>	% of gross enrollment	WDI
Tertiary enrollment	SE <sub>3</sub>	% of gross enrollment	WDI
<b>TIN Dimensions</b>			
Fixed-telephone	TIN <sub>1</sub>	subscriptions per 100 inhabitants	ITU
Mobile-cellular telephone	TIN <sub>2</sub>	subscriptions per 100 inhabitants	ITU
Fixed-broadband	TIN <sub>3</sub>	Individuals using the Internet (%)	ITU
<b>TAD Dimensions</b>			
<b>TAD new</b>			
Internet Users	TAD <sub>1</sub>	Individuals using the Internet (%)	ITU
High-tech exports	TAD <sub>2</sub>	% of manufacturing exports	WDI
<b>TAD old</b>			
Electric power consumption	TAD <sub>3</sub>	kWh per capita	WDI

Technology innovation, Technology adoption, Human capital and skill development indices are constructed based on relevant dimensions which are defined by International Telecommunication Union (see Table 1). Before calculating indices, it is necessary to convert all dimensions into same scale and data normalization for aggregation. The individual's indicator is normalized as follows:

$$Indicator\ index = \frac{[X_i - X_{Min}]}{[X_{Max} - X_{Min}]} \quad (1)$$

In equation (1),  $X_i$  is Indicator Value of a Country,  $X_{Max}$  – Maximum Value of an Indicator and  $X_{Min}$  – Minimum Value of Indicator. The standard approach adopted to assign equal weights to all indicators to compute aggregate index value. The mathematical notation of indices is presented as follows:

Human capital and skill development index (HCS),

$$HCS = \frac{1}{2}[MYS + MSE] \quad (2)$$

where  $MYS$  is mean year schooling and  $MSE$  is mean school enrollment and their mathematical notations as follows:

$$MYS = \frac{1}{3}[P_1 + P_2 + P_3] = \frac{1}{n} \sum_{i=1}^3 [P_i] \quad (3)$$

$$MSE = \frac{1}{3}[SE_1 + SE_2 + SE_3] = \frac{1}{n} \sum_{i=1}^3 [SE_i] \quad (4)$$

Technology Innovation index (TIN),

$$TIN = \frac{1}{3}[TIN_1 + TIN_2 + TIN_3] = \frac{1}{n} \sum_{i=1}^3 [TIN_i] \quad (5)$$

Technology Adoption index (TAD),

$$TAD = \frac{1}{2}[TAD_{old} + TAD_{new}] \quad (6)$$

where

$$TAD_{new} = \frac{1}{2}[TAD_1 + TAD_2] = \frac{1}{n} \sum_{i=1}^2 [TAD_i] \quad (7)$$

$$TAD_{old} = [TAD_3] \quad (8)$$

## MODEL SPECIFICATION

Based on the literature review, this article dedicates to empirically illustrate the dynamic relationships of panel of LMICs countries between technology innovation, technology adoption, human capital & skill and economic growth. We utilized augmented Solow growth model to explore the short run and long dynamics among under-considered variables. The mathematical form of model as follows:

$$ECO_{it} = A_i(t) \cdot FCF_{it}^\alpha \cdot LF_{it}^\beta \cdot HCS_{it}^\gamma \cdot TIN_{it}^\delta \cdot TAD_{it}^{1-\alpha-\beta-\gamma-\delta} \quad (9)$$

By taking logarithm of (9), panel empirical model is presented as follows:

$$\ln ECO_{it} = \ln A_i(t) + \alpha_{it} \ln FCF_{it} + \beta_{it} \ln LF_{it} + \gamma_{it} \ln HCS_{it} + \delta_{it} \ln TIN_{it} + \theta_{it} \ln TAD_{it} + \varepsilon_{it}, \quad (10)$$

where  $\theta = 1 - \alpha - \beta - \gamma - \delta$ . In Equation (10),  $ECO$ ,  $A(t)$ ,  $FCF$  and  $LF$  are economic growth, existing technology, investment and labor force, respectively. Whereas,  $HCS$ ,  $TIN$  and  $TAD$  are human capital & skill, technology innovation and adoption indices subsequently, and  $i$  is index of a country,  $t$  of a time. Equation (11) is the reduced form of dynamics Generalized Method of Moments (GMM) which used to estimate short and long run dynamics of

under-considered variables [7]. Panel system GMM is better estimation technique in case of small time span and larger number of cross-sections [36].

$$ECO_{it} = \varphi_{it} ECO_{it-1} + \alpha_{i1} FCF_{it} + \beta_{i2} LF_{it} + \gamma_{i3} HCS_{it} + \delta_{i4} TIN_{it} + \theta_{i5} \ln TAD_{it} + \eta_i + \phi_t + \varepsilon_{it}, \quad (11)$$

where  $\eta_i$  and  $\phi_t$  show specific fixed country effects and time effect, respectively. Indices  $i$  and  $t$  indicate country ( $i = 1, 2, 3, \dots, 48$ ) and time ( $t = 2007, 2008, \dots, 2016$ ), respectively. Finally,  $\varepsilon_{it}$  denotes the stochastic error term in  $i$ -th country in  $t$ -th time period.

## SHORT RUN DYNAMICS

Error Correction Method (ECM) computes the speed of convergence/divergence from short run to long run equilibrium in case of any shock occurred in economy. Panel ECM is utilized to estimate the short run dynamics. The panel ECM mathematical equation can be written as follows:

$$\Delta(ECO_{it}) = \alpha_1 \cdot \Delta(FCF_{it}) + \alpha_2 \cdot \Delta(LF_{it}) + \alpha_3 \cdot \Delta(HCS_{it}) + \alpha_4 \cdot \Delta(TIN_{it}) + \alpha_5 \cdot \Delta(TAD_{it}) + \lambda \cdot ECM_{it-1} + \varepsilon_{it}. \quad (12)$$

In equation (12),  $\alpha_1, 2, 3, 4, 5$  are estimated parameters, while  $\lambda$  is speed of adjustment from short run to long run equilibrium in presence of any shock occurrence in economy.

## ECONOMETRIC STRATEGY

The current article can be divided into five parts with respective of empirical analysis. First part elaborated the geometrical mean and descriptive statistics while cross-sectional dependence and panel unit root by panel fix effects regression model to explore dependence nature of countries and panel unit root among considered variables. Third part explained the short run dynamics while fourth part elaborate the long run dynamics by using GMM and Fully Modified Ordinary Least Square (FMOLS) [37, 38]. GMM is an efficient estimation approach to counter the endogeneity, and cross-section's specific effect issues [38, 39]. It also a better econometric method in case of small number of cross-section as compared to time span [38, 39].

## EMPIRICAL RESULTS AND DISCUSSION

### GEOMETRICAL MEAN AND DESCRIPTIVE STATISTICS

Figure 1. depicts the mean of ECO, FCF and LF divided by region of LMICs. The European and Asian countries are leader in economic growth and labor force as compared to all other LMICs. Whereas, Asia is ranked one as compared to other LMICs in investment as per percentage of GDP. Patterns of HCS, TIN and TAD are illustrated in Figure 2. Europea is far ahead in HCS and TIN while other regions have almost same pace in HCS level and TIN expect South Pacific region. Latin America maintained highest technology adoption rate as compared to Asia, Africa and Europe.

Table 3 presents the descriptive statistics and correlation matrix. The Panel-A elaborates the descriptive statistics of considered variables. It is worth to be noted that the mean value of FCF is 23.11 higher than ECO and LF while HCS has highest value among HCS, TIN and TAD in case of LMICs. Correlation matrix is reported in lower part of Table 3. ECO is positively associated with FCF, LF, and HCS while TIN and TAD negatively associated with ECO.

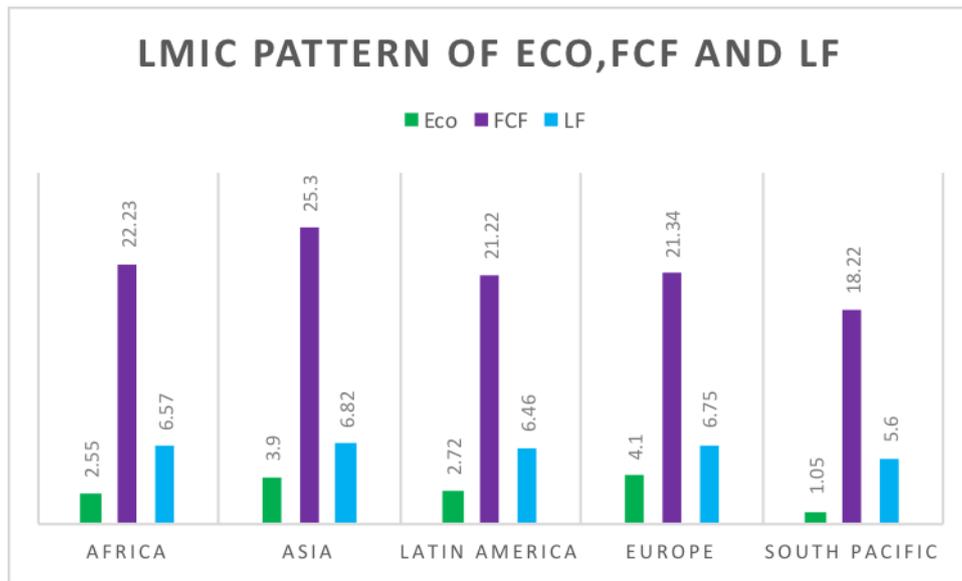


Figure 1. Mean of Eco, FCF and LF divided by region (2000-2016).

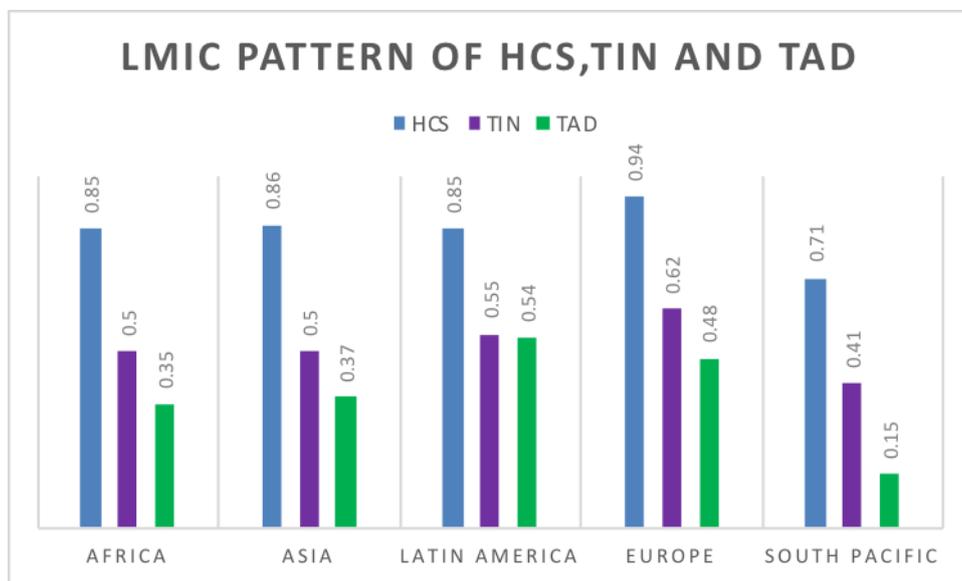


Figure 2. Mean of HCS, TIN and TAD divided by region (2000-2016). Source; (WDI, 2016) and (ITU, 2016)

Table 3. Descriptive statistics and correlation matrix,  $N = 816$ .

Panel-A: Descriptive statistics		ECO	FCF	LF	HCS	TIN	TAD
	Mean	3,09	23,11	6,61	0,85	0,50	0,37
	Maximum	30,35	68,02	8,70	1,00	1,00	0,97
	Minimum	-29,88	1,52	4,92	0,40	0	0
	Std. Dev	4,23	9,46	0,77	0,17	0,36	0,21
Panel-B: Correlation Matrix							
ECO	1						
FCF	0,225*	1					
LF	0,099*	-0,198*	1				
HCS	0,130*	0,096*	0,013	1			
TIN	-0,061*	0,096*	0,095*	-0,062*	1		
TAD	-0,045	-0,152*	0,478*	0,126*	0,419*	1	

\*shows 1 % significance level

## CROSS-SECTIONAL DEPENDENCE AND UNIT ROOT TEST

Before applying the unit root test, we firstly use cross-sectional dependence (CD) test to diagnose whether the LMICs are cross-sectional dependent or not [40]. The null hypothesis of this test states that all cross-sections are independent. The CD test results are reported in Table 4. The results indicate that null hypothesis is rejected which implies the dataset of LMICs is cross-sectional dependent. Therefore, panel unit roots tests cannot be applied. The utilized panel fixed effects regression and Wald test are used to test unit root in this circumstances [38].

**Table 4.** Cross-sectional dependence test results.

Variable	CD-statistics	P-value	Variable	CD-statistics	P-value
ECO	21,89	0,000	HCS	48,33	0.000
FCF	4,45	0,000	TIN	133,96	0.000
LF	96,28	0,000	TAD	50,07	0.000

$$\rho_{it} = \theta \cdot \rho_{it-1} + \varepsilon_{it}. \quad (13)$$

Equation (13) depicts the basic unit root mechanism through panel fixed effects regression.  $\rho_{it}$  is function of its lag(s)  $\rho_{it-1}$ . If coefficient of first lag ( $\theta = 1$ ) is equal to one, then its coefficient restriction hypothesis is validated which means the variable has unit root and the lag has no correlation with the normal variable [39].

Table 5 depicts the unit root tests by panel fixed effects regression and Wald test. The results show that all variables rejected the unit root hypothesis, which means the lagged dependent variables are significantly correlated with its normal variables. The Wald test significantly rejected the null hypothesis of lagged dependent variable not equal to one which implies that these variables contained a unit root process by transforming it at their first lagged.

**Table 5.** Unit root test results.

Unit root test by panel fixed effects regression						
	ECO	FCF	LF	HCS	TIN	TAD
<b>ECO(-1)</b>	0,460*					
<b>FCF(-1)</b>		0,915*				
<b>LF(-1)</b>			0,999*			
<b>HCS(-1)</b>				0,556*		
<b>TIN(-1)</b>					0,983*	
<b>TAD(-1)</b>						0,834*
<b>Wald test</b>	-17,26*	-5,55*	-2,33**	-12,50*	-2,35**	-9,09*

\*statistically significant at 1 %

\*\*statistically significant at 5 %

## LMICs LONG RUN ESTIMATES

Long run estimates are reported in Tables 6 and 7. The graphical comparison of magnitudes of explanatory variables, is illustrated in Figure 3 regardless significance level. In full panel LMICs, a statistical significant increase of 0.10 %, 0.29 and 2.64 units in ECO due to increase 1 % in FCF and one unit increment in HCS and TAD respectively as dynamic system GMM estimates while significant decline of 3.32 %, 7.47 units in ECO due to 1 % and 1 unit increase in LF and TIN [8, 9, 27]. We also estimated FMOLS to validate impact of exogenous variables on ECO [37]. FMOLS results also similar in impact nature with different magnitudes. In FMOLS case, a statistical significant increase of 0.12 %, and 2.97 units in ECO due to increase 1 % in FCF and one unit increment in HCS respectively while significant decline of 12.17 %, and 2.18 units in ECO due to 1 % and 1 unit increase in LF and TIN

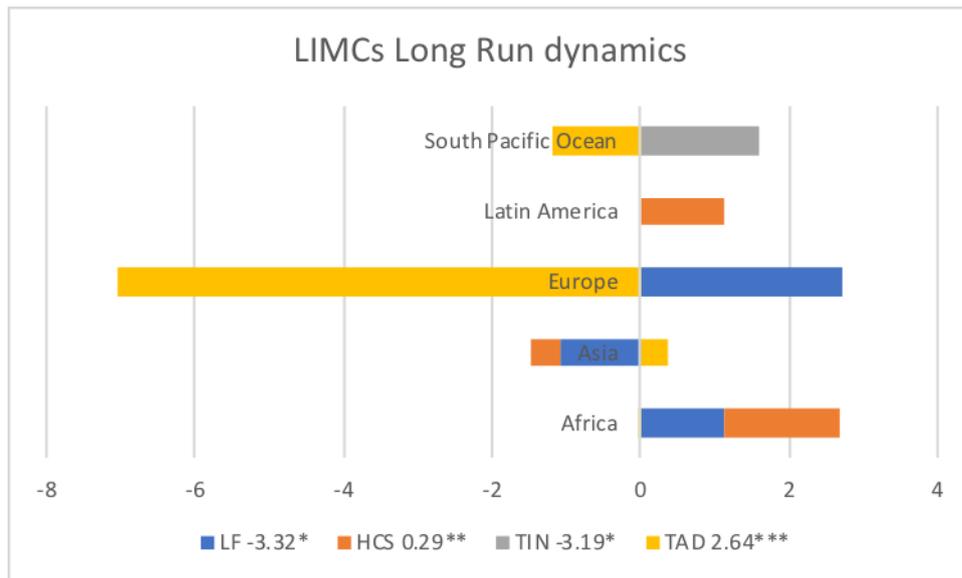


Figure 3. LIMCs Long run dynamics.

Table 6. Long run estimates of some LMICs.

	Full Panel		Africa		Asia	
	GMM	FMOLS	GMM	FMOLS	GMM	FMOLS
ECO(-1)	0,21*		0,24*		0,26	
FCF	0,10*	0,12*	0,06	0,07	0,14*	0,13*
LF	-3,32*	-12,17*	1,13	13,20	-1,10	-1,82
HCS	0,29**	2,97*	1,55	4,04*	-0,38	2,89***
TIN	-3,19*	-2,18*	-2,96*	-2,00	-2,01*	-0,60**
TAD	2,64***	1,65	-0,045	-2,68	0,35	-1,08
Sargan-Hansen-J statistic	286,91*		192,15*		203,23*	
Wald statistics	52,71*		22,25*		17,62*	
Instrument rank	141		141		141	

\*statistically significant at 1 %

\*\*statistically significant at 5 %

\*\*\*statistically significant at 10 %

Table 7. Long run estimates of some LMICs.

	Europe		Latin America		South Pacific Ocean	
	GMM	FMOLS	GMM	FMOLS	GMM	FMOLS
ECO(-1)	-0,20		0,18*		0,33*	
FCF	0,35***	0,09***	0,34*	0,23*	-0,01	0,19
LF	2,72	-27,08	3,04**	23,99*	0,84***	15,95*
HCS	5,94**	5,60***	1,12	0,40	1,69**	3,53***
TIN	-7,47*	-8,66*	0,78***	3,68*	1,58	-12,57
TAD	-7,03	-9,52	3,53***	1,34	-1,20	3,87
Sargan-Hansen-J statistic	34,02		120,32*		52,62*	
Wald statistics	12,62*		25,47*		15,72*	
Instrument rank	46		86		61	

\*statistically significant at 1 %

\*\*statistically significant at 5 %

\*\*\*statistically significant at 10 %

respectively. Category-wise analysis indicated enhancement in ECO due to increase in HCS (Africa, Asia, Europe, and South Pacific Ocean), TIN and TAD (Latin America), FCF (Asia and Europe), LF (Latin America and South Pacific Ocean). Sub-panel also explored the reduction in ECO due increase in TIN (Europe), TAD (Asia).

Technology innovation and adoption in education system produce skilled stock of human capital that in turn accelerates the economic growth of a country. However, bringing innovation in technologies require to train the HCS already employed so as to get the positive ECO. Similarly, countries with least technology adoption have shown positive changes in ECO as these countries adopted technologies according to their HCS, FCF, TIN and TAD capacity. R&D, HCS, TIN and TAD are the accelerators of ECO; however, all technologies are not appropriate for all courtiers. Therefore, LMICs need to be specific about the TAD depending upon the HCS, LF and FCF capacities of these countries [19, 29, 30, 35].

### SHORT RUN ESTIMATES OF LMICs

Table 8 elaborates short run dynamics of ECO with respect to FCF, LF, HCS, TIN and TAD in panel of LMICs, Africa, Asia, Europe, Latin America and South Pacific Ocean. The magnitudes of explanatory variables comparison is illustrated in Figure 4 regardless significance level.

In short run, FCF had positive impact on ECO in full panel, Africa while FCF had adverse impact on in Europe and Latin America. EUROPE AND Latin America are already technologically

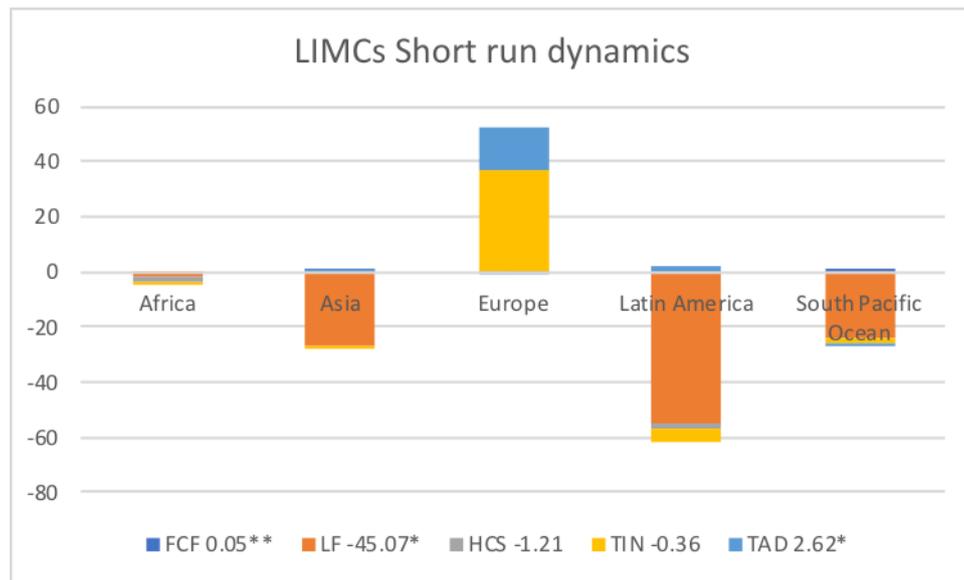


Figure 4. LMICs Short run dynamics.

Table 8. Short run estimates of LMICs.

Variable	Panel division					
	Full Panel	Africa	Asia	Europe	Latin America	South Pacific Ocean
$\Delta FCF$	0,05**	0,10*	0,04	-0,41	-0,41*	0,049
$\Delta LF$	-45,07*	-1,99	-27,00	-20,38**	-54,90	-23,5
$\Delta HCS$	-1,21	-2,13	4,02*	31,40*	-2,13	10,95*
$\Delta TIN$	-0,36	-0,78	-1,26	36,55	-4,89	-2,09
$\Delta TAD$	2,62*	4,52*	0,057	16,01	2,00	-1,48
$ECMt-1$	-0,623*	-0,58*	-0,536*	-0,51*	-0,34*	-0,42***

\*statistically significant at 1 %

\*\*statistically significant at 5 %

\*\*\*statistically significant at 10 %

advanced countries and are bringing innovation in technologies day by day. Therefore, FCF in full panel has negative impact. However, in countries of Africa and Asia there is ample room for improvement with respect to technology adoption, therefore these countries are showing positive results in FCF in full panel. HCS was positively significant for Asia, Europe and South Pacific Ocean which indicates a 4.02, 31.40 and 10.95 units in ECO as results of one unit increase in HCS. Asian developing countries are bringing reforms in their education system to produce stock of HCS, while African and few Latin American countries still need to work hard for the development of their education system so as to improve their HCS. There was a positively linkage in short run among TAD and ECO in case of Full Panel and Africa.

Panel ECM indicates the speed of adjustment towards long run equilibrium from short run dynamics in case of any shock in economy. Panel ECMt-1 showed 62.3 %, 58 %, 53.6 %, 51 %, 34 % and 42 % annual speed of adjustment towards long in Full Panel, Africa, Asia, Europe, Latin America and South Pacific Ocean, respectively.

## **CONCLUSIONS AND POLICY RECOMMENDATIONS**

This article investigates the effect of TAD, TIN and HCS on economics growth in panel of 48 LMICs from Africa, Asia, Europe, Latin America and South Pacific Ocean region using time span from 2000-2016. For this, we utilize data mining technique to develop TAD, TIN and HCS indices from their all respective dimensions into single aggregate factor. We use CD test to check cross-sectional dependence among LMICs regions. The system GMM used to estimate long run estimates. Moreover, FMOLS applied to affirm the long run estimates from system GMM as robust test. In case any shock happened in economy, panel ECM is applied to estimate the speed of convergence/divergence from short run to long equilibrium.

The main empirical findings indicate that TAD, TIN and HCS are crucial drivers of economic growth. HCS and investment have positive linkage with LMICs economic growth while TAD and TIN have different linkage across the LMCs regions due to diverse features. TIN has negative impact on economic growth of Europe, Africa, and Asia, respectively. While, TAD has insignificant impact on economic growth in all regions expect Latin America. Therefore, LMICs need to be specific about the TAD depending upon the HCS, LF and FCF capacities of these countries [19, 29, 30, 35]. Panel ECMt-1 showed 62.3 %, 58 %, 53.6 %, 51 %, 34 % and 42 % annual speed of adjustment towards long in Full Panel, Africa, Asia, Europe, Latin America and South Pacific Ocean, respectively.

In the Information Era, technology innovation and adoption are imperative for countries around the world to sustain successfully in contemporary societies. Stock of digitally skilled human capital accelerates the economic growth of a country. Economically advanced countries have crossed the threshold level of development by bringing innovation in their education system. These countries allocated substantial amount of fund for education to introduce innovative teaching and learning practices by bringing technologies in their classrooms so as to produce skilled workforce. The stock of digitally advanced human capital is an asset for their economic growth. The study results indicate HCS, TIN and TAD for LMICs of Asia, Africa and South Pacific Ocean regions are negative because these countries are not technology advanced countries. Therefore, there is more number of LMICs in these regions. On the other hand, Europe and Latin America are technological advanced regions and have less number of LMICs, therefore, FCF, LF and TIN and TAD are positive [11]. LMICs of the world are lagging behind in the economic growth. There is an urgent need for these countries to take necessary steps for the reforms in their education system. Concrete policy and strategies, R&D for education reform may help in producing stock of human capital that can boost up the economic growth of these countries. LMICs may adopt technologies that are already in practice in developed countries, however, all technologies are

not suitable for these countries; therefore, LMICs need to be specific in selecting appropriate technologies depending upon their need and economic structure [30]. Consequently, these LMICs would be able to reduce Digital Divide and can compete well in the Information Era. The impact of technology innovation and adoption types on economic growth, can be researchable question to dig out deeper insights for future research.

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# DIVERSIFICATION OF LIVELIHOODS THROUGH DATE PALM PRODUCTION IN AGRO-PASTORAL AREAS OF AFAR REGION, ETHIOPIA

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## ABSTRACT

**Background:** Date palm is the oldest fruit tree which is mostly cultivated in arid and semi-arid areas. This study aims to assess the contribution of date palm production in livelihood promotion of agro-pastoral regions of Afar, Ethiopia. The primary data were generated from questionnaires, interviews, focus group discussions and observation. Date palm producers were selected purposively while individuals were selected randomly from 117 samples households. Secondary data were also used.

**Results:** For the purpose of analysis, descriptive statistics for quantitative and narration for qualitative data were applied for analysis. Date palm production covered about 10-30 % of the food demands of 95,5 % households in the study area where most of the date palm producing households (88,9 %) consumed about 0,25-1,99 gm of date palm per day. Moreover, the primary income source for the majority of date palm producers is obtained from date palm production. Palm trees and its different parts are used to construct houses, bed frames, bridges and especially the leaves are used as a raw material to make baskets, fans, ropes, sacks and other materials.

**Conclusion:** Capacity building on the economic importance and agronomic and management practices of date palm to all stakeholders is recommended.

## KEYWORDS

date palm, production, livelihoods, agro-pastoral, Afar region

## CLASSIFICATION

JEL: Q12

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## **INTRODUCTION**

Date palm fruit is very nutritious and contains carbohydrates, proteins, fibres, fats, various vitamins and minerals. The highest sugar content makes date palm fruit one of the most nourishing natural foods available to man. The water content is between 15 % to 30 % depending on the variety and on the maturity stage of the fruit [1]. Moreover, date fruits provide excellent taste to the final product when used in baking. It is also used as a component in food preparations like sweets, snacks, confectionery, baking products, institutional feeding and health foods. Date juice, syrup, liquid sugar, protein yeast and vinegar and fermentation products like wine, alcohol, organic acids, etc. can be derived from date palm fruits.

According to Zaid and de Wet [2], date palm is cultivated in arid and semi-arid regions which are characterized by long and hot summers and no or at most low rainfall. Moreover, it requires very low relative humidity especially during the ripening period. If irrigation is available high temperatures up to 56 °C are also well tolerated by date palm. Rain during the flowering and harvest season is likely to cause some damage to the fruits. Rainfall immediately after pollination is detrimental since it washes the pollen grains and thus reduced fruit set. Moreover, rainfall may reduce temperature that is necessary for fruit set and flower's receptivity [3]. Generally, the amount of rainfall is less important than the conditions under which it occurs. Light shower accompanied by prolonged periods of cloudy weather and high relative humidity may cause more damage than heavy rainfall followed by clear weather and dry winds. Date palm can be planted in a wide range of soils with varying amounts of organic and mineral nutrients. Date palm is known to tolerate salinity more than any other cultivated fruit crop.

It is believed that date palm has been introduced to Ethiopia from Middle East countries about 200 years ago by traders from Yemen and Sudan [4]. Its production is generally not well developed in Ethiopia. Date palm is cultivated mainly by agro-pastoralists in Afar, Somali, Gambella, Dira Dawa and Benishangul-Gumuz regions. Especially in Afar Region the production of date palm has long history where it is established as wild crop in Afambo, Aysaita, Gewane and Amibara districts along the Awash River. The environmental and edaphic conditions in these areas are especially suitable for date palm production, since it is located within the Danakil Depression and Awash River basin. Although the annual production of date palm is not known, the quantity required is generally quite lower than the demand of the product in the country [5]. To satisfy this demand the government of Ethiopia imports annually about 1715 tons of date palm [6].

The agro-pastoralists in Afar Region produced date palm fruit mainly for their own consumptions and in some extent for local market to improve their livelihood. The production practices of date palm employed by agro-pastoralists are traditional which is characterized by improper cultural practices, use of inferior varieties and poor postharvest handling and marketing of date palm. As the result, date palms produced in the country are low in quantity as well as poor in quality. On the other hand, date palm production contributes a lot to food security, reduction of malnutrition and poverty and source of additional income generation for the poor agro-pastoralists. Moreover date palm plays significant role in the control of desertification and means of land reclamation in the country at large and in Afar Region in particular. The aim of this study was, therefore, to assess the contribution of date palm production for livelihood diversification in Afambo and Aysaita districts of Afar Region.

## **THE RESEARCH AREA AND METHODS**

### **DESCRIPTION OF THE STUDY AREA**

The present study was conducted in Afambo and Asaiyta districts which are categorized as Awsa Kee Gewane livelihood with average altitude ranging from 330 to 350 meter above sea

level [7]. The area has an average annual rainfall of 122 mm with bimodal rainy seasons. The first season is from February-March (*sugum* rains) while the second rainy season is from July-September (*karma* rains). The Awash River is the main source of water for irrigated crop production in the area. The vegetation in the region is a mix of shrubs, bushes and pasture land. Moreover, invasive weeds, particularly that of *Prosopis juliflora*, are the major threat of the range lands in the region. Large-scale farms owned by the government and private investors are found in the region where Tendaho and Middle Awash Agriculture Development farms are the main state farms providing casual employment opportunities to the local communities and immigrant workers [7]. The total population of Aysaita and Afambo districts is 90 398. Of that number 48 747 are males and 41 651 are females. The annual population growth rate is about 2,9 % [8].

## **SAMPLING TECHNIQUES AND PROCEDURES**

From four districts where date palm is mainly produced in Afar Regional State Afambo and Aysaita Districts were purposively selected because of their long experience in the production of date palm. Among the total of 19 pastoral associations found in Afambo and Aysaita districts, the three pastoral associations namely *Alasabolo*, *Humadoyta* and *Berga* were selected based on their experiences in production and consumption of date palm. The total number of households was determined according to the formula described by Kothari [9] with 95 % confidence interval while the number of households in different pastoral associations and agro-climatic zones was calculated based on the population size ratio formula described by Cochran [10] as indicated further in the text. The individual households in each pastoral association was however selected randomly. Accordingly a total of 117 households were selected with 57, 30, and 30 households in *Alasabolo*, *Humadoyta* and *Berga kebeles*<sup>1</sup>, respectively.

Both primary and secondary data were collected in the study. The primary data were generated through household surveys using semi-structured questionnaires, key informant interviews and focus group discussions. In focus group discussions local knowledgeable peoples in the *kebeles* were participated. Furthermore direct observations were made to generate primary data on physical conditions of date palm production in the study area and photos were taken. In addition, literatures related to the study area such as published and unpublished documents, governmental and non-governmental reports and other similar relevant documents were reviewed.

## **METHOD OF DATA ANALYSIS**

Qualitative data were summarized and narrated. Quantitative data collected from the household survey were entered and analysed using SPSS (Statistical Package for Social Sciences). Descriptive statistics such as frequency distribution, percentages and cross tabulation were applied for analysis. Moreover, the results were summarized in the form of tables and figures.

## **RESULTS AND DISCUSSIONS**

### **GENERAL DEMOGRAPHIC CHARACTERISTICS OF THE RESPONDENTS**

#### **Sex and marital status**

The household head sex and marital distribution are presented in Table 1.

As is indicated, sex distribution of household heads influenced the participation of agro-pastoralists on date palm production in the study area. Accordingly, 64,1 % of the households

**Table 1.** Sex distribution and marital status of the respondent households in the study area.

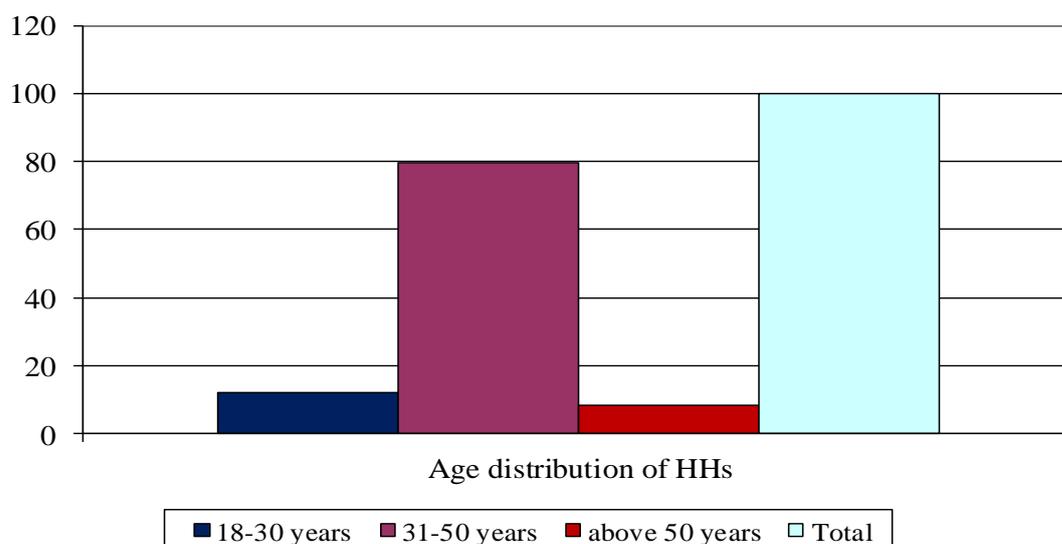
Sex of the household head	Category	Frequency	%
	Male-headed	75	64,1
	Female-headed	42	35,9
	Total	117	100,0
Marital status of the household respondents	Category	Frequency	%
	Single	9	7,7
	Married	97	82,9
	Divorced	6	5,1
	Widowed/widower	5	4,3
	Total	117	100,0

participating in date palm production were male headed while the remaining 35.9% were female headed. The reason is probably in that male agro-pastoralists have easier access to land while female headed agro-pastoralists may have difficulties to access land suitable for date palm production. These findings are generally in line with the findings of many researches which revealed that female-headed households and women in general have poor access and control over resources especially in agro-pastoral communities [11].

The marital status also influenced the participation of the agro-pastoralists in date palm production. Most of the respondents (82,9 %) in the study area were married while 7,7 % were single and the remaining 9,4 % were either divorced or windowed. Marriage is essential to facilitate farming and household activities under agro-pastoralists. Moreover according to the clan leaders as key informant divorcing is not the acceptable phenomena in agro- pastoral society. In case of disagreements, the clan leaders and elderly people including the family members of the couples are trying to resolve the problems occurred among the couples.

### Age distribution and educational level

Age distribution and educational level of the respondents are presented in Figure 1 and Table 2, respectively. According to the survey results, the majority of the household heads (91,5 %) participated in date palm production were at working ages which is probably associated with the fact that production and management activities of crops including date palm is a hard work job which requires physically matured personnel.



**Figure 1.** Age distribution (%) of the respondent households in the study area.

**Table 2.** Educational level of the respondent households in the study area.

Category	Frequency	%
Illiterate	83	70,9
Primary school	9	7,7
Middle school	0	0,0
High school and above	3	2,6
Informal education	22	18,8
Total	117	100,0

As Table 2 shows, most of the respondents (70,9 %) were illiterate. While 18,8 % of the households had informal education, only 9,3 % of the respondents visited formal education system. The level of education plays an important role in the introduction, distribution and adoption of improved agronomic and management practices which are necessary for increased production and productivity of crops including date palm. Moreover education helps to improve the knowledge, skills and attitudes of the farming communities and thus to create changes in human behaviours. Therefore, extension services, awareness creation and expansion of infrastructures such as schools, roads electricity are necessary in the study area.

### AREA ALLOCATED FOR THE DATE PALM PRODUCTION

Area allocated for date palm production and the experience of the sample households are presented in Table 3.

**Table 3.** Production area allocated date palm production in the study area.

Category	<i>Kebele</i>							
	Berga		Alassabolo		Humodoyta		Total	
	HH frequency	%	HH frequency	%	HH frequency	%	HH frequency	%
≤ 0,59	10	33,3	39	68,4	16	53,3	65	55,6
0,6-0,9	16	53,3	17	29,8	12	40	45	38,5
1,0-1,9	3	10,0	1	1,8	2	6,7	6	5,1
2,0-3,0	1	3,3	0	0,0	0	0,0	1	0,9
Total	30	100	57	100	30	100	117	100

The size of date palm production area in the sample *kebeles* is relatively different. Most of the sample households in *Alassabolo* (68,4 %) and in *Humodoyta* (53,3 %) *kebeles* allocated less than 0,59 ha cultivated land. However, about 53,3 % of the agro-pastoralists in *Berga kebele* allocated about 0,6-0,9 ha of cultivated land for date palm production. Generally, about 94,1 % of the sample households in the study area produced date palm on less than one hectare of cultivated land which is low compared to other countries where individual farmer owned more than ten hectares of land covered by date palm tree. Date palm plantation in Afambo and Aysaita districts is mostly concentrated around Awash River, shown in Figure 2.

Afar Regional State is one of the regions in Ethiopia having historical experience in irrigated agriculture. Crop production in the region is generally practiced on about 84,358 hectare of land, of which about 80.8% is irrigated. The Region has also long experience in the production of date palm especially in Afambo and Aysaita districts as indicated in the Table 3 and Figure 2. Generally, the research results revealed that about 77.8% of the respondents in the study area had 21-40 years of experiences in the production of date palm. However, the management practices employed by growers are traditional which have been acquired from their parents through time. According to the respondents no trainings and extension services have been given by respective stakeholders about the agronomic, management, and postharvest handling practices.



**Figure 2.** Date palm trees grown at Awash River bank in Alassabolo *Kebele* of Afambo District (photo taken during observation of the production area).

**Table 4.** Experience of date palm production in the study area.

Experiences, year								
10-20	8	26.7	4	7.0	2	6.7	14	12.0
21-40	21	70.0	45	78.9	25	83.3	91	77.8
41-60	1	3.3	8	14.0	3	10.0	12	10.2
Total	30	100	57	100	30	100	117	100

## CONTRIBUTIONS OF DATE PALM PRODUCTION FOR AGRO-PASTORAL LIVELIHOOD IN THE STUDY AREA

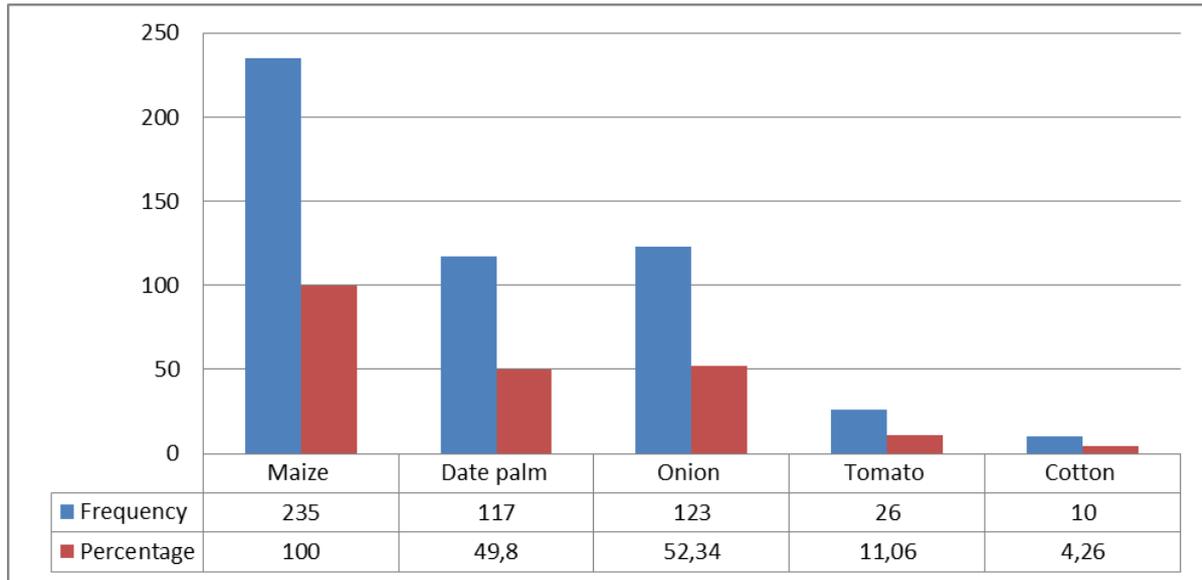
The major livelihood activities of agro-pastoral livelihood in Afambo and Aysaita districts is mixed farming where irrigated and rain-fed crop production is combined with livestock rearing- mainly cattle and shoats (sheep/goats). Casual labourers employment both in state and private agricultural farms is an important income source for casual labourers and other wealth groups in some areas. Moreover date palm production is also one of the major components of livelihood for agro-pastoralists in the area [7].

Date palm had multiple benefits in the agro pastoral livelihoods. It has excellent contributing potential to economic, social and cultural aspects in the areas. It is a multipurpose tree in providing various primary and secondary products which diversify its importance to the economic and social security of the people. Date palm cultivation helps to generate considerable employment opportunities and to facilitate eco-restoration that ensures livelihood and food security. Date palm production can be one of the best alternatives for developmental endeavours of the Afambo and Aysaita districts if promoted in a systematic manner.

### Major crop production in Afambo and Aysaita districts

The major crops that were being produced in the area include date palm, maize, onion, tomato and cotton crops. The production of these crops is entirely dependent on the availability of irrigation water [7].

The major crops produced in the study areas are presented in Figure 3.



**Figure 3.** Major crops produced in the study area.

According to the respondent, they households produced different types of crops. Almost about 100% of respondents produced maize while about 52,34 %, 49,8 %, 11,06 % and 4,26 % of the households produced onion, date palm, tomato and cotton, respectively.

### Crop area coverage and contribution as food source of households in the study area

The size of land holding refers to the pieces of land owned and cultivated by agro-pastoralists and their families. It is generally considered that agro-pastoralists hold small pieces of land to be used for crop production [12]. According to the survey results, few of date palm producers (16,2 %) and non-producers (18,2 %) have a crop land at the range of more than 3 ha. However, more than half of the date palm producers (56,4 %) have 2-3 ha of land covered by different types of crops. In non-date palm producers, only 45,8 % of the respondents have such amount (2-3 ha) of land which is covered by different crops.

In agro-pastoralist, there are different food sources in the study area. Crop production is one of the major sources of food in Afambo and Aysaita districts [7]. Based on the survey results about 55,6 % of date palm producers covered about 20-40 % of their food demand from crop

**Table 5.** Crop area coverage and contribution as food source of HHs in the study area.

Crop area coverage						
Area, ha	Producer		Non-producer		Total	
	Frequency	%	Frequency	%	Frequency	%
< 0,99	3	2,6	2	1,7	5	2,1
1-1,99	29	24,8	40	33,9	69	29,4
2-3	66	56,4	54	45,8	120	51,1
> 3	19	16,2	22	18,6	41	17,4
Total	117	100,0	118	100,0	235	100,0
Crop production as food source						
< 20	37	31,6	8	6,8	45	19,
20-40	65	55,6	33	28,0	98	41,7
41-60	15	12,8	77	65,3	92	39,
	0	0,0	0	0,0	0	0,0
Total	117	100,0	118	100,0	235	100,0

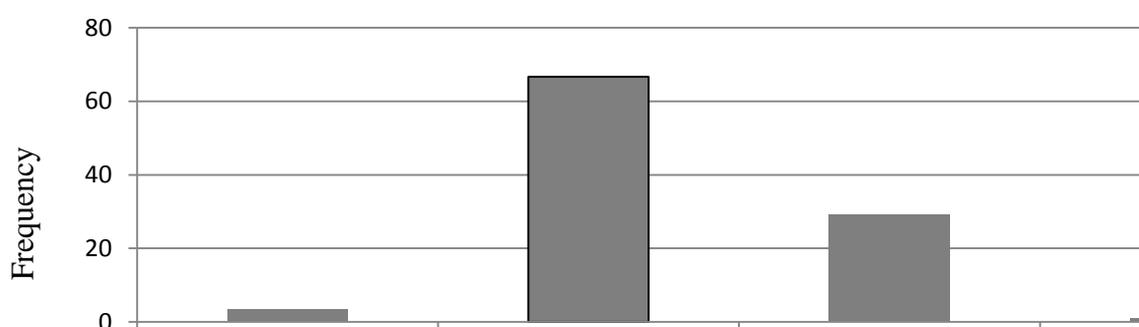
production (Table 5). But in case of non-date palm producers, 41-60 % of the food demand of the 65,3 % of the household is covered from crop production. The results showed that crop production had proportional contribution as food sources for both date palm producers as well as non-date palm producers. However, for most of date palm producers (87,2 %) only up to 40 % of their food demands are covered by crop production where the remaining food demand (60 %) may probably be covered by date palm and/or products from livestock. In case of non-date palm producers, about 60% of the food demand of 93,3 % of the respondents is covered by crop production in both districts. But, as Table 5 indicated below, in Afambo district 42,7 % of households covered about 20-40 % of their food demand from crop production and 39,1 % of households covered about 20-40 % of their food demand from crop production in Aysaita district which indicates crop production could be the importance of the sector other than date palm production to satisfy the food demand of such agro-pastoralist.

**Table 6.** Contribution of crop production as food source in Afambo and Aysaita districts.

Crop production as food source	Afambo		Aysaita		Total	
	Frequency	%	Frequency	%	Frequency	%
< 20	35	20,5	10	15,6	45	19,1
20-40	73	42,7	25	39,1	98	41,7
41-60	63	36,8	29	45,3	92	39,1
61-80	0	0,0	0	0,0	0	0,0
Total	117	100,0	118	100,0	235	100,0

### Contribution of date palm as food source in Afambo and Aysaita districts

Date palm is one of the most important sources of food for agro-pastoral communities including Afambo and Aysaita districts. The community can dry the fruits and store up to one year that can be used as a source of food especially during dry season.



**Figure 4.** Food source contribution of date palm for agro-pastoralists in the study areas.

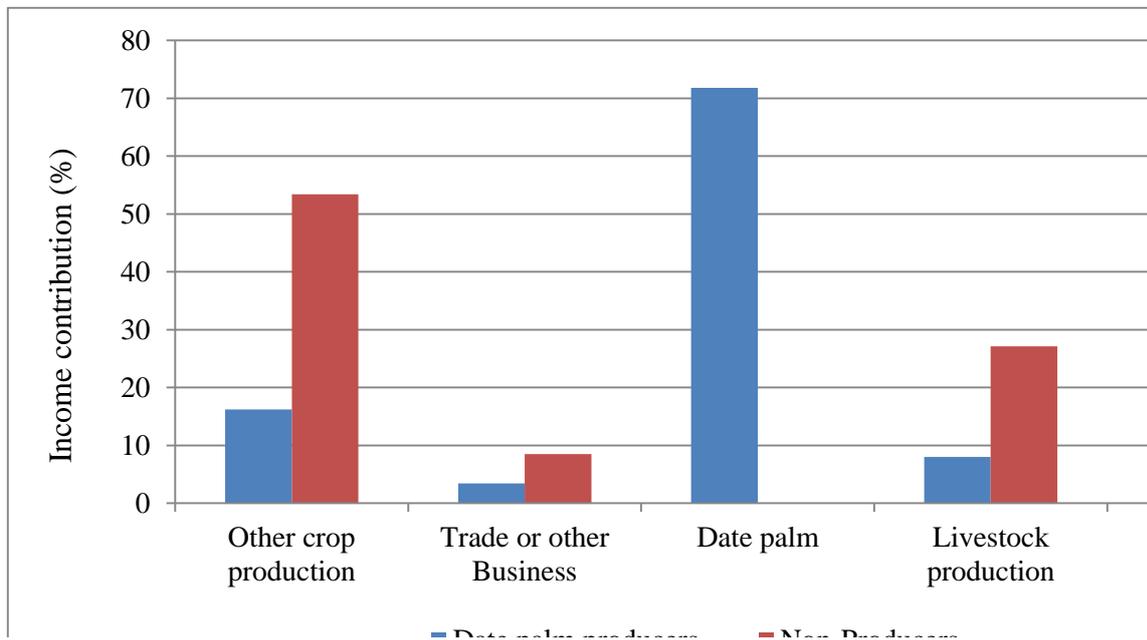
In Figure 4, 10-30 % food demands of the 95,8 % household are covered by date palm production sector of agriculture in the study area. The result indicates that date palm production in low land areas of the Region like Afambo and Aysaita districts is an important activity that helps to improve the food security in such rainfall scarce areas.

### Primary income sources of agro-pastoralists in Afambo and Aysaita districts

Livelihood diversification plays a significant and relevant role in improving food security and incomes of pastoral and agro-pastoral community including those in the study area [13].

According to Figure 5, the primary income source of the majority date palm producers (71,8 %) is sourced from date palm production and their products and some small amount of this group of people (3,4 %) gets their income from trade or other business. In the case of non-date palm producers, other crop production and animal production is the main sources of

incomes of the majority of the people (80,5 %). This indicates that date palm production is most important source of primary cash income of date palm producing. They earn cash income directly through selling the fruit and indirectly through selling of handcrafts, household utensils and mate which they make out of the leave of date palm tree.



**Figure 5.** Primary sources of income of the households in the study area.

### Secondary income sources of agro-pastoralists

The secondary source of incomes of the majority date palm producing households (60,7 %) incomes sourced from livestock and their products (Table 7). Similarly, the majority of non-date palm producing households (80,5 %) in the study area get their income from selling of livestock and their products. This result also similar with the research findings of Salman [11] who reported that livestock rearing was the secondary source of income in South Punjab of Pakistan.

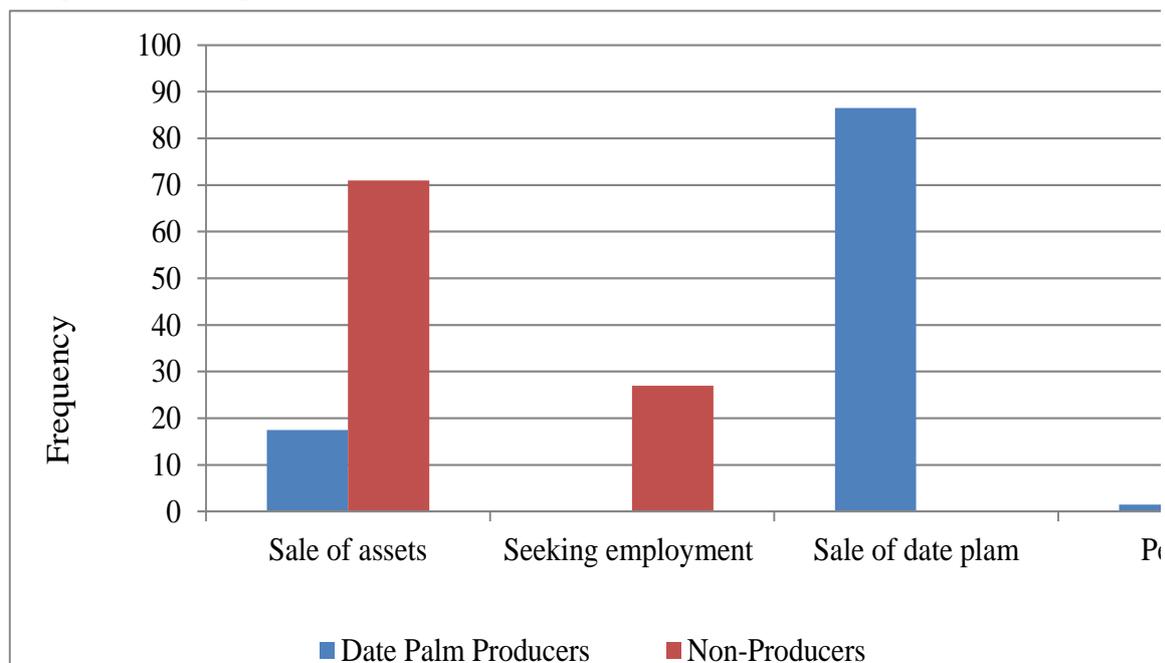
**Table 7.** Secondary income sources of the households in the study area.

Secondary source of income	Producer		Non-producer		Total	
	Frequency	%	Frequency	%	Frequency	%
Crop production	19	16,2	3	2,5	22	9,4
Petty trade	6	5,1	11	9,3	17	7,2
Date palm	13	11,0	0	0,0	13	5,5
Remittances	0	0,0	1	0,8	1	0,4
Livestock production	71	60,7	95	80,5	166	70,6
Agricultural labour	2	1,7	5	4,2	7	3,0
Non farming activities	2	1,7	1	0,8	3	1,3
Sale of fire wood and charcoal	4	3,4	2	1,7	6	2,6
<b>Total</b>	<b>117</b>	<b>100,0</b>	<b>118</b>	<b>100,0</b>	<b>235</b>	<b>100,0</b>

### Income sources of agro-pastoralists at the time of drought (shock, stress, ...)

Agro-pastoral households are vulnerable to different types of problems, shocks, stresses, and changing trends. Thus, vulnerability analysis is important to identify coping mechanisms of the community during shocks and stresses [14]. Survey results of the study area in this regard are presented in Figure 6.

According to the research results, selling of date palm fruits and other date palm products is the main source of income for the majority of date palm producing respondents (86.3%) during drought or other stressing conditions. On the other hand the main source of income for the majority of non-date palm producing respondents (71%) to cope up the stressing conditions is selling of assets such as cattle, shoots and camel and others. Moreover, some of the people in this group seek additional employment opportunities and start business to increase their sources of incomes and thus, to alleviate the problems associated with such drought or stressing conditions.

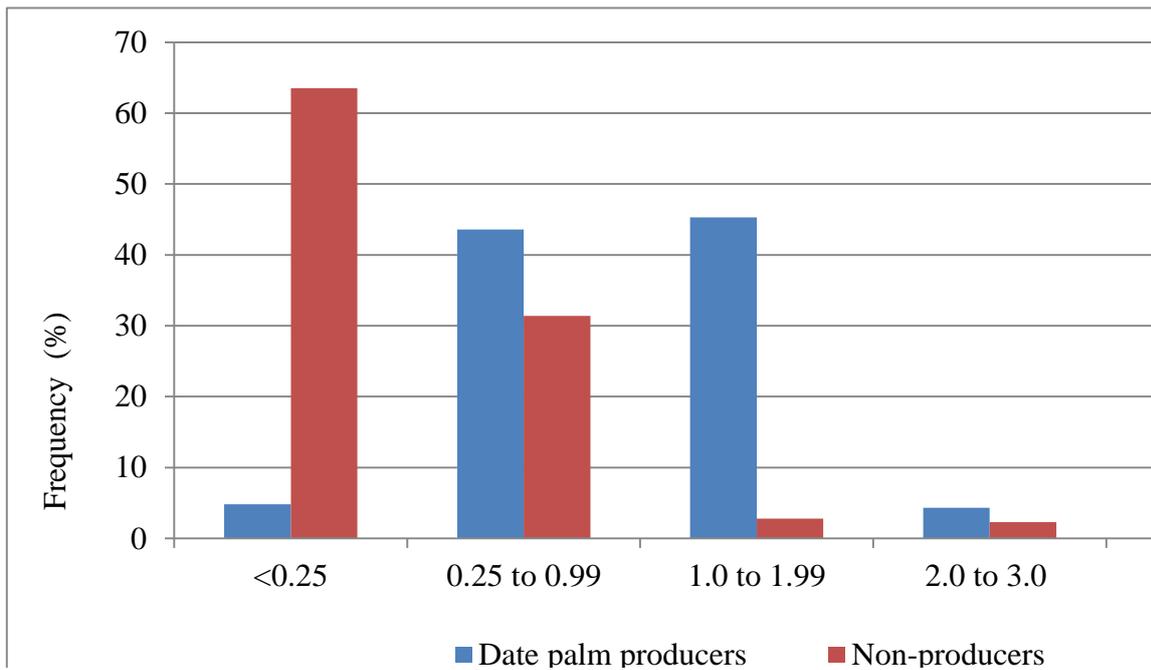


**Figure 6.** Income sources of households during drought conditions in the study area.

### **DAILY CONSUMPTION OF DATE PALM IN THE STUDY AREA**

As discussed previously date palm is one of the main food sources of pastoral and agro-pastoral communities in Afar Region where the daily consumption of date palm is presented in Figure 7. Accordingly 43,6 % date palm producing households in the study area consumed about 0,25-0,99 g of date palm per day whereas about 45,3 % of them consumed 1-1,99 g/day. However, most of non-date palm producers (65,3 %) consumed date palm less than 0,25 g/day. Only some of non-date palm producing respondents (31,4 %) consumed about 0,25-0,99 g/day date palm. Low consumption of non-date palm producers in the study area is obviously associated with the unavailability of date palm in their farm in both districts. Therefore, this group of people should buy date palm from the market which incurs additional expense in their food expenditure.

In Afambo district about 38,0 % households consumed about 0,25-0,99 g of date palm per day while about 35,9 % of the households in Aysaita district consumed about 0,25-0,99 g of date palm per day per person as indicated in Table 8.



**Figure 7.** Daily date palm consumption of the respondents in the study area, in grams per day per person.

**Table 8.** Daily date palm consumption of the HHs in each district.

Daily date palm consumption, g per day per person	Afambo		Aysaita		Total	
	Frequency	%	Frequency	%	Frequency	%
< 0,25	61	35,7	21	32,8	82	34,9
0,25-0,99	65	38,0	23	35,9	88	37,4
1,00-1,99	43	25,1	14	21,9	57	24,3
2-3	2	1,2	4	6,2	6	2,6
> 3	0	0,0	2	3,1	2	0,9
<b>Total</b>	<b>117</b>	<b>100,0</b>	<b>118</b>	<b>100,0</b>	<b>235</b>	<b>100,0</b>

As per Table 9, there is statistically significant difference on primary source of income between producers and non-producers ( $U = 5913,5, p < 0,05$ ). The mean rank for date palm producers is found to be higher (126,46) than the mean rank of non-producers (109,61). There is also statistically significant difference in income of date palm producers and non-producers during drought conditions ( $U = 3290,00, p < 0,05$ ). The mean rank for date palm producers is found to be higher (148,88) than the mean rank of non-producers (87,38). Moreover, there is statistically significant difference on date palm daily consumption between date producers and non-producers ( $U = 1651,00, p < 0,05$ ). The mean rank for date palm producers is found to be higher (162,89) than the mean rank of non-producers (73,49).

**Table 9.** Mann-Whitney U-test values. Results are significant to 5 %.

Variable	<i>U</i>	Sig.
Primary source of income	5913,50	0,046
Income during drought	3290	0,00
Date palm daily consumption	1651,00	0,00

These results tell us there is annual date palm production and yield obtained by agro-pastoralists in Afambo and Aysaita districts. These surplus date production enables agro-pastorals to sell their products and earn extra incomes. Moreover, the results indicated

the drought resistant ability of date palm fruit trees in Afambo and Aysaita districts. So agro-pastoralists can harvest yield and sell their product during normal and drought season which protect them to sell their livestock asset. Moreover, consuming date palm as food sources for date palm producing pastoralists in Afambo and Aysaita districts is common while non-producers first should buy the date palm fruit for consumption.

### **MARKET OUTLETS AND ANNUAL INCOMES OF HOUSEHOLDS FROM DATE PALM PRODUCTION**

Agro-pastoralists in Afambo and Aysaita districts use different marketing chain to sale their fruits. Accordingly, most of the respondents (69,2 %) sell their fruits to retailers in the study area (Table 10). While 13,7 % of the respondents sell the fruits produced directly for consumers about 17,1 % of them sell their fruits to wholesaler.

**Table 10.** Market outlets and annual income of date palm fruits produced in the study area.

<b>Market centre</b>	<b>Frequency</b>	<b>Percentage</b>
Consumer	16	13,7
Wholesaler	20	17,1
Retailer	81	69,2
<b>Total</b>	<b>117</b>	<b>100,0</b>

The respondents in the study area have different income sources. One of the income sources of the producers in the study area is sales obtained from date palm fruits and other materials which are made from parts of date palm trees. The annual income of date palm producers obtained from sales of date palm fruits and byproducts in the study area is summarized in Table 11 below. Accordingly, most of date palm producing respondents (64,9 %) earned about 5 001,00-20 000,00 Eth-Birr per year. While 32,5 % of the date palm producers earned less than 5 000,00 Eth-Birr per year about 14,5 % of the earned Eth-Birr at the range of 15 000,00-20 000,00 per year. But the average annual income of the producers was 8 166,68 Eth-Birr per year which is very low compared to the potential of the area. The findings of the research are similar with that of Salman [11] where date palms are important income sources. The income sourced from the sale of date palm fruits and byproducts can be used to purchase different materials such as food items, cloths, agricultural inputs and different services like medication and school fee for their children. These results show that date palm production helps to earn extra income which can be used to improve the living standards of the agro-pastoralists in Afambo and Aysaita district.

**Table 11.** Annual income of agro-pastoralists from date palm production.

<b>Annual income, birr</b>	<b>Frequency</b>	<b>Percentage</b>
< 5 000	38	32,5
5 001-10 000	59	50,4
15 000-20 000	17	14,5
≥ 25 000	3	2,6
<b>Total</b>	<b>117</b>	<b>100,0</b>

In general agro-pastoralist in Afambo and Aysaita districts have different sources of livelihood where date palm production is an important one. Therefore, the contribution of date palm production to the total livelihood/annual income of the date palm producers in Afambo and Aysaita districts is summarized as follows:

Annual income from crop production other than date palm	378 810
Annual income from date palm production	955 502
Annual income from livestock production	206 210

Annual income from Agricultural jobs our	62 310
Annual income from Trade	107 140
<b>Total</b>	<b>1503 760,00</b>

The annual contribution of date palm production to the total income of the agro-pastoralists is therefore 63,54 %.

**Use of date palm tree other than source of food**

A date palm has different uses for agro-pastoralists in Afambo and Aysaita districts. In addition to fruit production, leaves are used to make various products which help to improve the incomes of the agro-pastoralists. According to the respondents during focus group discussion in the study area date palm is used to construct houses, bed frames, bridges and other materials. Leaves are used to made baskets, fans, ropes, sacks and other materials. Moreover, the respondents believed that date palm trees are important for environmental protection since they considered the plant as trees. According to the household’s date palm are useful to protect desertification, soil and erosion and sandstorm and stabilize micro-climate. This result shows that beside of food and income source date palm is multipurpose fruit tree which contributions of economic, social and environmental security of agro-pastoralists in both districts.

**Constraints of date palm production in the study area**

Date palm production in Afar Region is concentrated at banks of rivers and seasonal streams without any cultural and management practices necessary for improved production and productivity. They are mostly neglected crops and grow as wild. Even in smallholder farms and relatively organized plantations, the agronomic practices employed are inappropriate for the production of date palm. The constraints of date palm production in the study area are generally summarized and presented in Table 12.

**Table 12.** Major constraints of date palm production in the study area.

Category	Frequency of households	%
Inappropriate agronomic & management practices	71	60,7
Shortage of quality planting materials	13	11,1
Diseases & insect pests problems	14	12,0
Poor postharvest handling practices	11	9,4
Lack of marketing linkage	8	6,8
<b>Total</b>	<b>117</b>	<b>100,0</b>

According to the survey results, the majority of the respondents (60.7%) perceive that the major constraint of date palm production in the study area is poor agronomic and management practices necessary for maximum yield of date fruit. The reasons for poor cultural practices are among others lack of knowledge and skills necessary for the production of date palm. According to the respondents high incidence of diseases and insect pests and their poor management were the second constraint of the sector in the study area. The knowledge and skills of agro-pastoralists about insect pest management options are extremely low. Moreover pesticides are not available in the study area.

Moreover the absence of improved date palm varieties and use of inappropriate propagation method were the other constraint of date palm production in the study area. Propagation of date palm in the study area was exclusively through seed which results low quantity and quality of date palm fruits. In addition poor postharvest handling practices such as poor storage, absence of curing, sorting, grading and packaging and lack of market linkage between producers and customers were also considered as a problem of the sector in the

study area. Date palm harvesting practice is done manually by cutting and collecting of the fruit bunches from the ground which incurs damages and thus decreases the shelf life and increases postharvest loss of date fruits.

## **LIVELIHOOD OUTCOME OF AGRO-PASTORALISTS**

Livelihood outcomes are the results of combination of different assets. It could be desirable due to opportunities and undesirable due to challenges as indicated elsewhere [11]. Well managed date palm production can improve the livelihoods of agro-pastoralists positively by increasing production and productivity. Based on the results of the present study about 39.1% of the households recognized that date palm has high production and productivity which can increase the food and incomes of agro-pastoralists (38.7%). Moreover, about 22.1% of households believed that date palm production improves food security of agro-pastoralists in both districts (Table 13). In Afambo district on the other hand, 40.4% of households said that date palm can increase food and incomes while in Aysaita district about 34.4% of households believed that date palm production increases food and incomes agro-pastorals. Generally, the results of the present study showed that date palm production contributed to the outcomes of livelihoods of agro-pastoralists by increasing production and productivity and increasing food and incomes and thus help to improve food security of the pastoral communities in Afar Region of Ethiopia.

**Table 13.** Livelihood outcome of agro- pastoralists.

<b>Livelihood outcome</b>	<b>Afambo</b>		<b>Aysaita</b>		<b>Total</b>	
	<b>Frequency</b>	<b>%</b>	<b>Frequency</b>	<b>%</b>	<b>Frequency</b>	<b>%</b>
High production & productivity	63	36,8	29	45,3	92	39,1
Increased food & income	69	40,4	22	34,4	91	38,7
Improved food security	39	22,8	13	20,3	52	22,1
<b>Total</b>	<b>64</b>	<b>100,0</b>	<b>171</b>	<b>100,0</b>	<b>235</b>	<b>100,0</b>

## **CONCLUDING REMARKS**

Date palm production has a long history in Afar Region. It is mostly cultivated by agro-pastoralist living along the Awash River. However, its production practice is more of traditional which is inherited from generation. About 20 % to 40 % of the food demands of date palm producing agro-pastoralists were covered by livestock production while non-date palm producers (41-80 %) covered their food demand from livestock production. The primary income source of date palm producers was sourced from sale of date palm fruits and other byproducts of date palm trees while the production of other crops was the primary sources of incomes of the majority of non-date palm producing households. The secondary income sources of date palm producers as well as non-producers were selling of livestock and their products. Moreover, date palm is an important source of income and food during drought or stressing conditions as the tree is resistant to drought. Generally, date palm production has important contributions for the environment, social and economic development by creating employment opportunity, protecting desertification, soil erosion and sandstorm and stabilizing micro-climate in Afar Region.

Although date palm is an important food security crop, its production in Afar Region is constrained by inappropriate agronomic and management practices, shortage of quality planting materials and high incidence of diseases and insect pests which requires due attention of the government and other developmental stakeholders.

## REMARK

<sup>1</sup>Kebele is a grass-root level administrative unit equivalent to a parish or local community.

## ACKNOWLEDGMENT

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# EVALUATION A CITY EMERGENCY MANAGEMENT EXERCISE FOR ORGANIZATIONAL LEARNING

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## ABSTRACT

All relevant emergency management services are necessary for a Smart City to achieve public protection and property safety in response to a major disaster or an unplanned event, including simulated flooding exercise measures. It is the first time that a Safety through Organizational Learning-methodology has been used for Evaluating a City Emergency Management Field Exercise. A city's ability to respond effectively to a natural disaster e.g. flood defence heavily depends on emergency management's preparation for successful responses. An efficient way to test the level of preparation of City Emergency Management is to hold a Field Exercise in a vulnerable city. Analysing with Safety through Organizational Learning allows the identification of concrete alternative corrective actions/measures by which the probability that similar events occur in the future can radically be reduced. Furthermore, such measures help organisational learning, thereby contributing to the development and maintenance of a long-term, safe organisational culture.

## KEYWORDS

city emergency management, exercise, SOL methodology, public safety, evaluation

## CLASSIFICATION

JEL: C10, C83, H84, Q54

## **INTRODUCTION**

The Disaster Management trains and exercises in order to develop our ability to handle disasters and crises, both individual organisations and local emergency management authorities. Qualitative methods of evaluation increase opportunities for identifying and utilising the lessons learned in exercises [1].

After the exercise, there must be time to take a step back and reflect on what has gone well and what has not. What are the ways and means by which improvements might be made? An evaluation reviews initiatives, operations and action, for example, in order to ensure and maintain or improve their quality. With this definition in mind, it is clear that all organisations should conduct evaluations. The basis for an exercise such as this is a more open and experience-based methodology, in which exercise participants are made to respond and take action in a situation rather than merely discuss it.

The framework of the analysis was given by the event-analysis method called Safety through Organizational Learning (SOL), through which the partakers could explore the safety gaps of a certain event or activity and had the opportunity to make suggestions for improvement. This event was one of the actions of the international field exercise, called EUWA [2].

The most frequently mentioned organizational safety gap was communication and its connecting areas, while the most important factors were those in connection with responsibility and regulations.

After identifying the problems, the partakers – on the second day of the analysis – formulated their improving suggestions that support the future organizational learning process, thus leading to developing a more effective way of handling real disaster and exercise situations.

ANIMA Polygraph Psychological Consulting Ltd. has already applied SOL analysis with several organizations to carry out organisational diagnostics and improve their organizational culture. The method has also been successfully used in different practical contexts, such as examinations of accidents happening during rescue activities and deliberate damages.

During the planning and preparation phase, it was important to gain a comprehensive picture of the process of the field exercise. It was also important to choose employees who were either present at the exercise or at least have a comprehensive picture of the process so that they can effectively promote cooperation and information-gathering. One of the main principles of SOL-analysis is to have leading employees of the company involved as they are the ones who are able to formulate and introduce effective management actions for the sake of successful exercises.

For SOL-analysis it is inevitable to have an event (a part of the exercise) which can be divided into components so that the contributing factors to be developed can be identified. Thus, the subject of analysis was not the whole field exercise, only the events of 5<sup>th</sup> April 2017. The 2-day-long analysis required the presence and continuous work of 7 experts, so it was also important to choose experts who are able to take part in the whole process and be present on both days.

## **APPLYING THE SOL-METHODOLOGY**

The SOL method was initially developed by a research group under the guidance of Bernhardt Wilpert at the Berlin University of Technology [3] in 1997.

It was initially developed for the nuclear power industry; however, a version for the chemical industry also exists and a computer supported version was later developed as well in

1999 0. The SOL method has been adopted by the Swiss and German nuclear industries as standard procedure for their in-depth event analyses 0. SOL aims at facilitating organisational learning from events by supporting the process of analysing events, ensuring its standardised conduct and mobilising expert knowledge and creativity in the analysis 0 The SOL method is based on the so called socio-technical system model (Fig. 1) and covers the identification of critical human factors as well as safety relevant technical, organisational and management factors.

As the very first step of the analysis of the selected event, a situational description is constructed 0, and after that all the relevant and available objective data are collected concerning this event, without questioning its significance. Later the analysed event is decomposed into smaller elements of the event. These elementary events or sub-events are called “event building blocks”, as individual actions performed by the personnel, organisational units or technological systems [8].

An event building block is describing one particular action of one given actor. Actors can either be persons, group of persons or technical components. The building blocks are arranged in an actor-time diagram and the available data are interpreted at the level of these building blocks. These elements are added to the actor-time diagram, thus facilitating the progress of the investigation and the further collecting of information [6].

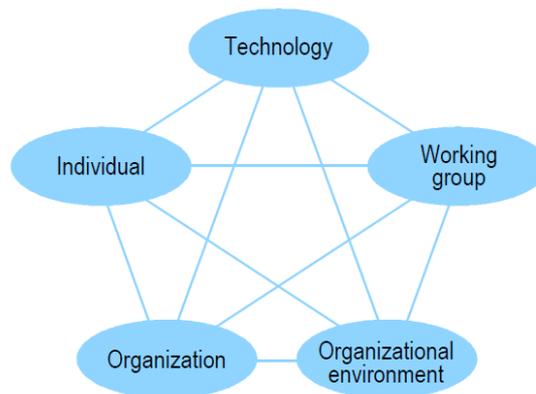


Figure 1. Socio-technical system model of event genesis [5].

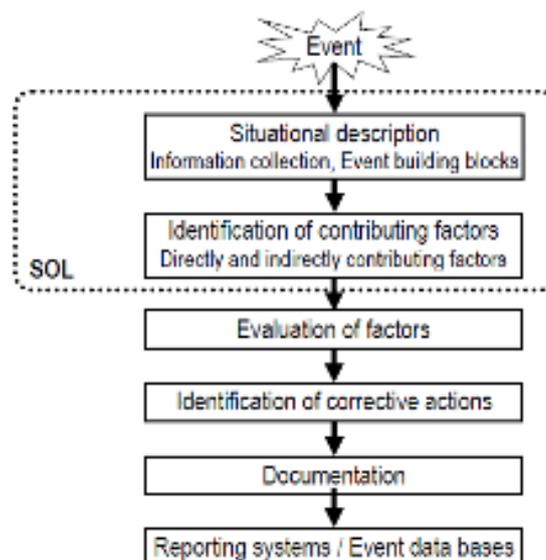


Figure 2. SOL & SOL-VE Analysis Procedure [6].

Analysing an event with SOL is conceptualised as a backward oriented problem-solving process which is presented in Figure 2. The SOL analysis means going through the steps indicated (Fig. 2) and usually takes three subsequent working days, requiring very intense and focussed work from the participating evaluators. While the pencil and paper version of SOL had already been successfully used also in civil aviation and in chemical process industry, SOL-VE has meanwhile been adopted by the Swiss and German nuclear industry as the standing operating procedure for event analyses [6].

## **AIM AND OBJECTIVES OF CITY EMERGENCY MANAGEMENT EXERCISE**

Cities worldwide are placing increasing importance on building up resilience to natural disasters, such as flood protection situation, caused by climate change. Smart cities can use rescuers and analytical capabilities to enhance and coordinate the information flow between emergency management and multiple actors, such as governmental authorities, emergency services and rescuers as a first responders, and citizens 0.

All relevant emergency management services which are necessary in a Smart City, in response to a major disaster, or unplanned event, including a simulated flooding exercise measures to public protection and property safety. Floods are the most common and widespread of all natural disasters—except fire. Most cities in Europe can experience some kind of flooding after spring rains, heavy thunderstorms, or winter snow thaws. Floods can be slow, or fast rising but generally develop over a period of days 0.

Disasters resulting from natural and man-made disasters, can have serious effects on cities and the areas they live in. It is therefore essential to ensure that emergency management systems are at all times ready to respond to crises in the most efficient manner, saving as many lives as possible and limiting damage to the environment and property. Emergency management exercises as part of the civil protection exercises are fundamental to prepare rescue teams to react fast and in a coordinated manner when disasters occur. Exercises at European level, involving a number of countries at a time [10]. Emergency Management, Themanagerial function charged with creating the framework within which communities (cities) reduce vulnerability to hazards and cope with disasters.

The goal of the EUWA exercise was to practice the process of requesting international assistance and responding to such a request after large scale floods in Hungary via the Union Civil Protection Mechanism. The following objectives were to be achieved:

- Verification and improvement of the procedures (alert, mobilization, deployment, etc.) of the participating intervention teams.
- Increased understanding of the Union Civil Protection Mechanism (including Host Nation Support Guidelines) deepened;
- Enhancement of the operational and coordinative cooperation amongst the intervention teams.
- Testing of the provision and receipt of civil protection assistance via the Union Civil Protection Mechanism (including communication and coordination with Emergency Response Coordination Centre).

In line with the aim and objectives of EUWA, the terms of reference of the Senior Exercise Evaluator, the provisions for exercise evaluation in the exercise instructions and in discussions with the Core Planning Group (CPG) of EUWA, the following areas have been preliminarily defined as the focus areas for the evaluation of EUWA. The evaluation focussed on three areas:

- existing coordination and cooperation tools, processes and procedures amongst the exercise participants, the exercise instructions and exercise information materials [9];

- systemic gaps, weaknesses and bottlenecks in the system of bi- and multilateral cross-border cooperation, interoperability and compatibility with special focus on floods within river basins [12]; and
- EUWA organisation and conduct (post-evaluation, i.e. after the end of the exercise).

The methodologies utilised are observation, analysis and recommendation (OAR), which enable the capture of ‘significant sub-events’ – using SOL terminology: “event building blocks” – with consideration of causal factors, responding actions and consequences providing outcomes for further development.

On-site and remote observation and interviews: Evaluators carried out physical and remote observations of organisations, modules, teams, staff and individuals undertaking their roles during the exercise. Evaluators assessed and documented the overall exercise structure and exercise conduct as well as the coordination and cooperation performance of the exercise participants based on the main objectives of EUWA without pinpointing individuals or specific organisations (unless explicitly requested to do so). Therefore, the focus was on processes and procedures.

## **USING THE SOL-ANALYSIS FOR EVALUATING EXERCISE**

### **FIRST STEP IN SOL-ANALYSIS**

SOL-methodology, as a proven tool for supporting organizational learning from safety relevant events means that an organization conducts systematic analyses of accidents, incidents or near misses and feeds the resulting experience back to its members using an appropriate reporting or management system. It was the first time that SOL-methodology was used for Evaluating a City Emergency Management Field Exercise by European Project Partners.

The conceptual framework of the analysis was that of the SOL as described in Section 1. For carrying out a SOL-analysis in our case it was inevitable to select an important, critical event (a decisive part of the exercise) the detailed analysis of which promised valuable experiences and learning possibilities. This selected event (situation) must later be decomposed into event building blocks so that the contributing factors belonging to these building block could be identified.

A short description of this selected event (situation) is as follows. On the 4th day of the whole exercise – on the 2<sup>nd</sup> day of the field exercise – at 13.00 hours a task was given to all the rescue teams (Hungarian, Slovakian, Serbian and Croatian team-members – about 200 persons altogether) to take part in the exercise: they had to prevent the BoO (Base of Operation) from being flooded using the method of building a sand-bag dyke-system. Due to the lack of effective protection, however, the BoO was “flooded” at 17.00 pm. Based on the experiences of the event, we were able to formulate development suggestions in the field of international assistance, to strengthen the EU Civil Protection Mechanism (EUCPM).

The 2-day-long SOL analysis required the presence and continuous work of seven selected experts as evaluators, so it was also important to select experts who are able to take part in the whole process and to be present on both days. The most frequently mentioned organizational safety gaps were found in the communication and its connecting areas, while the most important factors were those in connection with responsibility and regulations. After identifying the problems, the partakers – on the second day of the analysis – formulated their improving suggestions that support the future organizational learning process, thus leading to developing a more effective way of handling real disaster and exercise situations.

## **COMPONENTS IN TIME CONTEXT AND CONTRIBUTING FACTORS OF THE EVENT**

On the 1<sup>st</sup> day of the SOL-analysis the event (situation) chosen for analysis (problems rising during the process of international Base of Operation protection task) was decomposed into its components (event building blocks). Having identified these components, concerning each event building block we were seeking the answers to the following questions:

- **WHEN?** – The time of the event building block,
- **WHERE?** – The place/scene of the event building block,
- **WHO?** – The (main) actor(s) of the event building block,
- **WHAT?** – The action done by the (main) actor(s) during this event building block,
- **HOW?** – Description of the event building block, textual remarks on the actions.

At this early stage dealing with the **WHY** question was still definitely not allowed. As stemming from SOL method basic principles, it was an important criterion that all the way during the analysis consensual decisions be reached. This way the end product reflects the common and unanimous opinion of the seven evaluators. When recording the components, emphasis was put on the documents (log-book, end-report, photo and video documentation, radio conversation recordings) connected to the exercise. On the 2nd day the factors and the components of the event chosen for analysis were matched. The main question to be answered already was: **WHY** a certain event building block happened. All the participants were given a list of factors, which were grouped.

At this early stage dealing with the **WHY** question was not allowed. **WHY** questions are particularly relevant in the phase of analysis designed for identifying factors. The function of the early phase is description of events and situations. Following the basic principles of the SOL method, it was an important criterion throughout the analysis that a consensual decision be reached. This way the end product reflects the common and unanimous opinion of the seven evaluators. When recording the components, emphasis was put on the documents (log-book, end-report, photo and video documentation, radio conversation recordings) connected to the exercise. The seven participating evaluators of the analysis included the head evaluator, the Exercise Control (EXCON) of the exercise, organisers, heads and subordinates of the local commanding staff and the head of operations.

The phase relies heavily on earlier description of the situation, events. “One of the most important elements in identifying contributing factors are questioning data related to each and every event block. We need so-called “**WHY** questions” (Why he/she? Why then? Why there? Why that? etc.) because they help uncovering the extent to which events in event blocks occurred according to planning. When mismatch occurs compared to the planned or a more logical and safer solution, you have to find the contributing factor that most precisely covers the cause for the mismatch” [9].

## **IDENTIFYING CONTRIBUTING FACTORS AND EVALUATION**

The event building blocks finally were shown in chronological order in the actor-time diagram together with the contributing factors and their scores paired to them. After some debates the participants finally consensually decided to decompose the whole event into the following nine event building blocks.

1. European Union Civil Protection Team members were selected based on curriculum vitae template provided by the EU.
2. After communication nothing has happened for a long time.
3. Local Emergency Management Authority had not received information about spare capacity of international forces for 41 minutes.

4. The Slovak rescue team was not aware of the evolution of the situation on the base.
5. The danger the situation represented for the base, and the scale of the danger.
6. International forces did not start building the temporary protective system.
7. They considered that the information they received from the On Site Operational Coordination Center (OSOCC) was not credible.
8. Part of international teams did not bring standard protective gloves, so they requested protective gloves for 16 persons.
9. The Croatian team quit executing the task before completion.

The event building blocks finally were shown in chronological order in the actor-time diagram together with the contributing factors and their scores paired to them. After some debates the participants consensually decided to decompose the whole event into 9 event building blocks. For example, see 9<sup>th</sup> event in Tables 1 and 2.

**Table 1.** 9<sup>th</sup> event building block with 4W questions (BoO – Base of Operation).

WHEN?	WHO?	WHERE?	WHAT?	REMARK
17:00 05.04. 2017.	Flooding	BoO	BoO flooded	BoO flooded because of inappropriate system of flood defence (lack of sand bag dyke system).

**Table 2.** Evaluation of 9<sup>th</sup> event building block with weight numbers (E – Event, O – Organization, S – Summa).

CONTRIBUTING FACTOR	FACTOR	REMARK	E	O	S	Means	
The task given out by the LEMA was not carried out fully	Rule violation	Up to the time of the forecast floodwave (17:00) the sand-bag dyke system to protect the Base of Operation was not completed.  It was not possible to relocate the Base of Operation (due to lack of time and space).	5	3	8	<b>Event</b>	<b>5</b>
						<b>Org.</b>	<b>3</b>
						<b>Sum.</b>	<b>8</b>

Table 2 shows the analysis of the final critical event. It also shows that the exercise concluded almost without results because the simulation made it clear that in a real situation the base of operations would have been thoroughly flooded because of deficiencies in the structure of the protection system, thus endangering the lives of rescue teams and producing material damage. Teams refused to complete the given tasks because of deficient leadership. Instead of fulfilling their tasks, they continuously looked for objections and excuses on professional grounds.

### ANALYSIS OF THE CONTRIBUTING FACTORS AND THEIR VALUES

The participants matched 40 contributing factors to the 9 events building blocks, which means that to one event building block belonged 4,4 contributing factors on an average. Most often (11 times) it was the Communication factor, see in Table 3, which was chosen from all the factors by the participants. This means 27,5 % of all choices, which suggests that the identified problems most frequently are connected to certain kinds and forms of communication during the exercise. Responsibility and Organisation and management were also relatively often (4 times) chosen. The value of the event (E) indicates how much the factor in question contributes to the event itself. The organisational value (O) indicates how urgent the organisational measures to be taken are.

Table 3 depicts that – according to the opinion of the evaluators – although one can most often find Communication in the background of the problems, the average value of Responsibility

**Table 3.** The number of occurrence frequency and percentages of some main SOL-factors.

FACTORS	FREQUENCY	PERCENTAGES, %
Communication	11	27,50
Responsibility	4	10,00
Organization and management	4	10,00
Information	3	7,50

and Rules, regulations and Documentation is much higher. From the organisational values one can see that the latter 2 factors are very important organisational measures to be taken, so they will be reflected among the organisational development suggestions.

### SUGGESTIONS FOR MANAGEMENT MEASURES

City emergency management against flooding plays a vital role in overall flood protection. It can be divided into three stages:

- preparedness: pre-flood measures to ensure effective response;
- response and protection: measures to reduce adverse impacts during flooding;
- recovery: measures to assist the affected city to rebuild itself.

Preparedness includes the issuance of timely and effective early warnings and the temporary evacuation of citizens and property from threatened cities. Training in Exercise and public awareness; coordination among governmental and rescue teams (Fig. 3); effective stakeholder participation; and early warning systems are key components of preparedness planning [12].

Flood protection can be defined as the implementation of pre-planned activities during flooding to reduce the adverse impacts to the population at risk. Protection of critical infrastructure means, to remove citizens from facilities at risk, such as hospitals, schools, industrial sites, bridges, or houses of citizens (Figs. 4 and 5). City emergency management are expected to assess the immediate needs of affected cities, evacuate population in high-risk areas, mobilizing local rescue teams, take immediate measures to repair or restore damaged infrastructure.



**Figure 3.** International participants on EUWA field full scale exercise at Flood risk village of Szabolcsveresmart (Photo by DG ECHO).



**Figure 4.** Simulated Flooded House in virtual City and water rescuers as first responders (Photo by DG ECHO).



**Figure 5.** Map of the area after the dam failure at Simulated City of “Hunoria” in City Emergency Management Plan. Area for Field Exercise.

## CONCLUSION AND SUMMARY OF EVALUATION OF THE ANALYSIS

Using the method of the SOL-analysis, several hidden deficiencies of the exercise have been identified. They reported communication and the distortion of information as the most frequent reasons for problems. Besides these, they also identified the lack of responsible work as an even more serious problem. Bottlenecks regarding certain rules were also revealed.

The SOL-analysis as an evaluation technique in case of EU exercises, as it well serves the organisational learning of EU member states, thus contributing to safer living conditions of EU citizens. According Socio-technical system model, the purpose of the event analysis is to identify the real key individual, group or organisational human reasons for, and key technological factors of, the events that occurred. The SOL-methodology allows the identification of concrete alternative measures by which the probability that similar events occur in the future can be radically reduced.

The first time that SOL-methodology was used for Evaluating a City Emergency Management Field Exercise by European Project Partners. A city’s ability to respond effectively to natural disaster as a flood protection heavily depends on emergency management preparation for successful responses. Efficient to test the level of preparation of City Emergency Management holds a Field Exercise in vulnerable city. City emergency management requires understanding different flood scenarios that may require adaptive situational management actions 0. City Emergency management requires cooperation across different responders and administrative levels horizontally and vertically.

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# ONLINE SELF-DISCLOSURE THROUGH SOCIAL NETWORKING SITES ADDICTION: A CASE STUDY OF PAKISTANI UNIVERSITY STUDENTS

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## ABSTRACT

Social networking sites provide a virtual platform for socialization, interaction, and entertainment. The overuse of social networking sites has become a global phenomenon, especially among young generations. The purpose of this study is to investigate the addiction elements of social networking sites and the impact of such an addiction on online self-disclosure. Additionally, the moderation effect of openness and extraversion was also analysed. Data from university students in Pakistan was gathered online using the Google survey application. In total 290 samples were gathered and examined. SPSS and AMOS software programmes were used to analyse data. Findings confirmed that young generations tend to have greater online self-disclosure due to social networking sites addiction. Both moderation results also showed a significant relationship between social networking sites addiction and online self-disclosure. The results of the current study are also used as a guideline for making policies related to social networking sites addiction.

## KEYWORDS

entertainment, socialization, student, Pakistan, social networking

## CLASSIFICATION

JEL: O35

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## INTRODUCTION

Social networking sites (SNS) is a virtual platform, where visitors communicate, update status, post, and interact with several friends. SNS (e.g. Skype, Viber, Twitter, and Facebook) have attracted millions of users around the world including Pakistan. People easily connected using the applications of SNS with friends, relatives, and business persons all over the world. Due to the popularity of SNS in a globe, developing countries are at the forefront. In the perspective of Pakistan SNS is receiving distinction every day. Pakistani young generation and university students spend most of the time on SNS. Specifically, Facebook is currently the most utilized SNS in Pakistan with 9 million users in the nation. In April 2013, Pakistani Facebook users reported about 30% female and 70% male, in which most of them were young generations [1]. The past survey reported that about 24% of the young generation constantly online [2]. Surveys of several countries also indicated that SNS usage based on regional and cultural trends. Similarly, evidence from prior research studies confirmed that Pakistani youth spend most of the time on Facebook to communicate with friends, relatives, and posts different updates [3, 4]. Recently, only a few scholars highlighted the factors of excessive use of SNS in Pakistan [1, 3, 5]. Specifically, Ali [1] examined the effect of SNS use on youth and change in family relations. Kanwal, Chong [3] (2018) highlighted the SNS addiction elements. Khan [5], investigated the impact of SNS use on student academic performance. Therefore, it is necessary to understand and identify the influencing factors of SNS use, which develops addictive behavior in adults towards social networking sites.

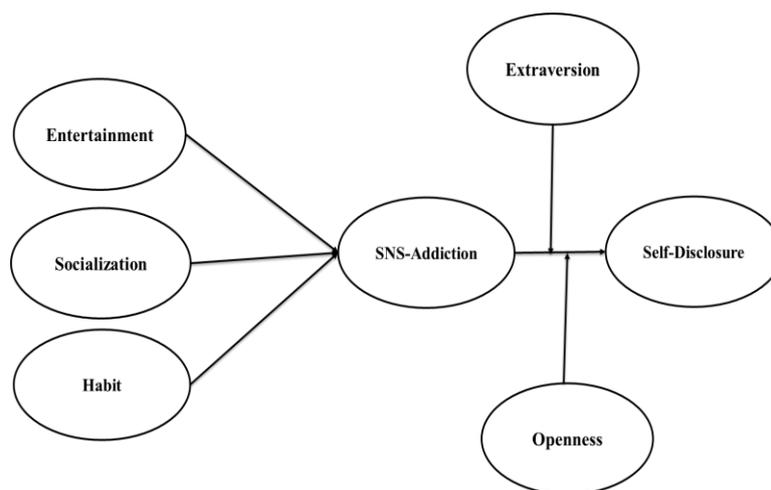
The excessive use of SNS has led the researcher to investigate the factors, which makes user addictive. Indeed, several users use social networking into their daily routines. For example, socialization, enjoyment, chatting, video calling, posting, updating status and comments on another status [2], and these features led users addictive of SNS. SNS addiction is outlined as overusing of SNS or consume most of the time on social networking [6]. In recent years, a plethora of literature on SNS addiction has been published because of its excessive usage. Recently, 1.28 billion users of Facebook has been reported in March 2017 [7]. Similarly, another research indicated that time spends on Facebook by young generation has increased from 40 min to 50 min from 2014 to 2016 [8]. Prior studies related to SNS addiction have highlighted a number of factors such as social, and psychological predictors of SNS addiction [9, 10], the relationship between excessive use of SNS, and psychological problem [11, 12]. Specifically, studies based on predictors of SNS. In addition past studies also reported that adult is addictive of SNS [13]. Several factors have been reported in relation to SNS addiction. For example, young generation chatting with friends and family members, academic purpose, posting updates, reading news. Given the attractiveness of SNS and their importance in young generations' lives, it is necessary to evaluate and identify the primary factors and significance that promoting SNS usage, especially at greater levels such as socialization, habit, and entertainment with using SNS.

Despite the several well-documented advantages of social media [14], scholars suggest that people use SNS for socialization, entertainment, and another work purpose [15-18]. Specifically, the user describes their personal information such as cultural information, demographic information, education and hobbies [17], they also post photos and making online-self-disclosure. According to past study, self-disclosure is the way of presenting self-information to others [19], which can enhance the familiarity among individuals [20]. Online self-disclosure refers to present self-information on SNS such as posting message, pictures and posting real-life stories [21]. Compare to face to face interaction, SNS interaction is extremely anonymous, and less visual which cause everyone to disclose important information on SNS [22]. As SNS functions as an outlet for online self-disclosure [23]. In

addition, SNS users not only expressing personal information but also posts or disclose the information of their friend, and family members [24]. Therefore, to examine the effect of SNS addiction on online self-disclosure is necessary and interesting.

Several scholars have investigated the SNS usage and personality traits of young adults [17]. Personality traits are defined as internal characteristics that shows the individual behavior or attitude [25]. For instance, Klein, Lim [26] argued that openness influences the scores in social networks. Similarly, Ishiguro [27] investigated the influence of openness and extraversion on social network friends. Back, Stopfer [28], also verified that SNS profile of user reflects the user personality traits because SNS consists user's personal information regarding personalities such as self-disclosure, appearance, friends and other factors around the environment. Extraversion feature describes users who are sociable, and cheerful. Openness describes users who are curious, and unconventional. SNS features enable users to create a profile and communicate with real-life friends in the virtual environment [29]. Moreover, SNS has been considered digital platform to pour personal information or experience on SNS. Therefore, its necessary to investigate the user personality attributes as a moderaror and provide evidence related to the SNS addiction and online-self-disclosure.

The purpose of the current study is to extend our understanding of SNS addiction and its related factors on online self-disclosure. In addition, this study also examines the moderating role of openness and extraversion, two characteristics of a big-5 personality trait. Additionally, current research study also further examines whether socialization, habit, and entertainment related to SNS addiction and predict the online self-disclosure with the relationship of SNS addiction. There are several theoretical contributions of this study. First, the author highlighted the factors, which led the user toward SNS addiction. Second, the current study contributes to the emerging body of literature about SNS addiction by providing the advance knowledge and support for the impact of SNS addiction on online self-disclosure. Third, this study considers the moderating role of personality traits. As users are interested in expressing personal information on SNS such as photos, status, location, and hobbies. Figure 1 shows our conceptual diagram, which will be developed in the following sections.



**Figure 1.** Research model.

This research study is organized as follows. Section 2 explains the relevant literature and hypothesis development. Section 3 describes the research methodology including data collection procedures, measurement items. Section 4 shows the results of data analysis together with moderation and mediation tests. Section 5 is a discussion section. Section 6 consists of a theoretical contribution. Finally, Section 7 explains the limitation of the study.

## **THEORETICAL BACKGROUND AND HYPOTHESES DEVELOPMENT**

### **ONLINE SELF-DISCLOSURE**

According to literature self-disclosure is an act of expressing personal information to others such as location, hobbies, and photos [22, 30]. Online self-disclosure is defined as the way of expressing self-related information to others on SNS [22]. Any personal information that can be regularly checked, update status/posts using SNS can be treated as self-disclosure [21]. SNS promotes the online self-disclosure [30], an anonymous visitor also analysis the pictures, posts, status and develop an opinion on your behavior in different ways. According to social penetration, theory self-disclosure is a fundamental concept in developing and maintaining relationships with others. Individual disclose their thoughts, experience, relationship status and fears in SNS. Adolescents disclose self-information with their friends on SNS.

Scholars have also explored self-disclosure on SNSs [22, 31-33]. Specifically, Chen and Hu [22] investigated the use of Sina Weibo, Chinese social media application. on self-disclosure and found that individual with high anxiety discloses less information as compared to others. Liu and Min [32] conducted study microblogging users of China and investigated the relationship between social benefits and online self-disclosure. Wang and Yan [33] examined the antecedents of online self-disclosure and online self-disclosure honesty. Zlatolas and Welzer [31] discussed the privacy issues related to self-disclosure and proposed a research model which consists of privacy awareness, policy, and control. Theoretical work suggests that SNS attracted the individual with personalized information, as its human nature peoples are very interested in getting information about others, though, this type of behavior also leds them towards SNS and they express their personal-information on SNS [34]. Therefore, the aim of this study is to explore the SNS addiction impact on self-disclosure in Pakistani youth context.

### **SNS-ADDICTION**

According to scholars, social media is a group of digital technologies, which facilities individual, groups to communicate, share, and discuss information generated by other users [35, 36]. Due to the flexible environment, open platform, and easy use of social media technologies individual become habitual users of social networking and want to remain online every time. This type of user behavior of using social media called SNS addiction or social media addiction. Like many other countries of the world, SNS become popular activity in Pakistan, especially in young generations. Specifically, SNS addiction means to utilize most of the time on social networking. It is defined as unnecessary association with SNS activities or overuse of SNS with different activities [37].

Social Networking Sites consists of virtual communities where an individual can create public profiles, communicate with real-life friends, and interact with other users based on mutual interest [38]. As a growing concern over the excessive use of SNS, scholars are interested in its causes and consequences of this behavior [16]. Despite rising interest in SNS addiction, few scholars knew about its consequence on self-disclosure [23, 32, 39]. Though these studies have increased our understanding of SNS addiction from numerous perspectives, research related to SNS addiction is in developing stage because it requires testable theories that clarify how SNS addiction influences the online self-disclosure. Therefore, investigating the influence of SNS addiction on online self-disclosure in the current study is an attempt to address this research gap in the SNS addiction literature.

### **ENTERTAINMENT, SOCIALIZATION, HABIT AND SNS ADDICTION**

SNS activities help the individual to fulfill the individual needs like to develop and maintain social relations with other people, interact and socialize with online friends. Research on SNS

suggests that SNS satisfies socialization needs of individuals [40], make it more likely that they are participating in real life. People use SNS application for a wide range of socialization purposes such as broadcasting messages to all contacts, information-sharing and commenting on others post or status. Individual easily interact, communicate, exchange ideas, and information with other using several online communication platforms including social communication channel (e.g. Facebook and Twitter), multimedia channel (Instagram, Dailymotion and YouTube) [41, 42]. Additionally, compared to their parents, young generations have extra capability of using SNS such as Facebook, and Twitter which arises their possibility of SNS addiction and encourages the interest of scholars to adolescent SNS addiction [43].

Recently some emerging features of SNS including entertainment, online gaming, online quiz competition motivate the young teenagers towards SNS. Specifically, entertainment [44] features is a key intrinsic motivator of SNS. Any activity on SNS that attracts the audience attraction and maintain their consternation and interest is known as entertainment [45]. According to scholars, individual use SNS for entertainment, as they hope that entertainment on SNS relieves their stress [46]. Similarly, a past study has shown that entertainment significantly influences the user's attitude, and increases their intention to use digital technologies [47]. Kim, Kim [48] also argued that hedonic motivation (entertainment, fun) is positively related to smartphone addiction.

Numerous prior literature has validated the arguments that several activities on SNS such as entertainment, socialization make the user habitual or addictive [38, 49-51]. Psychology literature conceptualized habit as "learned sequences of acts that have become automatic responses to specific cues". The habit of SNS, therefore, play a key role in continuing of using SNS. In prior research habit variable widely used by social media scholars [52-54]. Venkatesh, Thong [55] argued that habit was significantly associated with the user's intention to use mobile internet. Specifically, this habitual behavior of users towards technology convert in addiction. In the perspective of SNS, initially user uses SNS for entertainment, usefulness, and socialization purpose and become habitual or addictive. Theoretical work suggests that socialization, and entertainment through SNS motivates users towards SNS addiction. Based on theoretical argument, this study proposes the following hypotheses:

**H1:** Entertainment on SNS is positively associated with SNS addiction.

**H2:** Socialization on SNS is positively associated with SNS addiction.

**H3:** Habit of SNS is positively associated with SNS addiction.

## **THE MEDIATING ROLE OF SNS ADDICTION**

SNS usage refers to a virtual environment, where individual interact, exchange, communicate and maintain a social relationship with other for entertainment and socialization purpose. Specifically, young adults are addictive users of SNS and habitual sharing their life experience, ideas, and touch with old friends and family members [56]. For instance, a past study indicated that young generation engaged with online self-disclosure with their friends using digital technologies [57]. Consistently, scholars argued that Facebook can enhance the chances of self-broadcasting and increases the socialization with other friends [58]. Based on the past investigation, a recent research has contended that SNS (instant messenger) can increase German users self-disclosure [59]. In the world of technology, individual use SNS simultaneously and broadcast themselves in the globalized world, the opportunities for users to present themselves, their pictures, ideas have established dramatically. Self-disclosure on SNS provides several benefits such as interaction, relationship building, and self-presentation [60, 61].

Kizgin and Jamal [51] claimed that expressing self-information on SNSs is essential for building social communication with others. Substantial evidence has also documented the

significant link between SNS addiction and online self-disclosure [62, 63]. Studies related to self-disclosure on SNS proposed that people often disclosed a large amount of information on SNS [3, 32, 60]. Considering the past literature, it is likely to argue that SNS (Facebook) communication or interaction can enhance the Pakistani university student's online self-disclosure. Agreeing with past literature, this study outline the following hypotheses:

**H4:** SNS addiction is positively associated with the online self-disclosure.

**H5:** SNS addiction mediates the relationship between Entertainment, Socialization, and Habit with online Self-Disclosure.

## **THE MODERATING ROLES OF EXTRAVERSION AND OPENNESS**

Due to the success of SNS, researchers investigating the link between SNS and personalities of the user [17, 25, 27]. Personality traits are natural individual characteristics [64], which representing how a person may approach and answer to wide-ranging circumstances during their lives. Theories related to personality traits demonstrated the wide range of human activities on SNS such as SNS addiction, and student behaviors [65, 66]. Majority of scholars propose Big Five personality traits which included conscientiousness, neuroticism, agreeableness, extraversion, and openness [67]. This study includes openness and extraversion of the big five into the research design.

Openness to experience personality trait individual is knowledgeable, and always generate new ideas [68]. Skues and Williams [69] proposed that individual with high openness communicate through SNS to discuss interests. The openness element is an essential feature of personality traits that are related to human preferences modes [70, 71]. For example, past related literature has suggested that openness individual preferences online interaction, communication for numerous purpose such as online self-disclosure, relationship building and have more positive attitude towards innovative contents. Several literature, suggests that, heavier users of SNS associated with higher degree of openness to experience [72, 73]. Literature also suggests that, heavier users of SNS associated with higher degree of openness to experience. High openness individual is reflected novelty-seeking such as SNS are emerging application of the internet. Therefore, it is assumed that individuals who is more openness to experiences would more user of SNS and have an experiment of expressing self-information on SNS such as self-disclosure.

Extraversion trait associated with the interaction, fun activities, and talkative which enable individual to update status, broadcast self-information and addictive user of SNS [74]. Literature suggests that extravert's person will involve mostly in online social activities such as commenting on other posts, status updates, and online self-disclosure. Ross, Orr [72] investigated the association between SNS (Facebook) usage and personality traits and reported that extraverts persons are an addictive user of Facebook for interaction and social relationship. Similarly, Ishiguro [27] examined the link between extraversion and number of friends on SNS and found that extraverts persons have more friends on SNS. Extroverts individual are motivated to keep the friendship, social interaction with offline and online friends [24]. For instance, an extrovert person on SNS (Facebook) expressing more self-information, online self-disclosure and less share information about their friends. Relating to past literature support, this study suggests the following hypotheses:

**H6:** Openness positively moderates the relationship between SNS addiction and Self-Disclosure.

**H7:** Extraversion positively moderates the relationship between SNS addiction and Self-Disclosure.

## RESEARCH METHODOLOGY

### SAMPLES AND DATA COLLECTIONS

In order to achieve the objective of study a survey method was used. The respondents of this study from Pakistan and student of different universities. An online survey website was used to collect data from university students from Pakistan. The study focused on 5 different universities of Pakistan (Mehran University, Sindh University, Shah Abdul Latif University, NED and Karachi university). We collected data from university students and Pakistan for several reasons. First, Social networking is popular technology among students, as students used social networking for various purpose such as academic, entertainment and leisureliness. Second, this study was conducted in the Pakistani context, as Pakistan is a developing country in terms of technology and economy. There is no any policy implemented by government's officials to control the excessive use of social networking as compared to other developed countries. To make a clear understanding of survey questionnaire authors did several jobs. First, survey questionnaire was reviewed by 3 different management Professors. Second, a focus group study was arranged with 10 Ph.D. student who expert in survey design. Third a pilot study was conducted with 40 respondents and findings was found satisfactory. We eliminated these 40 respondents from final dataset.

To increase the response rate author also requests the professors of concerned university to share the link among students. In addition author also used social media application such as Facebook, Whatsapp, and Twitter to share the survey link among students. Within a period of four weeks, we received 290 samples. Due to the online nature of questionnaire, we did not found any incomplete or missing data in the dataset. Information about the samples is shown in Table 1.

**Table 1.** Information about samples.

		<i>N</i>	Percentage
<b>Gender</b>	Male	186	64,1
	Female	104	35,9
<b>Age</b>	≤ 30 years	191	65,9
	30-40 years	90	31,0
	40-60 years	9	3,1
<b>Education</b>	Bachelors	74	25,5
	Masters	170	58,6
	Ph.D.	44	15,2
	Currently not enrolled in further education	2	0,7
<b>Total</b>		290	100

### INSTRUMENTS AND SCALES

The research model of this study consists of 7 different constructs. All the variables were adopted by prior studies. Questionnaire was scored by using 7-point Likert scale, and was arranged by "strongly disagree" (1) and "strongly agree" (7). The constructs for research model were entertainment, socialization, habit, SNS addiction, personality (Openness, extraversion), and self-disclosure. The measurement items of entertainment were adopted by [75, 76]. The scale consists of 5 items and was measured in terms of use social networking for entertainment purpose such as gaming, watching movies, and sharing funny post or videos on walls. The scale of socialization consists 3 items and scale was adopted by [75, 77]. The instrument of socialization was assessed in terms of the use of social networking for socialization purpose

such as making friendship, chatting, developing new online friends and keep in touch with existing friends. The scale of habit consists 3 items. The measurement items and scales of habit are adapted from [78]. The measurement instrument of SNS addiction was measured from [79]. The SNS addiction items contain 5 items and were measured in terms of excessive use of social networking. The scale of personality was adapted from [80]. In this study, we adopted 2 factors of personality from Big 5 personality model such as openness and extraversion. The scale consists of 3 items of each factor and measured in terms of human personality and its effect on the use of social networking and online self-disclosure. The measurement scale of online self-disclosure was assessed from [81, 82]. The scale contains 10 items in total and measures in terms self-disclosure with use of social networking. In this study, we measured three control variables, i.e. sex, age, and education level. At the individual level, we controlled for gender, age, and educational level, that may influence student behavior [83].

## **DATA ANALYSIS AND RESULTS**

### **ANALYSIS OF BIAS**

The data in the existing study were perceptual and collected from a single source at one point in time, which is an obvious way to control common method bias [84]. Using Harman's single factor strategy, the outcomes specifies that 21 constructs have eigenvalues greater than 1, accounting for 92,87 % of the difference. The first construct explains 34.85% of the total variance, which is less than 50 %. Another evidence of common method bias existence, if ( $r > 0,90$ ) is in the intercorrelation matrix. Results of Table 3 indicate that intercorrelations of all the constructs are within range. Therefore analysis results did not reveal the evidence for any possible issue of bias in this dataset.

### **VALIDITY AND RELIABILITY**

In this study, we used SPSS 21.0 software to measure the validity and reliability of data. First, exploratory factor analysis (EFA) was computed using SPSS software. The findings confirmed that loadings of each item were greater than the minimum value 0.60, which support the proposed research model. In the reliability test, Cronbach's alpha (CA) was ranged from 0,80 to 0,92, were higher than the values of 0,70 as shown in Table 2, which is proposed by [85], indicating the good reliability of the scale. Table 3 indicates that all the values of composite reliability (CR) from 0.83 to 0.93 and also above the minimum value of 0,70 which is proposed by [86], showing that all the items in research model are reliable. All the average variance extracted (AVE) values from 0,55 to 0,81 which were above the minimum value of 0,50 which is proposed by [87], indicating the good convergent validity of the research model. Therefore all the analysis results validated that the research model had good convergent validity.

Further, we computed the decrement validity of research model in several ways. First, we analyzed the discriminant validity of the constructs by comparing shared variances among constructs. Table 2 indicates that all the values of  $MSV > ASV$ . Secondly, we compared the square roots of the AVEs for all constructs with inter-correlation matrix and found that square root of AVE of all the constructs was greater than the correlations between variables [88], as shown in Table 3. Therefore, in summary, we concluded that the research model possessed good validity, and reliability.

Along with the reliability, validity tests, variance inflation factor (VIF) is also computed. Findings indicate that VIF values for all the variables are below the threshold of 10 which suggested that there is no multicollinearity issue in the dataset [89]. The results indicated that

**Table 2.** Results of confirmatory factor analysis. AVE – average variance extracted, CA – Cranach’s alpha, CR – composite reliability, MSV – Maximum Shared Variance, ASV – Average Shared Variance, Discriminant validity: AVE > MSV.

Items	Items	Loading	CA	CR	AVE	MSV	ASV
Entertainment	5	0.778-0.899	0.84	0.87	0.70	0.22	0.16
Socialization	3	0.646-0.871	0.88	0.90	0.64	0.43	0.16
Habit	3	0.755-0.807	0.80	0.83	0.62	0.39	0.19
SNS-Addiction	5	0.637-0.875	0.86	0.86	0.56	0.43	0.18
Openness	3	0.890-0.914	0.92	0.93	0.81	0.17	0.11
Extraversion	3	0.859-0.933	0.90	0.93	0.82	0.13	0.09
Self-Disclosure	10	0.694-0.876	0.91	0.92	0.55	0.39	0.20

**Table 3.** Mean, standard deviation and correlations. NA – not applicable. Mean is assessed based on average factor scores, standard deviation (SD) and correlations are from the second-order CFA output. The diagonal elements are the square root of the AVE.

Variable	M	SD	1	2	3	4	5	6	7	8	9	10
1) Self-Disclosure	4.11	0.81	<b>0.74</b>									
2) SNS-Addiction	5.15	1.35	0.41	<b>0.74</b>								
3) Socialization	5.19	1.43	0.37	0.65	<b>0.80</b>							
4) Habit	5.73	1.19	0.62	0.36	0.36	<b>0.78</b>						
5) Entertainment	5.20	1.53	0.46	0.45	0.41	0.46	<b>0.83</b>					
6) Openness	5.30	1.36	0.38	0.24	0.22	0.38	0.31	<b>0.94</b>				
7) Extraversion	5.23	1.32	0.35	0.26	0.22	0.35	0.26	0.27	<b>0.90</b>			
8) Education Level	NA	NA	0.17	0.01	0.03	0.13	-0.04	0.08	0.11	NA		
9) Age	NA	NA	0.20	0.06	0.02	0.16	0.03	0.08	0.11	0.41	NA	
10) Gender	NA	NA	-0.35	-0.32	-0.29	-0.34	-0.27	-0.13	-0.11	-0.15	0.36	NA

\*statistically significant at 5 %  
 \*\*statistically significant at 1 %  
 \*\*\*statistically significant at 0,1 %

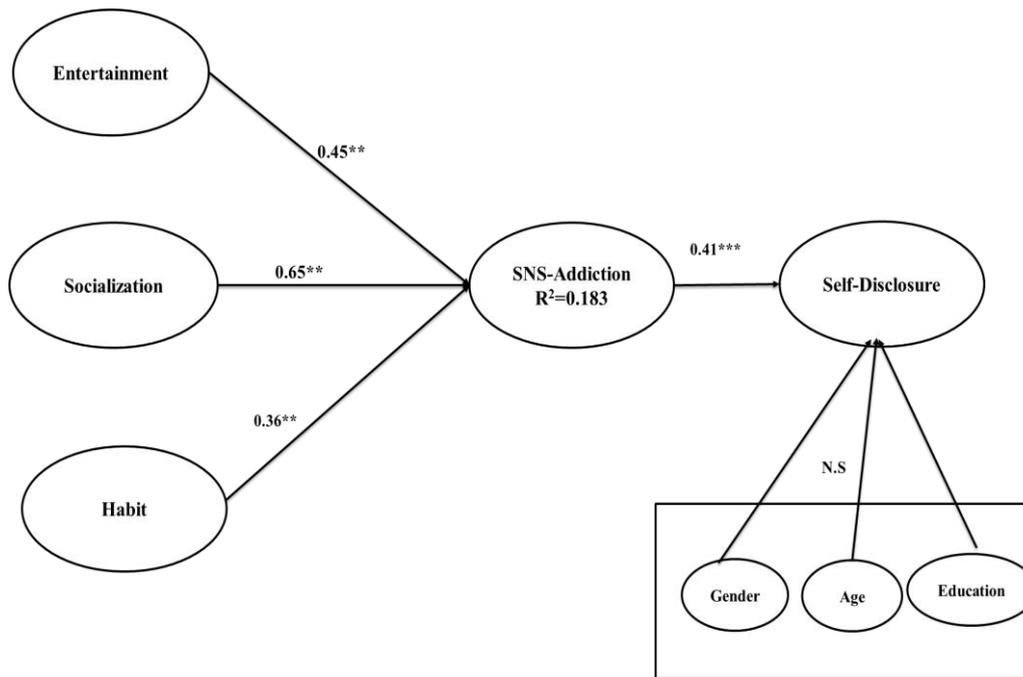
the maximum VIF value was 1.92 and the lowest tolerance value was 1.23, Therefore multicollinearity is not a significant issue in this study [90, 91].

**MEASUREMENT MODEL**

Next, AMOS software was employed to compute the goodness of fit measurement model and also to assess the significance degree of the proposed hypothesis. According to scholars, some model fit criteria must be measured to evaluate the model fit in SEM [92]. These factors are the Comparative Fit Index (CFI), Tucker-Lewis Fit Index (TLI), and Root Mean Square Error of Approximation (RMSEA) and Chi-square ( $\chi^2/df$ ). The results of this study indicates that in structural model, the approximate values are  $\chi^2/df = 2.23$ , CFI = 0.91, TLI = 0.90, IFI = 0.94, SRMR = 0.05, RMSEA = 0.06 which are within threshold values and are acceptable in this sample size.

**HYPOTHESES TESTING**

After suggesting the validity of research model, hypotheses were analyzed. Results in figure 2, shows that proposed hypotheses were validated. The findings indicates that entertainment ( $\beta = 0.45, p < 0.001$ ), socialization ( $\beta = 0.65, p < 0.001$ ), and Habit ( $\beta = 0.36, p < 0.001$ ) have a positive and significant effect on SNS addiction, thus H1,H2, and H3 is supported. In addition,



**Figure 2.** Results for structure model. Here \*\* denotes statistical significance at 5 % and \*\*\* statistical significance at 0,1 %.

the findings of SNS addiction ( $\beta = 0.41, p < 0.001$ ), shows that it has a positive significant effect on self-disclosure, which authenticated the hypothesis H4. In summary, findings confirmed that H1, H2, H3, and H4 is confirmed in this stage.

### Mediating Effect Test

In the current study, H5 has suggested the mediating effect of SNS-addiction with the relationship between entertainment, socialization, habit and the online self-disclosure. For that purpose, we employed the bootstrap sampling techniques (bootstrap sample size = 5000) as suggested by MacKinnon, Lockwood [93]. We test the mediation relationship of SNS-addiction with independent variables and dependent variables, Table 4. SNS-addiction mediates the relationship between entertainment and online self-disclosure because CL (0.040, 0.166) exclude zero. SNS-addiction mediated the relationship between socialization and online self-disclosure because CL (0.071, 0.257) did not contain zero. Same way SNS-addiction mediated the relationship between habit and online self-disclosure because the CI (0.030, 0.120) did not include zero. Hence, proposed H5 is validated.

**Table 4.** Results of the bootstrapping method for mediation. IV= Ent = Entertainment, Soc = socialization,, DV = SD – Self- Disclosure, MV = SNSA – SNS addiction.

IV	M	DV	Effect of IV on M (a)	Effect of M on DV (b)	Direct effect (c')	Indirect effect (a·b)	Total effects (c)	95 % CI	Result
Ent	SNSA	SD	0.421**	0.235*	0.304**	0.099**	0.403**	(0.040, 0.166)	Supported
Soc	SNSA	SD	0.636**	0.271**	0.168**	0.051	0.172**	(0.071, 0.257)	Supported
Habit	SNSA	SD	0.344**	0.201**	0.300**	0.069**	0.550**	(0.030, 0.120)	Supported

\*statistically significant at 5 %  
 \*\*statistically significant at 1 %  
 \*\*\*statistically significant at 0,1 %

### Moderating Effect of Openness and Extraversion

H6 and H7 suggested the moderating role of extraversion and openness. Scholars suggested hierarchical regression one of the most important tool for examining the interaction effect because it enables to enter the constructs order by their key significance [94]. Thus, hierarchical regression analysis was used to test the moderating effect of extraversion, and openness in this study, as shown in Tables 5 and 6. First, we analyzed hierarchical regressions for the dependent variable online self-disclosure with the relationship of independent variable SNS-addiction and moderator openness. Step,1 included only the control variables. The findings suggested that the control variables were not significant. In step 2 independent variable SNS-addiction effect was tested with dependent variable online self-disclosure. The results suggested that SNSA has a positive effect on self-disclosure with ( $\beta = 0.31, p < 0.001$ ).In step 4 moderator openness was tested. Finding verified that openness has a significant effect on the ( $\beta = 0.28, p < 0.001$ ).Finally, step 4 interaction terms (SNS-addiction·openness) was analyzed. The interaction results also significant with ( $\beta = 0.10, p < 0.05$ ) In sum, Openness variable positively moderates the relationship between SNSA and self-disclosure. Thus, H6 was validated.

**Table 5.** Results for hierarchical regression analysis (Moderator is Openness).

Variable	Model 1	Model 2	Model 3	Model 4
Gender	-0.36**	-0.25**	-0.24**	-0.23**
Age	0.17*	0.15*	0.13*	0.14*
Education level	0.09	0.10	0.88	-0.08
<b>Main Effects</b>				
Social Networking Sites Addiction (SNSA)		0.31**	0.25**	0.26**
<b>Moderator</b>				
Openness			0.27**	0.28**
<b>Interactions</b>				
SNSA* Openness				0.10*
R <sup>2</sup>	0.18**	0.27**	0.34**	0.35*
Adjusted R <sup>2</sup>	0.17**	0.26**	0.32**	0.33*
F Change	21.33**	35.30**	29.24**	4.68*

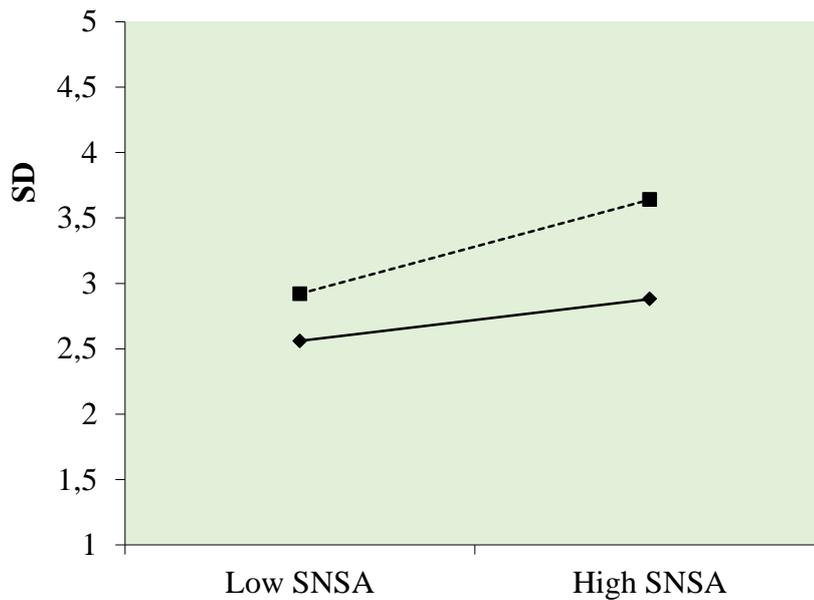
\*statistically significant at 5 %

\*\*statistically significant at 1 %

\*\*\*statistically significant at 0,1 %

In addition, we used the graphical procedure, to understand the moderation effect of openness as suggested by [95]. Figure 3 illustrated that openness positively moderate the relationship between SNSA and self-disclosure.

Next, we examined the hierarchical regressions for the dependent variable online self disclosure with the relationship of independent variable SNS-addiction and moderator extraversion. Step,1 entered all the control variables and found that control variables are insignificant. In step 2, SNS-addiction effect was analyzed with dependent variable online self-disclosure. The results suggested that SNSA has a positive effect on self-disclosure with ( $\beta = 0.31, p < 0.001$ ).In step 4 moderator extraversion was tested. Findings verified that extraversion has a significant effect on the ( $\beta = 0.23, p < 0.001$ ). Finally, step 4 interaction terms (SNS-addiction·extraversion) was analyzed. The interaction results also significant with ( $\beta = 0.15, p < 0.05$ ). In sum, extraversion variable positively moderates the relationship between SNSA and self-disclosure. Thus, H7 was validated.



**Figure 3.** Moderating effect of openness on the relationship between SNS-addiction and self-disclosure. Full (dashed) line denotes low (high) Openness.

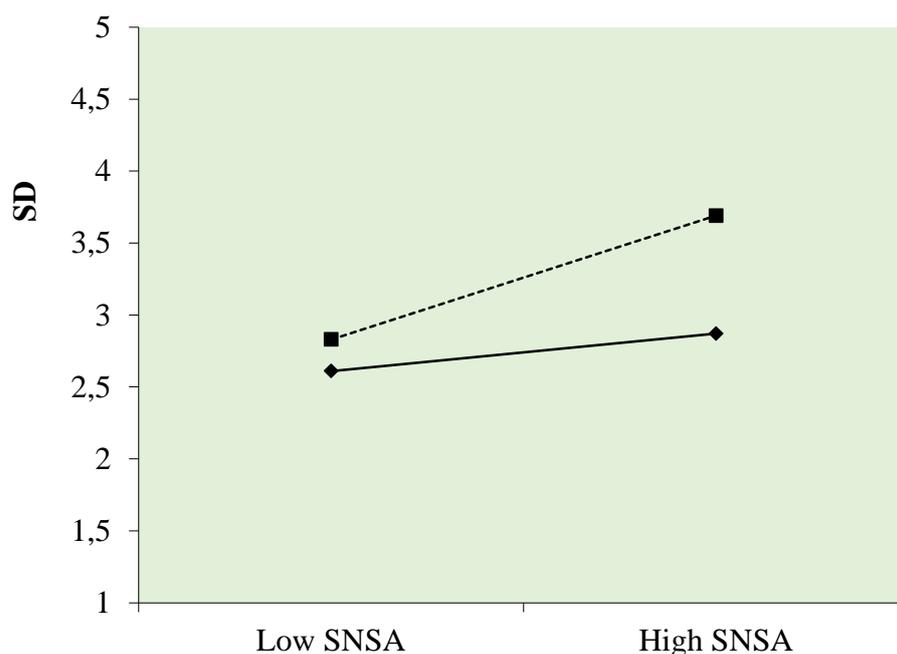
**Table 6.** Results for hierarchical regression analysis (moderator is extraversion).

Variable	Model 1	Model 2	Model 3	Model 4
Gender	-0.36**	-0.25**	-0.25**	-0.24**
Age	0.17*	0.10*	0.13*	0.15*
Education level	0.09	0.116*	-0.08	-0.07
<b>Main Effects</b>				
Social Networking Sites Addiction (SNSA)		0.31**	0.26**	0.28**
<b>Moderator</b>				
Extraversion			0.23**	0.26**
<b>Interactions</b>				
SNSA* Extraversion				0.15*
R <sup>2</sup>	0.18**	0.27**	0.32**	0.34*
Adjusted R <sup>2</sup>	0.17**	0.26**	0.31**	0.33*
F Change	21.33**	35.30**	21.09**	9.177*

In addition, we used the graphical procedure, to understand the moderation effect of extraversion as suggested in [95]. Figure 4 illustrates that extraversion positively moderate the relationship between SNSA and self-disclosure.

## DISCUSSION

The purpose of the current study is to explore the factors which lead the user towards SNS addiction. Findings suggested that socialization, habit, and entertainment on SNS are main causes of SNS addiction, which are according to our assumption. As this study proposed in H1, H2, and H3 that socialization, habit, and entertainment is positively related to SNS addiction, this analysis also consistent with several past studies. For example, scholars, also reported that SNS is an open public platform and provides several functions including chatting, socialization, and posting [2, 38], these features attract the users towards social networking, individual become habitual of SNS. Andreassen [96] also found that 24 % to 35 %



**Figure 4.** Moderating effect of extraversion on the relationship between SNS-addiction and self-disclosure. Full (dashed) line denotes low (high) Extraversion.

of Asian students were addictive of SNS. Similarly, Junco [97] found that young generation spends about 100 min/day on SNS with different activities. As this study also conducted in Pakistan and majority of the respondents of this study are students of Pakistan, who studied in different universities with different age groups. The majority were a young generation from 21 to 30 years old. Results validated that young adults especially students are more inclined toward SNS due to its leisure activities, such as socialization, entertainment, usefulness, and its flexible platform. Several universities provide fast, free internet on campus, classrooms, and dorm, students easily can access Wi-Fi with smart mobile phone devices everywhere, this type of facilities led to students, young generation to SNS addiction. As Pakistan is a developing country in terms of technology, government authorities did not implemented any policy related to excessive use of social networking as compared to developed countries. For example, Chinese government authorities has implemented some rules in the country on SNS [32], and most of the public social networks are blocked in China. However, Liu, Min [32] also reported usage of microblogging and self-disclosure.

This study also proposed mediating effect of SNS addiction with the relationship of socialization, environment, habit and online self-disclosure in H4 and H5. Results confirmed that SNS addiction mediates the positive relationship with SNS addiction elements and self-disclosure. These results document that SNS addiction could led young generations towards the online self-disclosure and these results also reported by prior research studies [63, 98]. This link may be attributable to the truth that on SNS, individuals who express their thoughts, posts, hopes, and hobbies would obtain essentially more attention of friends and family members. Therefore, SNS addiction leads the individual towards self-disclosure.

In addition, the study also considers the moderating role of extraversion and openness traits with the relationship of SNS addiction and self-disclosure in H6 and H7. Results showed that both factors are a potential moderator, as SNS are used for interaction, and communication. these findings are consistent with the past studies. For example, scholars also conducted several studies related to personality traits and addictive behaviors of users to various online activities, and found a significant positive relationship [99-101].

## **THEORETICAL AND PRACTICAL CONTRIBUTIONS**

The current research theoretical contributes to SNS addiction literature in several ways. First, this study considers important but an unexplored topic SNS addiction in Pakistan and this study addresses this research gap to attempt highlighted the SNS addiction elements in a student context. In addition, this research study provides the status of SNS usage in Pakistan. As the majority respondents of this study are university students, thus findings are much importance for scholars, parents as well for teachers, as these are major stakeholders of students, also the student are considered a key asset of the nation. Therefore, some monitoring systems should be implemented and student should be trained for the positive outcome of SNS.

Second, although Facebook has become one of the most common SNS platforms among university students in Pakistan, comparatively limited studies have analytically discovered the distinctive features of the SNS platform and its implications in the digital age. Hence, the existing research presents one of the attempts to carefully expose SNS addiction elements and online self-disclosure. Consisting of past literature [59, 102] findings demonstrate that SNS addiction can cause online self-disclosure.

Third, the findings of this study also proposed that SNS designers pay some attention to SNS addiction elements. SNSs addiction elements such as socialization, environment keep the individuals away from other useful internet websites sites [103] and makes addictive towards SNS. For example, LaRose, Lin [104] proposed that habits created in SNS can also promote the negative outcomes. Therefore, SNS providers should also consider the negative consequences from the addictive use of SNSs.

Finally, scholars and academician should arrange seminars, lectures and training to inform students or young generations about the benefits of SNS such as SNS can also be used for group discussions, and other academic purposes.

In summary, SNS like Facebook provides a new platform for adults to present themselves and to communicate with other friends. Young generation updates information to walls and uploading photos for online self-disclosure on SNS. SNS enables the individual to make profiles and engage in activities that reflect the self-disclosure.

## **FUTURE WORK**

This study investigated the recent research on SNS addiction, data collected from Pakistani university students, and raised many questions unanswered and more research on this emerging area is required to understand the full scope of SNS addiction and its solutions. First, the sample size of this study is small as compared to 1 million active users of the internet. In the future, scholars can extend the scope of this study by increasing the sample size and comparing the findings with study results. The results also have limited generalizability to other populations, such as adolescents or older adults who may be using Facebook and Twitter in different ways.

Secondly, this study focused in a specific group, especially students attending different universities in Pakistan, they may differ from other SNS users in many ways, such as their fast and easy access to the internet. They can easily upload several photos, posts, and information as compare to other internet users which take more time with a slow internet connection. In, future scholars can also test this model and include other respondents.

Third, this study only highlighted the very few SNS addiction elements such as socialization and entrainment related to SNS. Scholars are advised to investigate the other addiction elements, which are related to SNS addiction and online self-disclosure. This study considers extraversion, and openness traits as a moderator and found the significant moderating effect

of both. Scholars are advised to explore the direct relationship of personality traits with SNS addiction and online self-disclosure. Furthermore, scholars can also investigate the SNS usage and academic performance of students [104], and generate additional interesting results.

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# DETERMINANTS OF INNOVATION IN HOTEL AND TRAVEL AGENCY SERVICE INDUSTRY: IMPACT OF INFORMATION AND COMMUNICATION TECHNOLOGIES AND ENTERPRISE READINESS

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## ABSTRACT

Innovation is generally considered as one of the main key drivers of economic growth. Fostering innovation activity helps firms to improve and maintain a competitive advantage on a global market, which is especially important for tourism firms that operate in a very competitive environment. The goal of the article is to explore the determinants of innovations in hotel and travel agency services. We tried to investigate the impact of information and communication technologies and the enterprise readiness on the innovations in hotel and travel agency service industry. In order to achieve this goal, the empirical survey was conducted on a sample of hotels and travel agencies in Croatia and Montenegro. Principal component analysis with Varimax factor rotation was applied on a set of information and communication technologies items. Three logistic regression models were developed for the hotel firms and travel agencies, separately. The research results showed the usage of information and communication technologies as well as enterprise readiness for innovations have a significant impact on innovation activities, but the impact was different between hotel firms and travel agencies.

## KEYWORDS

innovation, ICT, tourism industry, Croatia, Montenegro

## CLASSIFICATION

JEL: L83, O31, Z32

## INTRODUCTION

Innovations are based on a new, creative and unique way of thinking, learning, doing or producing [1, 2]. They can also be defined as an application of new product or service; creation of new methods of enterprise, production or supply; introduction of changes in business activities regarding business processes and employees [3, 4].

Study of innovation activity and process in the service sector has attracted many attention in the last decade, as a result of emerging prominence of services and their influence in economic activity [4, 5]. Innovation in services may be defined “as the conversion of ideas into products, processes or services which are valued by the market” [6; p.283]. It “creates value for customers, employees, business owners, alliance partners, and communities through new and/or improved service offerings, service processes, and service business models” [7; p.5].

Tourism is considered as the world’s largest service industry [8] and innovation is recognized as one of the key factors for tourism enterprises’ competitiveness [9, 10]. Innovation is considered to be at the very center of tourism enterprises’ success and the primary survival condition [11], with various types of applications, such as mobile apps [12, 13], websites [14], and social media [15]. Beside ensuring differentiation in the market [16, 17] it helps enterprises to acquire long-term success by achieving lower costs and enhancing their products and services, as well as processes to satisfy changing client needs and habits [18, 19]. Innovativeness of tourism enterprises positively affects financial performance [20], and as well improves company image, enhances profitability and increases customer satisfaction [6]. Interesting results is that when it comes to clients they are generally willing to pay more for hotels that exhibit greater innovative activities [21].

Still, in spite of realizing the importance of innovation for tourism enterprises, it seems that tourism cannot be described as a best practice industry [22]. Results of the empirical studies indicate a modest level of innovation activity [20, 23], and thus many authors [16, 18, 24] indicate need for further research oriented towards understanding determinants in tourism innovation.

Innovation like in other service industries is under influence of many external and internal factors [25]. When looking generally, Weiermair [26] emphasizes three basic groups of factors which determine the level and pace of innovation in tourism, including supply and supply-related determinants, demand drivers and the level and pace of competition. Divisekera and Van Nguyen [27] stress the difference among innovation inputs concerned with internal enterprise elements (i.e. collaboration, human capital, information technology, and funding), and institutional factors (i.e. foreign ownership, market competition, firm size, and environment), while Tejada and Moreno [28] stress the importance of non-technological determinants as size, cooperation, capital structure and dependency on tour operators. A study by Grisseemann et al. [18] found employee engagement, customer participation, innovation management, innovation networks, and information technology to be the main drivers of innovation. However, innovations in technology are often a source of risks related to security issues [29].

As previous research above shows, Information Communications Technology (ICT) has been recognized to have a strong impact on tourism, and as Law et al. [30] emphasize ICT has brought changes at the operational and strategic level of management in tourism. As of the high information content, ICT was given a central role in the innovation activities of service firms [6]. Research, however, shows that only when ICT is combined with other internal strategic and enterprise issues, especially the ones related to employees, one can expect to improve productivity [25]. Importance of funding, as an important internal element, is also stressed.

As it is not possible to cover all potential determinants inside and outside enterprises, this article orients on the influence of the two aforementioned determinants that have been recognized to have a significant potential impact on innovation activity. They are the ICT and enterprise readiness encompassing several internal elements related to employees and their engagement and participation as well as capital structure and funding. Therefore, the purpose of this article is to provide additional understanding of the innovation activity in tourism enterprises, namely hotels and travel agencies, with special emphasis on analyzing the role of ICT and enterprise readiness in this process. In that sense, we hope to provide a deeper understanding of factors that could foster innovation and increase their competitiveness. The research was done on a sample of hotels and travel agencies in Croatia and Montenegro, with statistical analysis of data by using principal component analysis with Varimax factor rotation and three logistic regression models that were developed for the hotel firms and travel agencies, separately.

The article is organized into five sections. Introduction part is the first section where innovation as a driver of tourism development is emphasized, and determinants of innovations in tourism have been recognized. The goal of the article and methodology are shortly described in the Introduction part also. In the second section, Literature review, main issues of the article and hypothesis are described: impact of the ICTs and enterprise readiness on innovations in tourism industry and impact of the ICTs and enterprise readiness on innovations in hotel and travel agencies. According to the hypothesis, research model is presented. In the third section, data and methodology are described, together with research instrument and data collection method. Definitions of the variables for the regression models and factor analysis are explained also in this section. The results of the econometric examinations regarding the impact of the ICTs and enterprise readiness on innovation in hotel and travel agency service industry are presented in the fourth section. The last, fifth section of the article concludes the article. Comparison with other similar research is done, practical implications of the results are presented, as well as future research steps and limitations of the article.

## **THEORETICAL FRAMEWORK AND HYPOTHESES DEVELOPMENT**

Tourism presents a highly information-intensive industry with a considerably long value chain where information has one of the strongest influences [31]. For these reasons, the impact of ICT in the tourism industry is inevitable and integration of ICT in everyday business is essential for tourism success [32]. Its usage becomes relevant on all operative, structural, strategic and marketing levels as it can enable global interaction among all members of the value chain [33]. Moreover, ICT has a crucial role in innovation activities [22, 34, 35]. Empirical results show that ICT increases innovation activities [18] by “taking advantage of intranets for reorganizing internal processes, extranets for developing transactions with trusted partners and the Internet for interacting with all its stakeholders and customers” [33; p.74]. Aldebert et al. [36] stress how tourism managers need to bear in mind that tourism industry has moved to end-customer oriented technologies and attention has to be on a spread of mobile or RFID technologies. Moreover, e-business oriented on digitalization of all processes becomes crucial. As such, these areas provide an emerging impetus and niche for innovations in the tourism sector. Based on the importance stressed on ICT and its influence on innovations in tourism we propose our first hypothesis:

**H1:** ICT is a predictor of innovations, both in hotels and travel agencies.

Every innovation presents a form of change, and as such, it seeks enterprise-level readiness to accept such a change. Enterprise members’ commitment to implement a change, as well as capabilities to do so, can be seen as two major elements of enterprise readiness [37]. Enterprise readiness is expected to have a significant influence in determining service firm

innovation readiness [38]. Research on innovation in tourism has shown several elements to be important determinants in enterprise readiness for innovation, such as employee engagement and participation [18, 39], capital structure [28] as well as dedicated time and resources [40]. Employees have one of the crucial roles in the process as of the simultaneous production and consumption of services and importance of human factor in providing them [24]. Successful innovation seeks for employee commitment and engagement to carry that innovation. In addition, if financial resources are adequate and continuing this can determine innovation level and its implementation activities [40]. Additionally, empirical results provide strong support for external financial support to carry out the innovation process [23]. Based on the above stated we propose our second hypothesis:

**H2:** Enterprise readiness is a predictor of innovations, both in hotels and travel agencies.

Innovations of all kind are important for competitiveness and survival of all tourism enterprises. Still, large tourism enterprises are often characterized by higher levels of innovation [41] resulting from their ability to implement and support innovation more quickly [42]. In addition, empirical results indicate differences in innovation level among different enterprises, as lodging and accommodation sector seems to be the most innovative ones [6, 9]. This is somehow expected, as “inter-firm differences and inter-branch differences in production, investment and marketing conditions” [26; p.61] exist and they can affect innovation level and a process of different enterprises. Also, as of different roles and processes in the value chain, hotels, and travel agencies experience different roles of ICT in their enterprise [33]. Thus, based on the above we propose our third hypothesis:

**H3:** ICT and enterprise readiness have a different influence on innovations in hotels and travel agencies.

With the intention to better understand determinants of innovation activity in tourism enterprises, more specifically hotels and travel agencies, we have developed the research model as shown in Figure 1. The model specifically addresses the role of ICT and elements of enterprise readiness in the prediction of use of innovation in hotels and travel agencies. In that sense, we presume that innovation is under the positive influence of ICT (H1) and enterprise readiness (H2). We also presume that ICT and enterprise readiness have a different relationship with innovativeness in hotels and travel agencies (H3).

Research model is presented in Figure 1.

## **METHODS**

In this section following issues will be presented: research instrument and data collection method, sample characteristics and design and data analysis.

### **RESEARCH INSTRUMENT AND DATA COLLECTION METHOD TITLE**

Our research is focused on innovation at the level of the tourism firm. Hotel and travel agency service industry in Croatia and Montenegro has been used as case study. Email survey with two follow-ups has been conducted in autumn of 2013 in order to collect data on firms’ characteristics which may influence their innovativeness. In order to increase a response rate, the survey in Croatia was partly conducted in cooperation with The Association of Small and Family Hotels and The Association of Croatian Travel Agencies.

As it can be seen in Table 1 the survey instrument, a structured questionnaire adapted to the requirement of a mail survey, has three parts. The first one was dealing with firm’s characteristics regarding the type and size of the firm. The second one was focused on

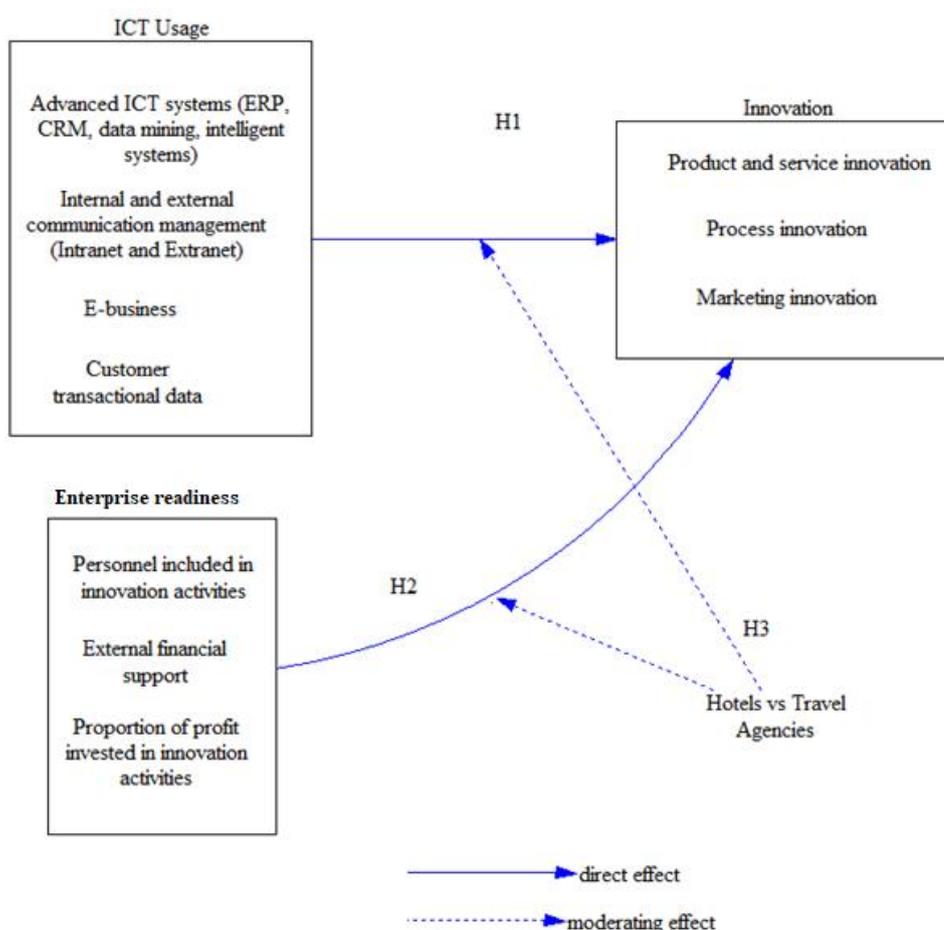


Figure 1. Research model (authors's work).

Table 1. Research instrument description (authors' survey).

Construct	Item name	Item description
Enterprisal readiness for innovation	OR1	Person / persons employed for innovative activities
	OR2	Some form of financial support for innovation activities have been received within last three years
	OR3	Part of profit allocated to innovation annually
Innovativeness	INNO1	New or significantly improved products or services introduced within last three years
	INNO2	New or significantly improved processes introduced within last three years
	INNO3	New or significantly improved marketing activities introduced within last three years
ICT usage	ICT1	LAN
	ICT2	Intranet
	ICT3	Extranet
	ICT4	Products/services offered through the Internet
	ICT5	Products/services ordered through the Internet
	ICT6	ERP Enterprise Resource Planning
	ICT7	CRM Customer Relationship Management
	ICT8	Consumer transaction data
	ICT9	Data mining
	ICT10	Intelligent systems

innovativeness, defined as, both, the firm's readiness for the innovations as well as a current level of innovativeness of the firm.

In line with the previous research on the innovation related to the specifics of tourism [36] we analyzed three types of innovations: product or service innovation, process innovation, and marketing innovation. The third part of the questionnaire oriented on the level of ICT used within the firm, and this was assessed through a construct consisting of 10 items describing different types of ICT. All of the items were dichotomous, with 1 standing for Yes, and 2 for No.

## SAMPLE CHARACTERISTICS AND DESIGN

An email survey in Croatia was sent to 169 hotel firms and 344 travel agencies. A list of hotel firms comprised of almost 90 % of all hotels in Croatia operating at the time when the survey was conducted. The list of hotels firms covered both large hotels and family and small ones. The list of travel agencies covered all agencies members of The Association of Croatian travel agencies (a total of 260 agencies) and a sample of active non-member agencies (a total of 84 agencies). A total response rate for the Croatian sample was relatively low 15 %, despite the use of names of the responding trade associations and the two follow-up letters. The higher response rate was obtained for the hotel sample (18 % or a total of 30 hotel firms) in comparison to that of travel agencies (13 % or a total of 46 travel agencies). The obtained response rate was in accordance to the well-documented response rate to mail surveys [43, 44], although somewhat lower than the 25 % obtained by Paraskevas and Buhalis [45] on the sample of small hotels in UK and Greece using e-mail survey. Still it is significantly higher than that obtained by Keegan and Lucas [44] who experienced a response rate of 10 % on the sample of small hospitality firms and doubled it with direct personal contact through the follow-up procedure.

Montenegro's sample was a convenient one, targeting both, hotel firms and travel agencies. The obtained sample comprised of 10 hotel firms and four travel agencies which leads to the total sample of 40 hotel firms and 50 travel agencies. Table 2 depicts the sample characteristics, compared between the hotel firms and travel agencies.

Hotel firms are significantly larger firms compared to travel agencies regarding the number of employees, both full-time and seasonal. While 57 % of hotel firms have up more than 10 employees, only every fifth tourist agency is in that category. Hotel firms are also bigger regarding the total revenue, with 16 % of all hotel firms and 6 % of all agencies having total revenue in 2012 over 10 million Euros, and over one-third of all agencies and only 5 % of hotel firms having total revenue below 100 000 Euros. Interestingly, there is no significant difference between the two groups regarding the increase/decrease in revenue during the last three years. The majority of all firms are private, with a share of public or mixed ownership higher, but not significantly, among the hotel firms. Hotel firms are also older than the travel agencies on average, with 16 % of all hotels firms and only 2 % of all agencies built before 1989.

**Table 2.** Sample characteristics, authors' survey (continued on p.215).

	Hotel firms (N = 40)		Travel agencies (N = 50)		p-value
	n	%	n	%	
Number of full-time employees	40	100,0	50	100,0	0,0023***
1	4	10,0	6	12,0	
2	2	5,0	13	26,0	
3-5	3	7,5	12	24,0	
6-10	8	20,0	9	18,0	
11-20	12	30,0	5	10,0	
21-100	4	10,0	4	8,0	
> 100	7	17,5	1	2,0	

**Table 2.** Sample characteristics, authors' survey (continuation from p.214).

Number of seasonal employees	40	100,0	49	100,0	0,0008***
0	7	17,5	17	34,7	
1-2	1	2,5	11	22,4	
3-5	8	20,0	5	10,2	
6-10	8	20,0	6	12,2	
11-20	3	7,5	7	14,3	
21-100	5	12,5	3	6,1	
> 100	8	20,0	0	0,0	
Type of ownership	40	278,9	50	272,0	0,1361
Private	35	87,5	48	96,0	
Public or mixed	5	12,5	2	4,0	
Year of establishment	38	100,0	50	100,0	0,0461**
Prior to 1989	6	15,8	1	2,0	
1989 to 1999	11	28,9	23	46,0	
2000 to 2005	13	34,2	12	24,0	
2005 up today	8	21,1	14	28,0	
Total revenue in 2012, €	37	100,0	50	100,0	0,0189**
< 100 000	2	5,4	17	34,0	
100 000-500 000	17	45,9	14	28,0	
500 000-1000,000	5	13,5	4	8,0	
1000 000-3 000,000	4	10,8	9	18,0	
3 000 000-10 000 000	3	8,1	3	6,0	
More than 10.000,000	6	16,2	3	6,0	
Revenue during the last 3 years	36	100,0	49	100,0	0,5896
Significantly increased	3	8,3	7	14,3	
Increased	19	52,8	18	36,7	
The same level	7	19,4	10	20,4	
Decreased	6	16,7	13	26,5	
Significantly decreased	1	2,8	1	2,0	
Part of corporation	40	100,0	50	100,0	0,4718
Yes	6	15,0	5	10,0	
No	34	85,0	45	90,0	
At more than one location	40	100,0	50	100,0	0,4479
Yes	8	2,0	7	14,0	
No	32	80,0	43	86,0	
In more than one country	40	100,0	49	100,0	0,8191
Yes	2	5,0	3	6,1	
No	38	95,0	46	93,9	
The main market	38	100,0	49	100,0	0,0863
Domestic	7	18,4	13	26,5	
Neighboring	4	10,5	0	0,0	
EU countries	24	63,2	29	59,2	
Other countries	3	7,9	7	14,3	

Note: *p*-value from Chi-square or Fisher Exact test.

\*\*statistically significant at 5 %

\*\*\*statistically significant at 1 %

## DATA ANALYSIS

In order to analyze collected data, three statistical methods have been used: (i) univariate analysis, (ii) principal component analysis (PCA), and (iii) logistic regression. Univariate analysis was performed comparing the difference in firm's characteristics and level of innovativeness between the hotel firms and travel agencies. The significance of differences was assessed by Chi-square or Fisher's Exact test in case of the small number of observations. Principal component analysis (PCA) with Varimax factor rotation was applied on a set of ICT items in order to address their underlying structure in the smaller number of factors. Logistic regression was performed to find possible predictors of innovativeness, separately for the two groups of tourism firms. The stepwise elimination strategy was applied to extract the significant predictors. Probabilities of less than 0,10 were accepted as the evidence of statistical significance.

## RESULTS

In this section, research results are described. In Table 3 innovation activities of hotels and travel agencies are presented. In all three categories, both, hotel firms and travel agencies, are oriented toward innovation activities. Hotel firms are fostering more innovative processes and marketing activities (70 %), while travel agencies are fostering more innovative products/services (89,6 %). It can be concluded that travel agencies in all three categories foster innovation activities more than hotel firms. Category Innovative products/services is statistically significant at 1 % for hotel firms and travel agencies ( $p$ -value = 0,0053), as well as innovative processes at 10 % ( $p$ -value = 0,0801). Categories Innovative marketing activities and Innovative processes are not statistically significant.

**Table 3.** Innovation activities of hotels and travel agencies (authors' survey).

	Hotel firms ( $N = 40$ )		Travel agencies ( $N = 50$ )		$p$ -value
	$n$	%	$n$	%	
Innovative products/services (INNO1)	40	100.0	48	100.0	0.0053***
Yes	26	65.0	43	89.6	
No	14	35.0	5	10.4	
Innovative processes (INNO2)	40	100.0	48	100.0	0.0801
Yes	28	70.0	41	85.4	
No	12	30.0	7	14.6	
Innovative marketing activities (INNO3)	40	100.0	49	100.0	0.1985
Yes	28	70.0	40	81.6	
No	12	30.0	9	18.4	

Note:  $p$ -value from Chi-square or Fisher Exact test.

\*statistically significant at 10 %

\*\*\*statistically significant at 1 %

In Table 4 ICT usage and enterprise readiness of hotels and travel agencies are presented through 10 items, presented in Table 1. In only three categories out of 10, hotel firms use ICT in a higher percentage (ICT1: 82,1 %; ICT4: 92,5 %; ICT8: 92,5 %), while in other categories, hotel firms use ICT in lower percentage (e. g.: ICT2: 38,5 %). Only 21,1 % hotel firms have person/persons employed for innovative activities and only 10 % of hotel firms have some form of financial support for innovation activities in the last three years. Approximately 50 % of profit is allocated to innovation annually.

The situation is quite similar to travel agencies. In only three categories out of 10, travel agencies use ICT in a higher percentage (ICT1: 80 %; ICT8: 86 %; ICT4: 64 %), while in other

**Table 4.** ICT usage and enterprise readiness of hotels and travel agencies (authors' survey).

	Hotel firms (N = 40)		Travel agencies (N = 50)		p-value
	n	%	n	%	
ICT1 – LAN	39	100,0	50	100,0	0,8070
Used	32	82,1	40	80,0	
Not used	7	17,9	10	20,0	
ICT2 – Intranet	39	100,0	50	100,0	0,5255
Used	15	38,5	16	32,0	
Not used	24	61,5	34	68,0	
ICT3 – Extranet	40	100,0	50	100,0	0,0833*
Used	20	50,0	16	32,0	
Not used	20	50,0	34	68,0	
ICT4 – Products/services offered through the Internet	40	100,0	50	100,0	0,0015***
Used	37	92,5	32	64,0	
Not used	3	7,5	18	36,0	
ICT5 – Products/services ordered through the Internet	40	100,0	49	100,0	0,1076
Used	16	40,0	28	57,1	
Not used	24	60,0	21	42,9	
ICT6 – ERP Enterprise Resource Planning	40	100,0	49	100,0	0,1130
Used	9	22,5	5	10,2	
Not used	31	77,5	44	89,8	
ICT7 – CRM Customer Relationship Management	40	100,0	50	100,0	0,1090
Used	10	25,0	6	12,0	
Not used	30	75,0	44	88,0	
ICT8 – Consumer transaction data	40	100,0	50	100,0	0,3296
Used	37	92,5	43	86,0	
Not used	3	7,5	7	14,0	
ICT9 – Data mining	39	100,0	47	100,0	0,1126
Used	19	48,7	15	31,9	
Not used	20	51,3	32	68,1	
ICT10 – Intelligent systems	39	100,0	48	100,0	0,0016***
Used	14	35,9	4	8,3	
Not used	25	64,1	44	91,7	
OR1 – Person/persons employed for innovative activities	38	100,0	49	100,0	0,1631
Yes	8	21,1	17	34,7	
No	30	78,9	32	65,3	
OR2 – Some form of financial support for innovation activities have been received within last three years	38	100,0	49	100,0	0,1442
Yes	4	10,5	11	22,4	
No	34	89,5	38	77,6	
OR3 – Some percent of profit allocated to innovation annually	39	100,0	50	100,0	0,0083***
Yes	23	59,0	42	84,0	
No	16	41,0	8	16,0	

Note: p-value from Chi-square or Fisher Exact test.

\*statistically significant at 10 %

\*\*\*statistically significant at 1 %

categories, travel agencies use ICT in lower percentage (e.g. ICT10: 8.3%). Only 34.7% of travel agencies have person/persons employed for innovative activities and only 22.4% of hotel firms have some form of financial support for innovation activities in the last three years. Approximately 84% of profit is allocated to innovation annually, which is higher percentage compared to hotel firms.

Differences between hotels and travel agencies are statistically different in the following categories: (i) Some percentage of profit allocated to innovation annually ( $p$ -value: 0.0083), (ii) ICT4 ( $p$ -value = 0,0015), (iii) ICT10 ( $p$ -value = 0.0016), (v) ICT3 ( $p$ -value = 0,0833).

The overall measure of sampling adequacy for the application of PCA on ICT items was acceptable (overall MSA of 0,697). Relying on Kaiser criterion, PCA resulted in the extraction of four factors with eigenvalues greater than 1,0, accounting for 64 % of total variance. Four-factor structure following the Varimax rotation applied in order to increase the interpretability of the factors is presented in Table 5.

**Table 5.** Factor loadings for ICT dimension (authors' survey).

ICT dimensions		Factor 1	Factor 2	Factor 3	Factor 4
ICT1	LAN	0.164	0.156	<b>0.515</b>	0.070
ICT2	Intranet	0.096	<b>0.824</b>	0.139	-0.018
ICT3	Extranet	0.175	<b>0.819</b>	0.097	0.032
ICT4	Products/services offered through the Internet	0.079	0.122	<b>0.720</b>	0.147
ICT5	Products/services ordered through the Internet	0.013	-0.020	<b>0.756</b>	-0.231
ICT6	ERP Enterprise Resource Planning	<b>0.839</b>	0.075	0.022	-0.110
ICT7	CRM Customer Relationship Management	<b>0.855</b>	0.172	0.110	0.013
ICT8	Consumer transaction data	-0.044	-0.018	-0.007	<b>0.935</b>
ICT9	Data mining	<b>0.633</b>	0.151	0.130	0.408
ICT10	Intelligent systems	<b>0.713</b>	0.062	0.126	-0.032

The four extracted factors are: (i) Factor 1: Advanced ICT systems (ICT6-ERP, ICT7-CRM, ICT8-Data mining, ICT10-intelligent systems); (ii) Factor 2: Internal and external communication management (ICT2-Intranet, ICT3-Extranet) ; (iii) Factor 3: E-business (ICT1-LAN, ICT4-Products/services offered through the Internet, ICT5-Products/services ordered through the Internet), and (iv) Factor 4: Customer transactional data (ICT8). By extracting these four factors, it was possible to determine specific dimensions of ICT that serve as determinant of innovation activity.

Logistic regressions were performed in order to identify the predictors of innovativeness in the hotel industry and travel agencies. As dependent variables, three variables describing the innovativeness within the firm were used: INNO1 – innovation in products/service, INNO2 – innovation in processes and INNO3 – innovation in marketing activities. As the independent variables, there was the firm's readiness to introduce the innovative activities (person employed for innovation activities, external financial support for innovation activities, a proportion of profit invested in innovation activities) and four ICT factors. The results are presented in the following tables.

Logistic regression yields (Table 6) that Innovation of products and services (INNO1) for hotel firms depends on Profit allocated to innovation (OR3) and Advanced ICT systems (Factor1):

$$\text{logit}(p) = 1,94 + 1,34 \cdot \text{OR3} + 0,91 \cdot \text{Factor1}. \quad (1)$$

The increase of profit allocated to innovation increases the odds of the implementation of innovation of product and services in the hotel industry. Hotels with higher profit allocation to innovation are more likely to have innovative products and services. Similarly, hotels with higher usage of advanced ICT systems innovation are more likely to have innovative products and services. Specifically, an increase of factor score by one increases odds of innovative products and services used for 2,49 times (i.e. odds ratio =  $e^{0,91}$ ). The model correctly separates 83 % of cases.

For travel agencies, more variables retained in the model: Persons employed for innovative activities (OR1), Profit allocated to innovation (OR3), Advanced ICT systems (Factor1) and E-business (Factor3). The obtained model is:

$$\text{logit}(p) = -30,11 + 63,45 \cdot \text{OR1} + 77,31 \cdot \text{OR3} - 25,45 \cdot \text{Factor1} + 25,97 \cdot \text{Factor3}. \quad (2)$$

Here, model completely separates travel agencies that use innovative products and services from those not using (correct classification by the model is 100%).

**Table 6.** Logistic regression results for dependent variable INNO1 (innovation in products or services) (authors' survey).

	Hotel firms		Travel agencies	
	<i>b</i>	<i>p</i>	<i>b</i>	<i>p</i>
Intercept	1.94		-30.11	
OR1			63.45	0.000***
OR3	1.34	0.000***	77.31	0.000***
Factor 1	0.91	0.085*	-25.45	0.000***
Factor 3			25.97	0.000***
Classification table	%		%	
Correctly yes	86.36		100.00	
Correctly no	76.92		100.00	
Correctly – overall	82.86		100.00	
-2 Log likelihood	28.08		0.00	
Nagelkerke R <sup>2</sup>	0.55		1.00	

\*statistically significant at 10 %

\*\*\*statistically significant at 1 %

Process innovation (INNO2) in hotel firms depends on Persons employed for innovative activities (OR1) and Advanced ICT systems (Factor1), Table 7:

$$\text{logit}(p) = -41,50 + 20,35 \cdot \text{OR1} + 1,84 \cdot \text{Factor1}. \quad (3)$$

The high regression coefficient for OR1 (20,35) is a consequence of the fact that all hotel firms with persons employed in innovative activities are also innovative in their business processes. So, the presence of OR1 gives 100 % chance of the presence of process innovation.

Model for travel agencies includes different predictors: Financial support for innovation activities (OR2), Profit allocated to innovation (OR3) and Customer transactional data (Factor4). The model is:

$$\text{logit}(p) = 42,17 + 53,83 \cdot \text{OR2} + 107,97 \cdot \text{OR3} + 33,51 \cdot \text{Factor4}. \quad (4)$$

The model results with 97,7 % correct classifications. travel agencies obtaining financial support for innovation activities, investing higher part of the profit in innovation and having a higher score of Customer transactional data are more likely to be innovative in their business processes.

Predictors for Marketing innovation (INNO3) in hotel firms are Persons employed for innovative activities (OR1), Profit allocated to innovation (OR3) and Advanced ICT systems (Factor1) (Table 8):

**Table 7.** Logistic regression results for dependent variable INNO2 (innovation in processes) (authors' survey).

	Hotel firms		travel agencies	
	<i>b</i>	<i>p</i>	<i>b</i>	<i>p</i>
Intercept	-41.50		42.17	
OR1	20.35	0.023**		
OR2			53.83	0.000***
OR3			107.97	0.000***
Factor 1	1.84	0.001***		
Factor 4			33.51	0.007***
Classification table	%		%	
Correctly yes	70.83		100.00	
Correctly no	72.73		83.33	
Correctly - overall	71.43		97.67	
-2 Log likelihood	27.57		3.82	
Nagelkerke R <sup>2</sup>	0.52		0.93	

\*\*statistically significant at 5 %

\*\*\*statistically significant at 1 %

$$\text{logit}(p) = -39,04 + 19,72 \cdot \text{OR1} + 0,72 \cdot \text{OR3} + 2,12 \cdot \text{Factor1}. \quad (5)$$

The coefficient for OR1 is high because all hotel firms with persons employed for innovative activities use some innovative marketing activities. Further, hotel firms investing in innovation are more likely to apply to marketing innovations.

Again, the model for travel agencies includes different predictors: Financial support for innovation activities (OR2), Internal and external communication management (Factor2) E-business (Factor3). The model is:

$$\text{logit}(p) = -41,17 + 19,97 \cdot \text{OR2} - 0,92 \cdot \text{Factor2} + 0,78 \cdot \text{Factor3}. \quad (6)$$

**Table 8.** Logistic regression results for dependent variable INNO3 (innovation in marketing activities), authors' survey.

	Hotel firms		Travel agencies	
	<i>b</i>	<i>p</i>	<i>b</i>	<i>p</i>
Intercept	-39.04		-41.17	
OR1	19.72	0.078*		
OR2			19.97	0.016**
OR3	0.72	0.070*		
Factor 1	2.12	0.003***		
Factor 2			-0.92	0.045**
Factor 3			0.78	0.033**
Classification table	%		%	
Correctly yes	83.33		97.14	
Correctly no	81.82		33.33	
Correctly - overall	82.86		84.09	
-2 Log likelihood	22.31		30.61	
Nagelkerke R <sup>2</sup>	0.64		0.43	

\*statistically significant at 10 %

\*\*statistically significant at 5 %

\*\*\*statistically significant at 1 %

The regression results from Tables 6, 7 and 8 are summarized in Table 9.

**Table 9.** Summary of the logistic regression results (authors' survey).

	Innovation of products and services		Process innovation		Marketing innovation		Hypotheses 1 and 2
	Hotel firms	travel agencies	Hotel firms	travel agencies	Hotel firms	travel agencies	
<b>Enterprisial readiness</b>							
OR1		(+) 1%	(+) 5%		(+) 10%		½ ✓ Partially confirmed
OR2				(+) 1%		(+) 1%	
OR3	(+) 1%	(+) 1%		(+) 1%	(+) 10%		
<b>Usage of ICT</b>							
Factor 1	(+) 10%	(-) 1%	(+) 1%		(+) 1%		½ ✓ Partially confirmed
Factor 2						(-) 1%	
Factor 3		(+) 1%				(+) 1%	
Factor 4				(+) 1%			
Hypothesis 3	✓ Confirmed		✓ Confirmed		✓ Confirmed		

All three items of the enterprise readiness for innovation, as well as all four dimensions of ICT, are significant predictors for at least one dimension of innovation. While, for example, the Customer transactional data, as one of the ICT dimensions (Factor 4) is a significant predictor just for the process innovation for travel agencies only, a variable Persons employed for innovative activities (OR1) is the significant predictor for all three dimensions of innovation – travel agencies having persons employed for innovative activities are increasing their odds to have innovative products and services, while hotel firms are increasing their odds to have, both, process innovation and marketing innovation. Financial support for innovation activities (OR2) is increasing odds of process and marketing innovation in travel agencies only.

The use of the Advanced ICT systems (Factor 1) is increasing the odds of pursuing innovation of product and services, processes and marketing in hotel firms, but is, at the same time decreasing odds of obtaining innovative products and services in travel agencies, similarly as the Internal and external communication management (Factor 2). Finally, E-business (Factor 3) is increasing odds of obtaining innovative products and services and innovative marketing in travel agencies, only.

## CONCLUSION

Continuous innovation presents an instrument for the survival of modern firms. It enables development of new products and services, performance on new markets and provides channels for attracting new customers. Innovation is playing an important role also in the tourism industry, leading among others to better financial performance and higher customer satisfaction. Still, as seen from the literature many authors call for additional research on determinants of innovation in tourism.

For that purpose, this article analyzed the influence of ICT and enterprise readiness elements on a level of innovation in products/services, processes, and marketing activities. Additionally, we analyze whether their influence is different among hotels and travel agencies. By using univariate analysis, principal component analysis (PCA), and logistic regression our hypothesis were tested on the sample of hotels and travel agencies in Croatia and Montenegro.

When looking generally, level of innovation in both Croatian and Montenegrin hotels and travel agencies is high. In accordance with the previous research [6] it is seen that enterprises rarely innovate in only one field, and as it is the case of our sample, enterprises foster several types of innovations simultaneously. Still, travel agencies in all three categories of innovation,

foster innovation activities more than hotel firms. These results are somewhat different to the previous research which indicate that hotels are the most innovative as compared to other types of tourism enterprises [6, 9].

Our results also revealed a significant but somewhat different impact of enterprise readiness and ICT usage items on fostering the three-dimension innovation activity between hotel firms and travel agencies. Hotel firms should put special attention on the implementation and use of the advanced ICT systems such as ERP, CRM, Data mining, and/or intelligent systems in order to increase odds of innovation in their business, regardless the type of innovation (i.e. products and services, processes and marketing). In addition, a person/persons employed for innovative activities would increase the odds of the introduction of innovative processes in their business, and innovative marketing activities of hotels firms, while the allocation of some percent of profit to innovation would increase the odds of innovative products and services and marketing. Predicting the innovation activity in travel agencies is more dependent on the type of innovation. If innovation of their products and services is in a focus, they should allocate some profit to innovation and employ a person/persons in charge of innovative activities who would foster the use of E-business (LAN, Products/services offered/ordered through the Internet). In order to increase the odds of the process innovation in travel agency sector, the agencies should put more attention to use of customer transactional data together with the allocation of some funds to innovation, both from their own profit and by applying for some external support. Finally, both, relying on E-business and the external support for innovation would increase the odds of innovative marketing activities in travel agency sector.

Several limitations of current research need to be acknowledged. This study was done on a sample of enterprises from Croatia and Montenegro, thus findings might be under influence of cultural specifics of the sample. The sample size is another issue, as its' size and design do not allow universal generalization of the results. Additionally, this article analyzed the prediction of only several determinants of innovation, namely ICT and enterprise readiness, and many more determinants inside and outside of the enterprise need to be acknowledged for the future research. For instance, importance of cooperation [9, 28], driving forces of other business sectors and public sector related to tourism [42], or institutional factors as foreign ownership, market competition, and environment [27]. Nevertheless, we believe the article provided some additional insight into the subject of ICT and enterprise readiness as determinants of innovation in the tourism industry.

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# USE OF TWITTER BY NATIONAL TOURISM ORGANIZATIONS OF EUROPEAN COUNTRIES

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## ABSTRACT

In the last few decades, National tourism organizations (NTOs) emerged into the critical institutions for the countries branding and identification worldwide. The increased relevance of the NTOs in the development of tourism of specific countries also increased their focus to Web 2.0. technologies and their social media prominence. The primary objective of this study purpose is to investigate the utilization of the social media profiles of the NTOs of European countries. In order to get comprehensive and systematized results, authors brought up three research questions: (i) what is the activity of NTOs according to social media utilization, (ii) what is the level of coherence among countries according to time of establishment and language of Twitter accounts of NTOs in European countries and (iii) is there relationship among Twitter activity of NTOs and country tourism activity? The study investigates the usage of social media by reviewing the official profiles of NTOs in the main social media channels, and subsequently extracted data from their Twitter accounts in order to establish the possible correlations among the NTOs' Twitter activities and countries' characteristics. Statistic software the Statistica is used as a tool to examine output data analytics. Distinctive knowledge emerged from the investigation, noteworthy both for scholars and adaptable for business. Research established that European countries NTOs have recognized the importance of social media and that most of NTOs actively use the combination of various social media in order to achieve their strategic goals. Relationships among activity on social media and tourism results have been confirmed. We provide examples of the best practices which can serve as a helpful strategy development models for the NTOs' practitioners. Finally, we outline the possible directions for further research in the area of social media utilization of NTOs.

## KEYWORDS

tourism, social media, national tourism organizations, EU, social media analytics

## CLASSIFICATION

JEL: O33

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## **INTRODUCTION**

The relevance of social media in tourism is established and investigated by numerous authors worldwide. From its initial purpose as a tool for people to connect, social media shifted to an omnipresent technological concept that transformed overall business communication techniques [1]. As a result of social media expansion, users transformed into the media themselves in order to exchange knowledge, information, and experiences, which support development possibilities for various industries [2].

For the tourism and hospitality sector, there are numerous advantages from social media utilization. The whole travel circle has affected by the influence of the social media: it begins from vacation planning, destination, and products promotion, and expanded to decision making during the trip and becoming analytic data machine afterward [3].

Development of the Web 2.0. technologies and expansion of the e-WOM by the social media has an immediate impact on tourist destination reputation and encompasses all travel stages: before, during and after visiting destination [4].

The focus of this article is to explore the social media activity of official National tourism organizations (NTOs) of the 28 European Union country members. This investigation is exploratory and interpretative in nature, as it aims to answer three research questions disclosed. The questions together will consequently unveil the patterns and methods of how EU countries utilize social media in order to promote their countries. The research questions are set as follows.

**RQ1:** What is the activity of NTOs according to social media utilization?

**RQ2:** What is the level of coherence among countries according to the time of establishment and language of Twitter accounts of NTOs in European countries?

**RQ3:** Is there a relationship among Twitter activity of NTOs and country characteristics?

The article begins with the Introduction section which points out the relevance and objectives of the investigation. Next section is Theoretical background, which gives a brief literature overview on the topic. The Results section discloses different insights into countries and social media data. First, general tourist information as overnight arrivals and overall population about EU member countries were given. Furthermore, by content analysis of the web pages of the national tourism organizations (NTOs) of the countries, utilization of four most prominent social media was explored for each country. An extensive investigation is conducted on the Twitter data output, as the most distinguished microblog globally. Insights were extracted from the official Twitter accounts, and with the program software 'Statistica' the statistic analysis was performed. In the 'Discussion' section, answers on the three research questions were presented. Lastly, conclusion and the future research directions were pointed out.

## **BACKGROUND**

### **NATIONAL TOURISM ORGANIZATIONS**

NTOs represent the key institutions for tourism development, branding, and marketing of the country [5]. Numerous factors are included in establishing NTOs' strategies and forms, such as size and culture, political, economic and social aspects of the nation [6].

NTOs bring together various players from the tourism industry [7]. They serve as the link for the private and public sector in terms of tourism and national promotion activities as they provide a connection among business suppliers and tourist services performance companies [8].

Various authors [9] assert that national branding, and its importance is equally relevant as the reputation of the companies and brands. However, branding procedures and strategies are not established as they are in the private sector and the companies due to the recent attention and awareness of the potential benefits of the matter.

Therefore, strategic planning combined with other activities emerged as the primary function of the NTOs [10]. Functions of NTO's are centered around systematic and long term promotion of the destination worldwide in order to achieve growth of the market share [11] and to establish 'a strong brand image with clearly identified and powerfully projected brand value,' [12].

## **OFFICIAL TOURISM MARKETING**

NTOs' marketing tools and channels have excessively transformed since their first appearance at the beginning of the 20th century [13]. Initially, NTO's operated on the local level and expanded with the package holiday appearance and presence of the holiday brochure letters [14].

Holiday brochure and posters represented the most important and innovative mass tourism marketing thenceforth [15], till the point where usage of visual means was introduced [116]. Images of destinations with the follow-up promotion with guides included designed by NTOs' and Town Council promotion department served as a prevalent marketing tool used by NTOs' continuously until the emergence of the Internet [17].

Internet and technology development had a substantial impact on the whole tourism sector, the way travelers gather and exchange information, and consequently, on NTOs' functions and operations [18]. The principal challenge for NTO's was adapting to technological change, and this was the time when the first NTOs' web pages appeared [19].

The rise of the Web 2.0. technologies and social media impact brought great prominence to developing marketing strategies in tourism [20]. NTOs' placed social media in the center of their marketing operations which enabled the two-way communication with tourists, posting in real time, tracking traveler movement and decision making in a destination in goal to achieve a comparative advantage on the market.

## **SOCIAL MEDIA IN TOURISM**

Social media is one of the most significant phenomena of the present times, and its reshaping communication as we know it, at both personal and business level [21]. According to statistics from 2018 [22], there were about 2,46 billion social media users in 2017, which estimates at 71 percent of all internet users, and these figures are ever increasing.

One of the industries in which social media has significant influence is tourism and hospitality. Travel industry itself is experiencing growth every year and has become one of the most dynamic sectors for economic development and job creation [23]. Results highlight that tourism directly contributed 23 trillion US\$ in 2016, and indirectly '7.6 trillion \$ to the global economy, and supported 292 million jobs' [23]. The numbers equal to 10.2% of the world's GDP, and approximately 1/10 of all posts. Authors [24] confirm social media support this growth and that it is playing a dominant role in traveling, from planning, using social media in a destination, to sharing travel experiences [25]. Therewithal, researches [26] carry out that travelers not only exchange knowledge; they also share experiences through social media. These are not just facts about travel attributes such as information about the destination, attractions and weather conditions, but through posts on social media, they may additionally include imaginations, visions, and emotions about holiday features.

There is a big difference in how social media in tourism was used and how it has used today [27]. Experts [28] outlined that social media platforms enable travelers to initialize and share

online knowledge, emotions and experiences and experiential moments much broader than before which revolutionize primarily undisclosed and private experiences to global databases which can be interpreted and analyzed by tourism institutions and organizations.

Social media role in the travel industry surfaced from marketing tool for destination and product promotion to a system that enables to create market positioning, creating personalized supply and hence, gain competitive advantage.

The most prominent SM are Facebook, Twitter, Instagram, and YouTube. With millions of users worldwide, they facilitate strong involvement from both the public and private sector [29].

Twitter, as the most popular microblog and is presenting what is going on in the world [30]. Twitter is the social media selected for the analysis considering its forceful relevance for the tourism industry as the main e-WOM generator and destination branding channel [31].

## **TOURISM ACTIVITY OF EUROPEAN COUNTRIES**

Tourism is the sector of high importance in the European Union due to the fact that the EU countries are the most visited globally with more than half of international arrivals [32]. Tourism generates one third all jobs and contributes its economic and strategic purposes [33]. The primary goal for the EU considering tourism is to attain the optimal balance of tourism activities in the member countries [34]. EU assize, quoted by the Coles et al. [35] state that: 'European tourism needs to be managed with foresight, proactively rather than retrospectively responding to change, with its managers more keenly sensitized to the regularity of enlargement events, adjustments in EU governance, economic and social reorganizations in existing and new member states, and the potential restructuring of markets'.

Tourism significance for EU is unquestionable. Yet, many fast-growing economies are attracting numerous travelers and decreasing market share from EU countries [36]. In fact, eight from ten most visited countries were not from the European Union, according to Business Insider [37].

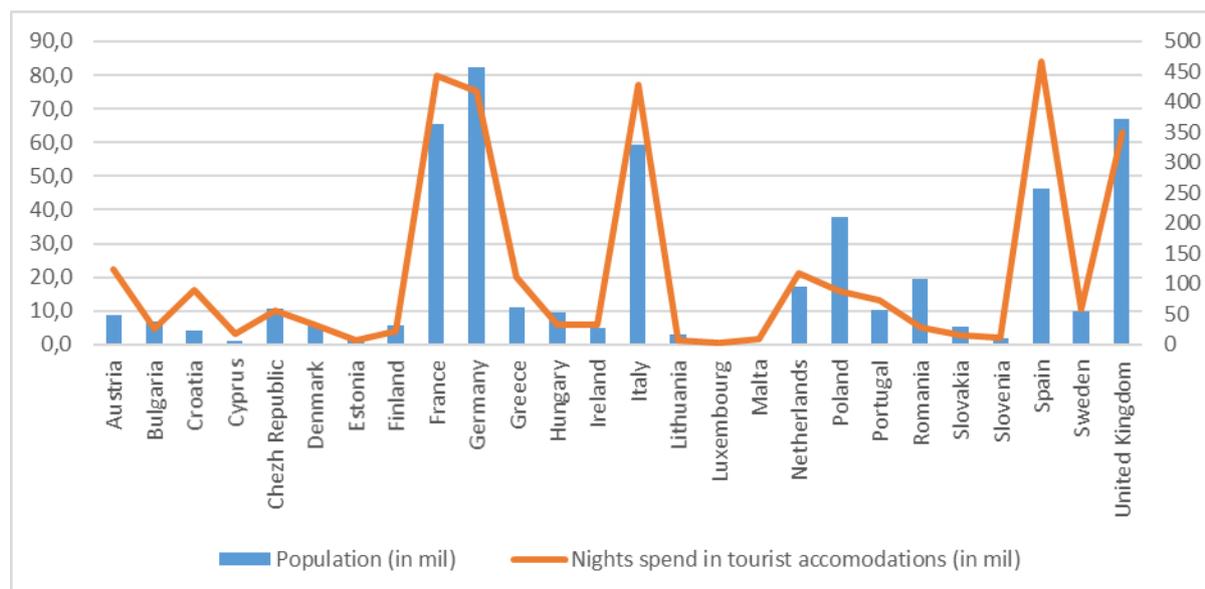
In order to maintain their tourism championship status, EU countries must continually pursue scope for further growth, and economic development. The utilization of social media in order to expand their marketing strategies, and gain a competitive advantage is one of the most prominent and efficient strategies at the moment [38].

Figure 1 shows 28 EU countries and information on their population and nights spent in 2018. The most populated countries are Germany, the UK, and France, and the least populated countries are Estonia, Latvia, and Luxembourg. In most cases, high population follows high overnight rate and vice versa. Although, there are some exceptions, such as he Spain, which obtains the highest number of overnight stays (467 million) and is inhabited whit just 46 million residents. Moreover, France and Italy have significantly more overnights that are populated, and Croatia emerges as a country that Croatia has by far the most significant difference among population and nights spend. Furthermore, countries such as Poland and Romania show the distribution in favor of a population, with fewer tourists overnight. However, the lowest populated countries have the lowest tourism results as well.

## **RESULTS**

### **SOCIAL MEDIA ACTIVITY OF EUROPAN NTOs**

Table 1 outlines the social media appearance for 28 EU member countries.



**Figure 1.** EU countries by populations and nights spent in tourism accommodation (2018, in mil). Source: authors' work, based on Eurostat data.

**Table 1.** Social media activity of NTOs of European countries. Source: authors' work.

Country	Twitter	Instagram	Facebook	YouTube
Austria	✓	✓	✓	✓
Belgium	∅	∅	∅	∅
Bulgaria	✓	∅	✓	✓
Croatia	✓	✓	✓	✓
Cyprus	✓	✓	✓	∅
Czech Republic	✓	✓	✓	✓
Denmark	✓	✓	✓	✓
Estonia	✓	✓	✓	✓
Finland	✓	✓	✓	✓
France	✓	✓	✓	✓
Germany	✓	✓	✓	✓
Greece	✓	✓	✓	✓
Hungary	✓	✓	✓	∅
Ireland	✓	✓	✓	✓
Italy	✓	✓	✓	✓
Latvia	∅	✓	✓	✓
Lithuania	✓	✓	✓	✓
Luxembourg	✓	✓	✓	✓
Malta	✓	✓	✓	✓
Netherlands	✓	✓	✓	✓
Poland	✓	✓	✓	✓
Portugal	✓	✓	✓	✓
Romania	✓	✓	✓	✓
Slovakia	✓	✓	✓	✓
Slovenia	✓	✓	✓	✓
Spain	✓	✓	✓	∅
Sweden	✓	∅	✓	∅
United Kingdom	✓	✓	✓	✓

Facebook is the social media, which is the most, represented among EU countries, 27 of 28 European countries NTOs have an official Facebook account. Only Belgium does not have an official Facebook account due to the country's marketing strategy to promote three separate regions instead of the country as a unity. The fact that Facebook is the most used social media among EU countries is consistent with social media popularity. Records from January 2019, verify Facebook as the most used social network worldwide, with nearly 2,3 billion users [39]. Twitter and Instagram are the second disseminated network among European countries; only Belgium and Latvia are countries that have not created official accounts.

## **SOCIAL MEDIA ACTIVITY OF EUROPEAN NTOs**

Twitter account languages and the date NTO of EU countries joined the Twitter network has been presented in Table 2.

Column 'Twitter account language' displays the language of the Twitter post on each official NTO account. Most account post on the English language in order to obtain a more far-reaching audience and being understood on the global level. However, Austria and Bulgaria came up as an exception: Austrian profile post on the German language and Bulgaria is

**Table 2.** Twitter account language and joining date for NTO EU countries. Source: authors' work.

<b>Country</b>	<b>Twitter account</b>	<b>Twitter account language</b>	<b>Join</b>
Austria	Österreich Werbung	German	09/2008
Belgium	-	-	-
Bulgaria	bulgariatravel.org	English/Bulgarian (Cyrillic)	06/2011
Croatia	Croatia full of life	English	06/2009
Cyprus	VisitCyprus	English	02/2009
Czech Republic	Visit Czech Republic	English	04/2009
Denmark	VisitDenmark	English	03/2009
Estonia	Visit Estonia	English	05/2009
Finland	Visit Finland	English	11/2009
France	France.fr	English	07/2009
Germany	Germany Tourism	English	11/2008
Greece	Visit Greece	English	09/2010
Hungary	WOW Hungary	English	04/2009
Ireland	Tourism Ireland	English	02/2012
Italy	Italia	English	10/2011
Latvia	-	-	-
Lithuania	Lithuania	English	01/2009
Luxembourg	Visit Luxembourg	English	12/2011
Malta	VisitMalta	English	05/2009
Netherlands	Meet in Holland	English	04/2011
Poland	Poland Tourism	English	06/2009
Portugal	Visit Portugal	English	08/2009
Romania	Romania Tourism	English	04/2009
Slovakia	Slovakia Travel	English	07/2011
Slovenia	Feel Slovenia	English	06/2009
Spain	Spain	English	12/2008
Sweden	VisitSweden	English	01/2009
United Kingdom	VisitBritain Biz	English	04/2010

posting some content on English, some on the Bulgarian language on Cyrillic alphabet. Austrian reasons could be the drive to preserve authenticity as a marketing strategy, which is their policy for all events that take place in their country. As for Bulgaria, posts on local language could be intended for the residents. The approach turns out favorable for Austria, as the number of their followers and tourism, but not so much for Bulgaria which scores low both in tourism both in Twitter popularity ratings.

The column 'Join' presents the dates for when each countries NTO joined the Twitter network. Twitter initially launched 13 July 2006, anyhow, its relevance for the tourism sector has been recognized and widely utilized since 2008 [30]. Austria NTO was the first one to establish an official Twitter account. That could be one more reason why the country created an account on national language. Many countries followed up shortly, with more than half of the official accounts (15 of 26) established in 2009. Only two countries besides Austria had Twitter since 2008, Germany and Spain. Last countries that created a Twitter account were Luxembourg, Italia, and Ireland, in late 2011, or at the beginning of 2012. The last country joined in February 2012, so all Twitter accounts are at least seven years active.

Spain is the country that emerged as with the strongest activity of their NTO's Twitter account among EU countries in the most categories included. As for the engagement categories: Tweets, Following, Events, and Multimedia, Spain emanates as the first or the second rated in the three of the four categories. That could be connected to the fact that Spain has the largest number of followers, among those countries included in the research, and is the second by likes of all the countries. Furthermore, Spain is not only the champion of the Twitter data results, is the country with the overall nights in EU, so the marketing strategy of the country could be taken as an example for developing models or frameworks. Withal, all countries rated highly in engaging categories, such as Portugal, Greece, Slovenia, and Italy, have more overnight stays than the population which implicates tourism success. Contrarily, countries with the lowest engagement, as Bulgaria, produce low tourism results.

## **TWITTER MEDIA ACTIVITY OF EUROPEAN NTOs**

Twitter activity across EU countries for NTOs' profiles are given in Table 3. Among European NTOs, 26 of 28 have their official Twitter accounts, except Belgium and Latvia. Belgium's tourism Twitter accounts are distributed in three regions: Flanders, Wallonia, and Brussels. However, Belgium does not have a unique Twitter account at the national level. In addition, Latvia's NTO does not have a Twitter account at all, while Latvia has Facebook, Flickr, Instagram, and Youtube media.

The first column represents all countries that are members of the European Union. The second column shows the number of tweets of the given country. Tweets are 'text-based posts long of up to 140 characters available to account followers' [40]. Portugal NOT produced the largest number of tweets among all the European countries, followed by Spain and then Greece. Slovakia, Romania, and Bulgaria emerge as the European countries with the smallest number of tweets.

The third column indicates the number of followers followed by specific country. Spain, which also is the country with the most travelers overnight stays, is the most active in following other accounts. The second most active country by following is Slovenia, then Portugal. Bulgaria, Romania, and Estonia are the most passive in following other Twitter accounts, among the EU countries.

The fourth column shows the number of followers for the given NTOs' Twitter accounts. Spain has the highest number in the follower's category and represents the only country which has more than 300 million followers. Hungary NTO has the second largest number of followers, and Italian NTO is rated as the third. Countries that have the least followers for

their NTO accounts are Bulgaria, Slovakia, and Lithuania. Among them, the Bulgarian NTO has by far the least number of followers.

The fifth column represents how many likes each country has. The Czech Republic, Spain, and Germany have obtained the most likes from their followers. Oppositely Bulgaria, Malta, and Hungary have the least likes on their posts. The sixth column 'Lists/events' stage event announcements held in the country. Italy, Germany, and Denmark distinguish themselves from other countries by the number of events. The seventh column shows multimedia content on the country profiles. Multimedia content of the top three countries by publishing number, are mostly referring to the photos of the culture, architecture, history, and nature of the given country. Spain, Italy, and Greece publish mostly photos on their profiles, and Sweden, Austria, and Romania post the smallest number on their Twitter accounts.

Figure 2 shows the connection among the number of Tweets and total likes and followers, indicating the connection among three variables exists in most of the countries Twitter account.

The majority of the countries that have the largest number of tweets have also the largest number of followers. Tourism champions that like Spain, Greece, and Italy, subsume a high number of Tweets followed by the high level of followers.

**Table 3.** Twitter of European NTOs across countries. Source: authors' work based on Twitter accounts on EU countries.

Country	Number of Tweets	Following	Followers	Likes	Lists/Events	Multimedia (photo and video)
Austria	3199	343	15083	613	3	339
Belgium	-	-	-	-	-	-
Bulgaria	1464	57	897	44	0	568
Croatia	11921	3076	103099	17006	1	3524
Cyprus	3659	1176	14890	489	0	1040
Czech Republic	13858	2321	33358	78825	0	5757
Denmark	11895	1416	74440	6079	11	4483
Estonia	2266	113	10367	2166	2	475
Finland	6482	731	65774	5229	1	1524
France	6393	1174	31592	4244	8	2239
Germany	14115	1096	14193	4521	11	4698
Greece	30653	1675	103745	17281	1	6742
Hungary	3324	173	291498	169	2	381
Ireland	21078	1279	105665	16487	6	5247
Italy	19415	1269	131606	10013	18	7294
Latvia	-	-	-	-	-	-
Lithuania	2250	1312	3800	744	3	1288
Luxembourg	4654	1590	10457	10054	1	699
Malta	2273	213	29572	75	0	1858
Netherlands	9764	4079	5166	2014	5	2399
Poland	1453	714	16509	392	0	649
Portugal	91615	4805	89539	12090	70	6318
Romania	899	28	30779	4999	94	380
Slovakia	884	139	2475	1502	1	551
Slovenia	15220	5195	43949	13048	13	2845
Spain	43460	24345	315314	24376	11	28700
Sweden	2408	709	28494	187	2	192
United Kingdom	11058	970	15375	1092	7	1376

Ten of twenty-six countries included in the investigations have more followers than likes and tweets and achieve positive tourism results. However, there some outliers presented as well. For instance, Hungary has among the least number of Tweets and is the second-rated by the number of Followers. That could be connected with external influences, such as interest for the countries. Another outlier is Portugal which has an excessive number of Tweets but now followed by the followers. The Czech Republic is an example of inconsistencies as well with the high number of likes, and a lower number of followers. This relationship could be investigated with content analysis of the posts to explore the high engagement of the followers. Notwithstanding the outliers, the relationship among the variables given is unassailable, and the knowledge that excessive tweeting can influence on the popularity of the Twitter account can be useful for NTO's and companies.

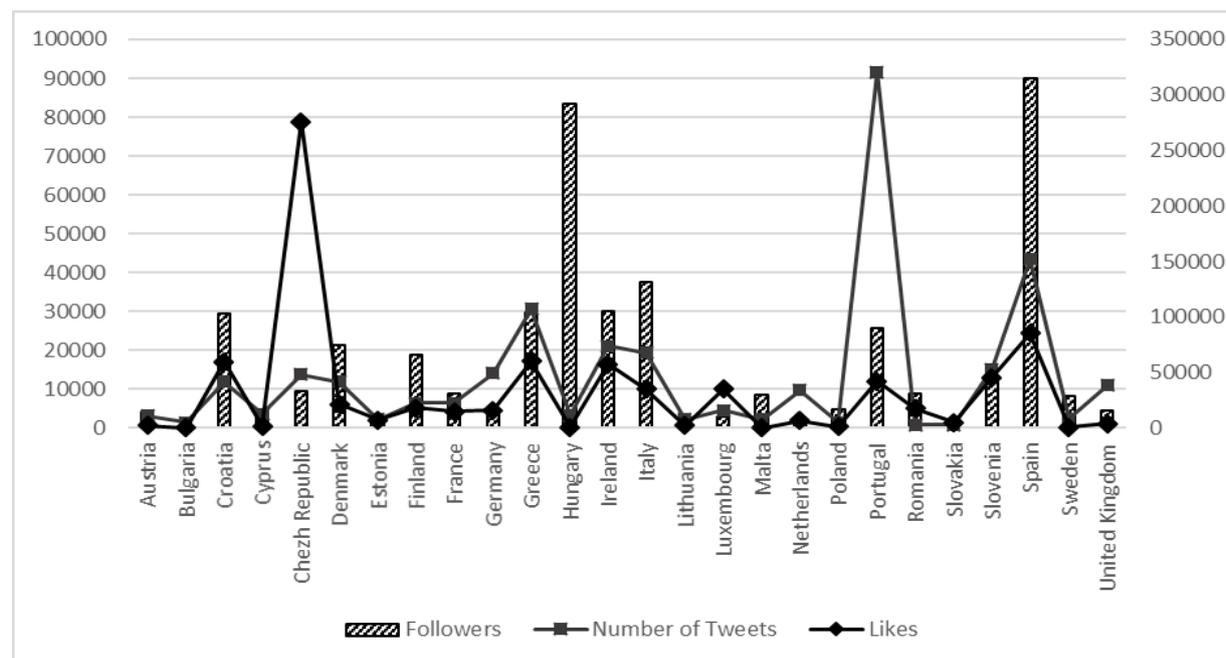


Figure 2. The Twitter activity of European NTOs. Source: authors' work.

## RELATIONSHIP BETWEEN TWITTER ACTIVITY OF NTOs AND TOURISM ACTIVITY OF EUROPEAN COUNTRIES

Table 4 and Figure 3. analytically and visually confirm the connection between tourism activity and Twitter account activity. As the preliminary research in this area, the correlation analysis of the following variables was conducted: 'Nights spend in tourism accommodations,' 'Number of Tweets,' 'Following,' 'Followers' and 'Likes'. Variable connections showed weak (0-0,25), medium (0,25-0,5) and strong correlation (0,5-0,75).

Outcome results confirmed the relationship among all variables included.

The variable 'Nights spent in tourist accommodation' is taken as a tourism success measure. The results indicate that all Twitter activity has a connection with the nights spent in the tourist accommodation in observed countries. The number of followers and the nights spent in the tourist accommodation have the medium correlation; and the number of tweets and the nights spent in the tourist accommodation show weak correlation. The fact confirms that both 'Tweets' and 'Following' are relevant variables measuring Twitter activity, while the 'Followers' and 'Likes' are relevant variables measuring Twitter account popularity. However, it could be premature to conclude that Twitter activity influences the tourist arrivals in a specific country. The example of Spain whose results came on top of both following,

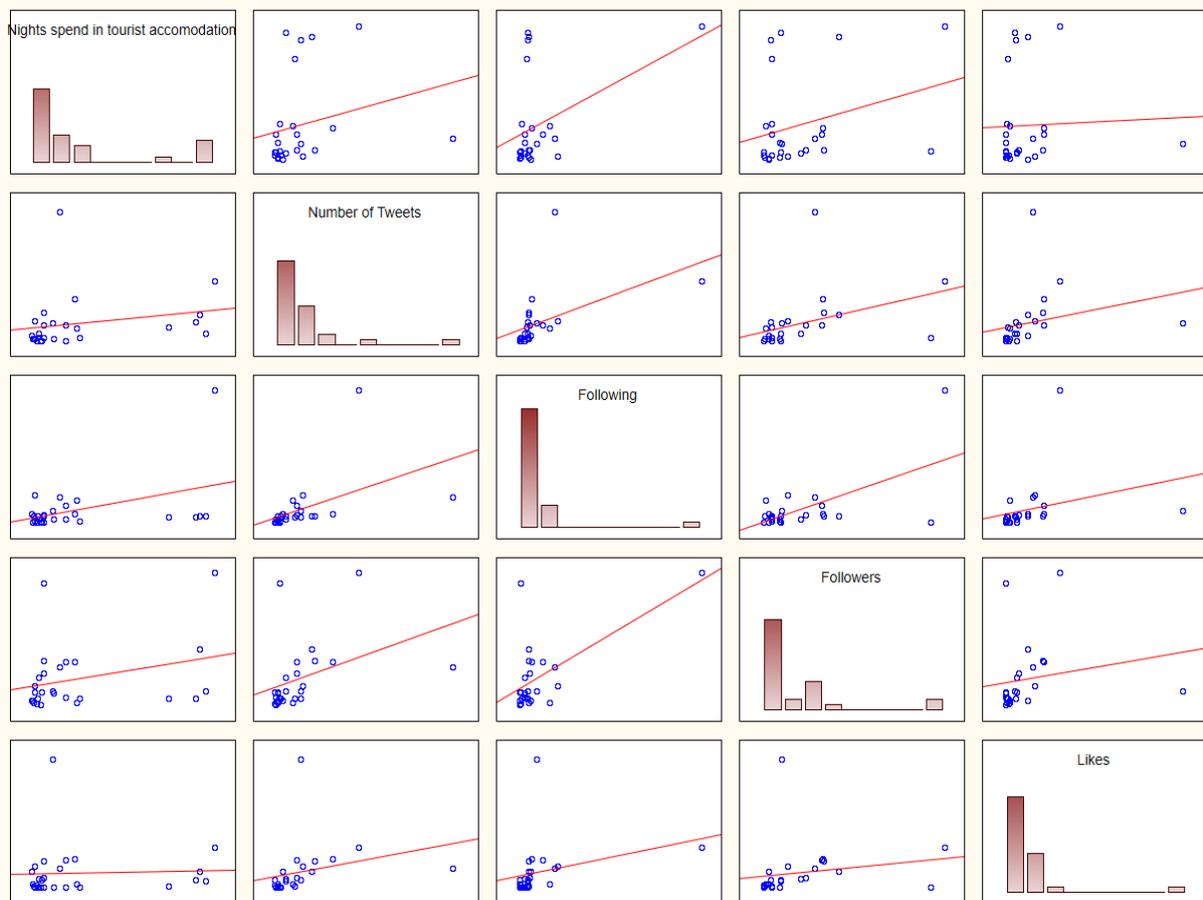
**Table 4.** The relationship among tourism activity and Twitter account activity. Source: authors' work.

	Nights spent in tourist accommodation	Number of Tweets	Following	Followers	Likes
Nights spend in tourist accommodation (in mil)	1,000	0,230*	0,431**	0,302**	0,041*
Number of Tweets		1,000	0,488**	0,392**	0,268**
Following			1,000	0,622***	0,284**
Followers				1,000	0,179*
Likes					1,000

\*weak correlation (0 – 0,25).

\*\*medium correlation (0,25 – 0,5).

\*\*\*strong correlation (0,5 – 0,75).



**Figure 3.** The relationship among tourism activity and Twitter account activity.

followers and nights spend in category indicates that this could be true. On the other hand, it is possible that countries with strong tourism activity also invest more in tourism marketing, and thus in social media marketing, specifically Twitter marketing.

Variable ‘Number of Tweets’ measures the activity of the Twitter account. It shows the medium-level correlation with all activity and popularity measures. That would presume that Twitter accounts who tweet more, also follow more different Twitter accounts and, therefore, produce more activity which positively correlates with popularity measures such as the number of followers and likes. The number of tweets category confirm the insights from Figure 2 which connects a number of tweets to the number of followers and likes. Both results imply that the higher engagement to the account, the higher popularity will result.

Variable 'Following' shows the strong correlation with the variable 'Followers.' The indication is that more the account follows other profiles and shows activity, it becomes more visible and is more engaging, so, consequently gains more followers. Furthermore, more popular accounts, which have more followers tend to engage even more, so they follow and post more often in order to get even better results.

Lastly, the variables 'Likes' and 'Followers' show a weak correlation. It is more likely that the NTO's EU country profile with more followers will also have more likes altogether.

Figure 3 supports the conclusion of Table 3. Scatter diagram shows the strongest correlation among Following and the Followers category. The second pair of variables with the strongest correlation is 'Following' and 'The number of tweets' variables. However, scatter diagrams indicate that substantial number of outliers is present among the given data and that the further research is needed in this area.

## CONCLUSION

The goal of the research was to investigate social media activity of European NTOs', with the focus to Twitter utilization. By answering three research questions, the importance of social media has been pointed out, and the connection among social media activity and tourism results has been entrenched.

The first research question examined social media activity of NTOs of European countries. The majority of the countries observed have all four social media (Facebook, Twitter, Youtube, and Instagram). The analyzed confirmed countries awareness to the importance of social media utilization as the indispensable factor of nation's promotion and branding. The research outputted that more than 97 % of European countries use at least one social media and that over 93 % of NTO's actively use the combination of social media in order to reach a varied audience, spread WOM, and promote their tourism. Social media mechanisms substantiated as to the most powerful marketing and strategy channel nowadays.

Twitter evinced as the most useful social media in tourism sector because of its strong impact on the WOM and the possibility to shape tourism supply based on user preference extracted from Twitter. Many European countries recognized the benefits of Twitter for creating destination image and branding, as well as developing long term destination strategic plan based on Twitter utilization. Instagram has the main advantage in its wide popularity, plus the emerging number of travel bloggers who have the power to promote destination and influence users significantly.

Our results confirm the previous research, that social media uses among EU countries grew from 2012 when more than half countries did not have official accounts to nowadays when they are the omnipresent and far-reaching influential tool and the source of competitive advantage [41].

The second research question focused on the coherence among countries according to the time of establishment and language of Twitter accounts in European countries. It has been established that almost all countries post on the English language due to the goal of viral reach and comprehension. However, two countries post on local languages and alphabets, and looking at their overall results, they turned out lower than the average according to their Twitter NTOs' activity, so this could be considered as the possible reason. Most of the countries NTOs established their Twitter accounts not later than in 2012. Time of joining Twitter accounts could be associated with countries interest in tourism marketing development, but some of the European tourism champions like Italy and Ireland created their accounts later. Although both Ireland and Italy created their Twitter accounts later, they have nowadays more

tweets and followers than Austria and Germany, who created their accounts as the first. An explanation can manifest in the fact that all the countries created their account in a relatively short period and no country is considered as an outlier, so their outputs mainly depend on their engagement and activity and not on time of the account establishment.

Last research question investigated the possible relationship between Twitter activity and country characteristics. Results indicated the moderate correlation between Twitter activity and the tourism results for the European countries. Furthermore, the correlation between Twitter activities and the popularity of the specific profiles appeared. The strongest relationship in the correlation matrix was among ‘Following’ and the ‘Followers’ category, and the all other connection among ‘activity’ categories and ‘popularity’ of the account was confirmed. Therefore, the conclusion is that countries who engage more, tweet and post more, outcome better results and have more followers and likes. This is valuable knowledge for both the academy and practice as well.

In addition, cases of the best practice emerged, Spain turned out to produce among top three results in almost all categories, and all countries who engage and post frequently turned out to have more followers, and great tourism results in terms of overnight stays. On the other hand, countries having lower activity, in addition, produce lower results. Therefore, the conclusions of our research could be useful for the practice of the smaller countries, whilst investigation reported lower results in both tourism and Twitter outputs. Smaller countries should invest more in social media activities because of the word-of-mouth impact and the viral reach of social media. Croatia and Slovenia could serve as an excellent example of social media utilization in smaller countries [42]. This knowledge could serve both for researches and businesses to investigate more of the factor which impacts this correlation in order to generate new models to business strategies.

Limitations of the research are as following. First, the correlations among Twitter activity and tourism outputs are calculated based on the raw data on the country level, thus indicating that this research poses as the preliminary. Second, the causative and consecutive connections between Twitter activity of NTO and tourism activity in a specific country remains ambiguous, and further investigations should be focused to unveil if Twitter results impact on the tourism output. Moreover, instances that disclosed as ‘outliers’ can be valuable for future investigations as well. For instance, Chez Republic Twitter activity displayed a prevalent number of likes, and yet a number of followers which could be interesting for more comprehensive research of which factors implicate on the frequent engagement of followers, while their number remains lower.

## **APPENDIX**

**Table 5.** Links to the NTOs’ Twitter accounts. Source: authors’ work (continued on p.238).

<b>Country</b>	<b>Link to the NOT’s Twitter accounts</b>
Austria	<a href="https://Twitter.com/austriatourism">https://Twitter.com/austriatourism</a>
Belgium	-
Bulgaria	<a href="https://Twitter.com/BGtravelOrg">https://Twitter.com/BGtravelOrg</a>
Croatia	<a href="https://Twitter.com/Croatia_hr">https://Twitter.com/Croatia_hr</a>
Cyprus	<a href="https://Twitter.com/visitcyprus">https://Twitter.com/visitcyprus</a>
Chez Republic	<a href="https://Twitter.com/VisitCZ">https://Twitter.com/VisitCZ</a>
Denmark	<a href="https://Twitter.com/@GoVisitDenmark">https://Twitter.com/@GoVisitDenmark</a>
Estonia	<a href="https://Twitter.com/visitestonia">https://Twitter.com/visitestonia</a>
Finland	<a href="https://Twitter.com/OurFinland">https://Twitter.com/OurFinland</a>
France	<a href="https://Twitter.com/UK_FranceFR">https://Twitter.com/UK_FranceFR</a>

**Table 5.** Links to the NTOs' Twitter accounts. Source: authors' work (continuation from p.237).

Germany	<a href="https://Twitter.com/GermanyTourism">https://Twitter.com/GermanyTourism</a>
Greece	<a href="https://Twitter.com/visitgreecegr">https://Twitter.com/visitgreecegr</a>
Hungary	<a href="https://Twitter.com/wow_hungary">https://Twitter.com/wow_hungary</a>
Ireland	<a href="https://Twitter.com/TourismIreland">https://Twitter.com/TourismIreland</a>
Italy	<a href="https://Twitter.com/Italia">https://Twitter.com/Italia</a>
Latvia	-
Lithuania	<a href="https://Twitter.com/visitLithuania">https://Twitter.com/visitLithuania</a>
Luxembourg	<a href="https://Twitter.com/luxembourginfo">https://Twitter.com/luxembourginfo</a>
Malta	<a href="https://Twitter.com/visitmalta">https://Twitter.com/visitmalta</a>
Netherlands	<a href="https://Twitter.com/meetinholland">https://Twitter.com/meetinholland</a>
Poland	<a href="https://Twitter.com/PolandtravelUS">https://Twitter.com/PolandtravelUS</a>
Portugal	<a href="https://Twitter.com/visitportugal">https://Twitter.com/visitportugal</a>
Romania	<a href="https://Twitter.com/RomaniaTourism">https://Twitter.com/RomaniaTourism</a>
Slovakia	<a href="https://Twitter.com/SlovakTB">https://Twitter.com/SlovakTB</a>
Slovenia	<a href="https://Twitter.com/sloveniainfo">https://Twitter.com/sloveniainfo</a>
Spain	<a href="https://Twitter.com/spain">https://Twitter.com/spain</a>
Sweden	<a href="https://Twitter.com/VisitSweden">https://Twitter.com/VisitSweden</a>
United Kingdom	<a href="https://Twitter.com/VisitBritainBiz">https://Twitter.com/VisitBritainBiz</a>

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