Double Degree

Department of Economics and Management

Master's Degree in Finance

Faculty of Economics and Finance

Master's Degree in Financial Markets and Investment

Testing the Balassa-Samuelson Effect in the Digital Era on the Example of Selected Countries

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Academic Year 2025/2026

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TESTING THE BALASSA–SAMUELSON EFFECT IN THE DIGITAL ERA ON THE EXAMPLE OF SELECTED COUNTRIES

Master's Thesis

Study programme:	Financial Markets and Investment
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Bc. Miriam Vyrvová

Affidavit

I hereby honestly declare that I have written the master’s thesis independently and I have listed all the sources. I also declare that I have used AI tools in accordance with the principles of academic integrity.

In Bratislava Bc. Miriam Vyrvová

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ABSTRACT

VYRVOVÁ, Miriam: *Testing the Balassa–Samuelson Effect in the Digital Era on the Example of Selected Countries.* – Bratislava University of Economics and Business. Faculty of Economics and Finance; Department of Banking and International Finance. – Thesis Supervisor: assoc. prof. Ing. Jana Kotlebová, PhD. – Bratislava: Faculty of Economics and Finance. University of Pavia. Department of Economics and Management. – prof. Patrizio Tirelli. – Pavia, 2026, 97 p.

The master's thesis focuses on investigating the validity of the Balassa-Samuelson effect in the digital era using a panel of selected European developed and emerging economies. The aim of the thesis is to examine whether productivity differentials between tradable and non-tradable sectors explain movements in the real effective exchange rate and whether this relationship has changed with digital transformation. The empirical analysis applies a two-way fixed effects panel model to quarterly data for 26 European countries over the period 2000Q1–2025Q4. The analysis distinguishes between Euro Area and Non-Euro Area countries, compares traditional and digital-adjusted sector classifications, and is complemented by robustness checks and a wage-channel extension. The results provide limited evidence of a uniform Balassa–Samuelson effect in the pooled sample but reveal important heterogeneity across monetary regimes and sectoral classifications. In the Euro Area, the productivity–REER relationship is weak or reversed, while in Non-Euro Area countries it becomes more visible when digital tradability and the wage channel are considered. The findings suggest that the Balassa–Samuelson mechanism has not disappeared but has become more conditional in increasingly digitalised and integrated European economies.

Keywords: Balassa–Samuelson effect, digitalisation, exchange rate, non-tradable goods, price level, purchasing power parity, tradable goods

ABSTRAKT

VYRVOVÁ, Miriam: *Testovanie Balassa-Samuelsonovho efektu v období digitalizácie na príklade vybraných krajín* – Ekonomická univerzita v Bratislave. Národohospodárska fakulta; Katedra bankovníctva a medzinárodných financií. – Vedúca práce: doc. Ing. Jana Kotlebová, PhD. – Bratislava: Národohospodárska fakulta. Univerzita v Pavii: Fakulta ekonómie a manažmentu. – prof. Patrizio Tirelli – Pavia, 2026, 97 s.

Diplomová práca sa zameriava na skúmanie platnosti Balassa-Samuelsonovho efektu v digitálnej ére s použitím panelu vybraných európskych rozvinutých a rozvíjajúcich sa ekonomík. Cieľom práce je preskúmať, či rozdiely v produktivite medzi obchodovateľnými a neobchodovateľnými sektormi vysvetľujú pohyby reálneho efektívneho výmenného kurzu a či sa tento vzťah zmenil vplyvom digitálnej transformácie. Empirická analýza využíva panelový model s fixnými efektmi pre krajiny a čas na kvartálnych dátach pre 26 európskych krajín za obdobie 2000Q1–2025Q4. Analýza rozlišuje medzi krajinami eurozóny a krajinami mimo eurozóny, porovnáva tradičnú a digitálne upravenú sektorovú klasifikáciu a je doplnená testami robustnosti a rozšírením o mzdový kanál. Výsledky poskytujú iba obmedzené dôkazy o jednotnom Balassa-Samuelsonovom efekte v spoločnej vzorke, no zároveň poukazujú na významnú heterogenitu medzi menovými režimami a sektorovými klasifikáciami. V eurozóne je vzťah medzi produktivitou a reálnym efektívnym výmenným kurzom slabý alebo obrátený, zatiaľ čo v krajinách mimo eurozóny sa stáva viditeľnejším po zohľadnení digitálnej obchodovateľnosti služieb a mzdového kanála. Zistenia naznačujú, že Balassa-Samuelsonov mechanizmus nezanikol, ale v čoraz viac digitalizovaných a integrovaných európskych ekonomikách sa stal podmienenejším.

Kľúčové slová: Balassa-Samuelsonov efekt, digitalizácia, výmenný kurz, neobchodovateľné tovary, cenová hladina, parita kúpnej sily, obchodovateľné tovary

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LIST OF ABBREVIATIONS

BIS	Bank of International Settlements
B–S	Balassa–Samuelson
CEE	Central and Eastern Europe
CPI	Consumer Price Index
DDS	Digitally Deliverable Services
DOLS	Dynamic Ordinary Least Squares
DSGE	Dynamic Stochastic General Equilibrium
DSTRI	Digital Services Trade Restrictiveness Index
EU	European Union
FD	First Differences
FE	Fixed Effects
FMOLS	Fully Modified Ordinary Least Squares
GDP	Gross Domestic Product
ICT	Information and Communication Technologies
IPS	Im–Pesaran–Shin
IT	Information Technologies
LLC	Levin–Lin–Chu
LOP	Law of One Price
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary Least Squares
PMGE	Pooled Mean Group Estimation
PPP	Purchasing Power Parity
RE	Random Effects
REER	Real Effective Exchange Rate
RER	Real Exchange Rate
TFP	Total Factor Productivity
TOT	Terms of Trade
U.S.	United States
ULC	Unit Labour Costs

Introduction

Real exchange rate dynamics are a central topic in international macroeconomics. They play a key role in determining external competitiveness, price levels, and economic performance. One of the theoretical explanations of the real exchange rate movements is the Balassa–Samuelson effect, which links productivity differentials between tradable and non-tradable sectors to relative price changes and the real exchange rate appreciation.

While the traditional Balassa–Samuelson framework is based on the critical assumptions, such as strict distinction between tradable and non-tradable sectors or the absence of the between-country labour mobility, digital transformation likely challenges these assumptions. Therefore, this thesis addresses the impact of digitalisation on the standard Balassa–Samuelson effect.

Understanding the determinants of the real exchange rate movements is particularly important for policy makers, as real exchange rate misalignments can affect inflation dynamics, external balances, particularly trade and current account positions, as well as overall macroeconomic stability. In this context, assessing whether traditional theoretical mechanisms remain relevant in modern economies is important.

While the Balassa–Samuelson hypothesis has been extensively studied, empirical evidence remains mixed. Earlier studies often find support for the hypothesis; however, more recent contributions suggest that the relationship between productivity differential and the real exchange rate may be weaker, unstable, or dependent on structural characteristics. Despite the growing importance of digitalisation, its role in shaping the Balassa–Samuelson mechanism has not been fully explored.

This thesis aims to examine the validity of the Balassa–Samuelson effect in European economies and to assess whether its relevance has changed in the context of digital transformation. In particular, the analysis investigates whether productivity differentials significantly affect real effective exchange rate movements, whether this relationship differs across monetary regimes, time periods, development groups, and sectors, and whether the increasing tradability of digital services alters the traditional mechanism.

To address these questions, the empirical analysis employs a panel data framework based on a two-way fixed effects model using quarterly data for 26 European countries over the period 2000Q1–2025Q4. The analysis distinguishes between Euro Area and Non-Euro Area countries in order to account for monetary-regime heterogeneity. It also compares the traditional sector classification with a digital-adjusted specification, in which ICT and financial services are treated as tradable sectors. Additional specifications examine the role of digital services trade restrictiveness, development-stage heterogeneity, sectoral heterogeneity between manufacturing and ICT, and the wage transmission channel.

The contribution of this thesis lies in providing updated empirical evidence on the Balassa–Samuelson effect using recent European data and in examining how digital transformation, monetary-regime heterogeneity, and sectoral reclassification shape the relationship between productivity differentials and the real effective exchange rate. By incorporating digital-adjusted sector definitions and a wage-channel extension, the thesis contributes to the debate on whether traditional productivity-based exchange rate mechanisms remain relevant in increasingly digitalised and integrated European economies.

The rest of the thesis is structured as follows. Chapter 1 reviews the theoretical and empirical literature on the Balassa–Samuelson effect, real exchange rates, and digital transformation. Chapter 2 defines the objective of the thesis and presents the research questions. Chapter 3 describes the data, variable construction, and empirical methodology. Chapter 4 presents empirical results, while Chapter 5 discusses the findings, limitations, and policy implications.

1 Literature Review

The relationship between productivity differentials and real exchange rate (RER) movements has been a fundamental part of international macroeconomics for a long time. At the core of this discussion is the Balassa–Samuelson (B–S) effect, which provides a theoretical structure for understanding differences in price levels across countries. The B–S hypothesis explains why developed countries—characterised by high productivity in manufacturing—exhibit higher domestic price levels than developing countries by using a clear distinction between tradable and non-tradable sectors. However, as the global economy becomes increasingly digitalised, the traditional boundaries of this model are being challenged, necessitating a re-evaluation of its core assumptions.

1.1 Purchasing Power Parity and Real Exchange Rate

1.1.1 Purchasing Power Parity

The Purchasing Power Parity (PPP) represents an important theoretical benchmark for understanding exchange rates and cross-country price level differences. It is especially relevant to the B–S framework, since the latter assumes that deviations from PPP may reflect structural productivity differences rather than currency misalignment (Rogoff, 1996; Taylor & Taylor, 2004).

The PPP theory states that national price levels should be equal across countries, when expressed in a common currency, implying the same purchasing power internationally. In other words, a unit of one country's currency should be able to purchase the same basket of goods in a foreign country as it does at home. The intuition behind the PPP is reflected in the law of one price (LOP), which states that internationally traded goods should be sold for the same price across countries when converted to a common currency. In practice, however, transaction costs such as tariffs, taxes, and transportation costs often violate the LOP, as they create price differences across countries (Rogoff, 1996; Taylor & Taylor, 2004).

The PPP hypothesis is usually discussed in two forms—absolute PPP and relative PPP. Absolute PPP assumes equality in purchasing power across countries when prices are expressed in a common currency. However, this is difficult to verify in practice, since consumption baskets are not uniform across economies. Hence, most empirical studies rely on relative PPP instead. Relative PPP states that exchange rate movements should broadly reflect inflation differences between countries. If absolute PPP hold, it implies that relative PPP also holds. However, the reverse does not necessarily apply (Taylor & Taylor, 2004).

Although the PPP serves as a benchmark for exchange rate analysis, it does not hold perfectly in practice. The ability of arbitrage to equalise goods prices internationally is limited, due to transport costs, trade barriers, and non-traded components in many goods, resulting in deviations from PPP persisting over time (Rogoff, 1996).

1.1.2 Real Exchange Rate

The real exchange rate is a relative price measure that captures either the price of domestic goods relative to foreign goods, or the price of tradables relative to non-tradables within an economy. In macroeconomic interpretation, the RER reflects deviations from PPP and indicates international competitiveness of countries. The RER is determined by a combination of macroeconomic and structural factors, including relative price movements, nominal exchange rate dynamics, terms of trade (TOT), capital flows, and policy conditions. As a result, it represents a general equilibrium outcome, determined jointly by conditions in goods and asset markets, and macroeconomic policies, rather than by a single factor (Demir & Razmi, 2021; Itskhoki, 2021; Rodrik, 2008).

The RER plays an important role in economic development, because it influences the allocation of resources across sectors. In particular, the RER affects the profitability of tradable sectors, which are typically linked to productivity gains and technological spillovers. A relatively undervalued RER can support exports, investment, and the overall expansion of productive sectors by improving the competitiveness of domestic producers in international markets. In contrary, an overvalued RER may reduce the profitability of tradable sectors, weaken exports, and slow down industrial expansion. However, the relationship between the RER and growth is not uniform across countries, as it depends on country-specific conditions and the broader macroeconomic environment (Demir & Razmi, 2021; Rodrik, 2008).

An important concept related to the RER is its misalignment. It refers to deviations from the equilibrium exchange rate, which is associated with the maintenance of both external and internal balance. Such deviations can take the form of overvaluation or undervaluation. Generally, countries with undervalued RER often exhibit faster and stronger growth, whereas an overvalued RER may harm growth. However, determining the equilibrium level is not straightforward and depends heavily on the chosen method. Therefore, the concept of RER misalignment is essential, as different methods of measurement may lead to different results (Demir & Razmi, 2021; Rodrik 2008).

1.2 The Balassa–Samuelson Effect

The B–S effect represents a key theory in international economics that provides an empirically grounded explanation for a well-known phenomenon: the systematic tendency for the price levels to be higher in rich, developed countries than in poorer, emerging ones. The theory, introduced independently by Balassa (1964) and Samuelson (1964), fundamentally challenges the standard PPP doctrine. It holds that observed price differences arise mainly from structural differences in productivity growth across economic sectors, rather than currency misalignment. The B–S effect, therefore, provides an important framework for understanding international price level differences, long-run RER dynamics, and cross-country income comparisons (Demir & Razmi, 2021; Itskhoki, 2021)

The traditional B–S model rests on a distinction between tradable and non-tradable sectors. In this framework, the tradable sector consists of goods that can be easily and profitably traded internationally, including, for example, manufactured goods or agricultural commodities. The main characteristic of this sector is that prices are subject to international competition and arbitrage (Balassa, 1964). In this stylized setting, many services are treated as non-tradable, because they depend on local labour and domestic market conditions. Classic examples of non-tradables include personal services, housing construction, or restaurant meals. Prices in the non-tradable sector are mainly determined by domestic supply and demand conditions, which are intrinsically linked to local wage levels (Samuelson, 1964).

1.2.1 The Mechanism of the Balassa–Samuelson Effect

The mechanism of the B–S effect can be described in the following steps:

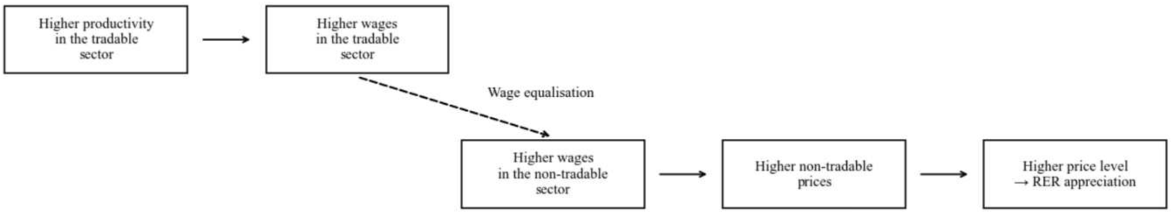
1. **Productivity Differential:** The primary driver is a disparity in productivity growth rates between the tradable and non-tradable sectors. Within economies, the tradable sector is typically the primary source of technological progress and innovation. This sector benefits from large-scale production efficiencies, capital intensification, and rapid integration of new technologies, resulting in high rates of productivity growth. On the contrary, the non-tradable sector—particularly personal and local services—is more labour-intensive and less affected by technological changes. This productivity differential is the core factor that drives the B–S effect. This disparity is evident in the cross-country context, where high-income economies typically have higher productivity levels compared to developing economies.

2. **Wage Equalisation:** Higher productivity growth in the tradable sector enables companies to offer higher wages to their employees. However, these wage increases cannot remain limited to the tradable sector due to the assumption of labour mobility across sectors within a country. Employees in the non-tradable sector must be offered comparably high wages to prevent a significant shift of the workforce from the non-tradable sector to the tradable sector. This process of wage equalisation is a critical feature of integrated national economies.
3. **Divergence in price dynamics:** In the tradable sector, strong productivity growth often offsets wage growth, allowing firms to offer higher wages without necessarily raising the prices of their outputs. Furthermore, these prices are limited by international competition; if domestic prices were set too high, companies would be undercut by imports. However, in the non-tradable sector, the productivity growth remains low. Since wages must mirror those in the tradable sector to ensure labour retention, companies in the non-tradable sector are forced to raise their prices to cover the rising labour costs. As a result, non-tradables become more expensive in advanced economies relative to developing economies.
4. **Exchange Rate Divergence:** Exchange rates are determined in international markets and depend primarily on the prices of tradables. Since these goods are subject to arbitrage, their prices naturally converge toward international price parity when converted at the market exchange rate. However, the general price level—measured by indices such as the Consumer Price Index (CPI) or the GDP deflator—is a weighted average of both tradable and non-tradable goods and services. In wealthy countries, this aggregate measure is pulled upward by the higher costs of non-tradables. Consequently, comparing the elevated overall price level of a wealthy country with that of a less developed one makes the currency of the rich country appear overvalued.

Eventually, the PPP doctrine, which assumes that the exchange rate should equalise the costs of an identical basket of goods, fails because it incorrectly applies the economic logic of internationally tradable goods to the entire economy, including structurally more expensive non-tradables (Balassa, 1964).

The sequence of this transmission mechanism is summarised in Figure 1.

Figure 1: The Transmission Mechanism of the Balassa–Samuelson Effect



Source: Author's own elaboration based on Balassa (1964) and Samuelson (1964).

1.2.2 The Formal Model

Balassa (1964) introduced a model with the following structure:

- Two countries (Country 1 and Country 2),
- Two tradable goods and one non-tradable good,
- Labour as the only factor of production,
- Perfect labour mobility within each country, but immobility across countries,
- A fixed relationship between inputs and outputs in production.

Having established the model's structure, the key implications of the model can be expressed through the following steps:

1. **The Initial Price Level Comparison:** The core relationship is expressed as an inequality: the PPP—defined as the ratio of price levels between Country 2 and Country 1—is lower than the equilibrium exchange rate expressed in currency of Country 1, regardless of which country is used as the weight. Hence:

$$\frac{\sum p_2 q_1}{\sum p_1 q_1} < r_1^2, \tag{1}$$

   and

$$\frac{\sum p_2 q_2}{\sum p_1 q_2} < r_1^2, \tag{1.1}$$

   where:

   - p_1, p_2 denote the prices levels in Countries 1 and 2,
   - q_1, q_2 denote the consumption weights in Countries 1 and 2,
   - r_1^2 denotes the equilibrium exchange rate (Balassa, 1964).

2. **The Functional Relationship:** Building on this inequality, Balassa (1964) argues that the deviation of PPP from the equilibrium exchange rate is systematic, rather than random, and is linked to economic fundamentals. Therefore, the ratio of the PPP to the exchange rate is expressed as an increasing function of relative income per capita between the two countries:

$$\frac{PP_1^2}{r_1^2} = F({y_2}^1), \tag{2}$$

where:

- PP_1^2 denotes the purchasing power parity of Country 2's currency in terms of Country 1's currency,
- r_1^2 denotes the equilibrium exchange rate, expressed in the currency of Country 1,
- ${y_2}^1$ denotes the income per capita in Country 2 relative to Country 1 (Balassa, 1964).

3. **The Mathematical Proof:** The following derivation provides a formal representation of the mechanism described by Balassa (1964). The theoretical mechanism is established by linking productivity differentials to relative price levels. The argument begins with the assumption that international trade leads to the equalisation of prices of tradable goods across countries through the LOP:

$$P_T^1 = r_1^2 P_T^2. \tag{3}$$

Under conditions of perfect competition, prices equal marginal costs. Thus, wages in the tradable sector reflect labour productivity. This implies that the international wage ratio is proportional to the tradable-sector productivity differential:

$$\frac{W^1}{W^2} = \frac{A_T^1}{A_T^2}, \tag{4}$$

where:

- W^j denotes the wage in Country j,
- A_T^j denotes the labour productivity in the tradable sector of Country j.

Given domestic labour mobility, wages are equalised between the tradable and non-tradable sectors within each economy. Consequently, the price of non-tradables is determined by the domestic wage and sector-specific productivity:

$$P_N^1 = \frac{W^1}{A_N^1}, \qquad P_N^2 = \frac{W^2}{A_N^2}. \tag{5}$$

Combining the pricing conditions for tradable and non-tradable sectors implies that the relative price of non-tradables within each country depends on relative sectoral productivity:

$$\frac{P_N^j}{P_T^j} = \frac{A_T^j}{A_N^j}. \tag{6}$$

If productivity differences are larger in the tradable sector than in the non-tradable sector, i.e.

$$\frac{A_T^1}{A_N^1} > \frac{A_T^2}{A_N^2}, \tag{7}$$

then higher wages in the more productive country lead to higher relative prices for services. Thus, the relative price of non-tradables satisfies:

$$\frac{P_N^1}{P_T^1} > \frac{P_N^2}{P_T^2}. \tag{8}$$

This result confirms cross-country productivity differentials generate systematic deviations from PPP by raising the relative price of non-tradables in more productive economies. Because prices of non-tradable goods are incorporated into the general price level but do not directly affect the exchange rate, the overall price level rises more in the high-productivity country. This mechanically forces the PPP below the exchange rate, thereby confirming the initial inequality—Equation (1) and (1.1).

4. **Empirical Verification:** The theoretical prediction is evaluated using cross-country data on price levels and relative income. The empirical proposition advanced by Balassa (1964) can be expresses in regression form as followed:

$$\frac{PPP_1^2}{r_1^2} = \beta_0 + \beta_1 \left(\frac{Y_2}{Y_1}\right) + \epsilon, \tag{9}$$

where:

- the dependent variable $\frac{PPP_1^2}{r_1^2}$ measures the ratio of PPP to the equilibrium exchange rate,
- the independent variable $\frac{Y_2}{Y_1}$ serves as an observable proxy for underlying productivity differentials,
- β_1 is the slope coefficient, while ϵ represents an error term.

The B–S hypothesis predicts $\beta_1 > 0$, implying that countries with higher relative income levels exhibit higher price levels due to productivity-driven increases in wages and non-tradable prices (Balassa, 1964).

5. **Extension to Relative PPP:** The B–S mechanism can also be expressed in a simplified form by focusing on changes in relative prices over time. In this setting, differences in productivity growth in the tradable sector and relative price movements are expressed through the relationship:

$$\frac{GNP\ Deflator}{WPI_M} = f(Productivity\ Growth\ in\ Manufacturing), \tag{10}$$

where:

- GNP deflator serves as a proxy for the general price level,
- WPI_M denotes Wholesale Price Index of manufactured goods, representing the price of tradables,
- $f(\cdot)$ is assumed to be an increasing function.

Higher productivity growth in manufacturing leads to higher wages economy-wide, increasing the prices of non-tradables and widening the gap between the overall price level and tradable-goods prices (Balassa, 1964).

1.3 Previous Empirical Studies on the Balassa–Samuelson Effect

1.3.1 Theoretical Foundations

The B–S hypothesis, formulated by Balassa (1964) and Samuelson (1964), provides the theoretical foundation for research on long-run deviations from PPP and RER appreciation. The core assumption holds that economies with faster productivity growth in the tradable sector tend to exhibit higher relative prices in non-tradables and, consequently, real appreciation. This prediction is especially relevant in studies of converging economies. Converging economies—those where tradable sector productivity grows faster than in advanced benchmark economies—should experience sustained real appreciation over time (De Gregorio et al., 1994). Therefore, the empirical validation of this hypothesis has evolved through several phases, beginning with intensive analysis of Central and Eastern European (CEE) transition economies in the 1990s and early 2000s, where the mechanism was expected to operate most visibly.

1.3.2 Transitional Economies as a Natural Laboratory

The transition of CEE economies from centrally planned to market economies provided a unique opportunity to test the B–S hypothesis under conditions closely approximating the theory's prediction. These economies experienced rapid productivity growth in newly privatised industrial sectors, profound labour reallocation, and quick integration into global markets—structural changes that the hypothesis anticipates. Because these shifts happened relatively quickly during the 1990s and 2000s, they allowed researchers to observe transmission mechanism that, in mature economies, might only unfold gradually over decades.

Égert (2002) provided important evidence using both time-series and panel cointegration methods for five transition economies—the Czech Republic, Hungary, Poland, Slovakia, and Slovenia—throughout the 1990s.

While confirming the statistical presence of the B–S effect, his analysis revealed important factors that constrain the translation of productivity gains into observable inflation. Most significantly, he demonstrated that the construction of the CPI, which bundles domestically produced non-tradables with imported consumer goods and often includes administratively controlled prices, acts as a systematic filter that reduces the measured inflationary impact. Using actual CPI weights rather than GDP shares substantially reduces estimated B–S-driven inflation: for instance, in Hungary, the estimate fell from approximately 3-4% to 1.5-2.3% during 1996-2001 period, and in Poland from 2.8-3.8% to 1.7-2.4%.

Moreover, Égert documented that observed real appreciation (e.g., 4.8% annually in the Czech Republic, 4.1-6.1% in Poland) systematically exceeded productivity-justified appreciation. This inconsistency indicates that other factors—such as capital inflows, the correction of initial undervaluation, and demand-side shift—dominated RER movements even in these favourable laboratory conditions.

Building on these insights, Mihaljek and Klau (2003) provided a more disaggregated analysis of six CEE economies, including Croatia. They introduced a critical methodological refinement by distinguishing the "international" B–S effect, which explains inflation differentials between an emerging country and a developed benchmark, from the "domestic" Baumol-Bowen effect, which explains relative price changes within the domestic economy alone. This distinction significantly altered empirical estimates. When the model was properly specified using Euro Area comparators, the authors found that productivity differentials explained, on average, only 0.2 to 2.0 percentage points of annual inflation differential. The results revealed considerable heterogeneity across countries. While the effect reached 1.0 percentage point in Hungary and 0.5 in the Czech Republic, it was merely 0.15 in Poland and Croatia. Mihaljek and Klau demonstrated that earlier studies, which reported effects of 3–4% annually, were likely biased. These overestimations occurred because previous researchers often mixed domestic price shifts with international differentials, neglected productivity growth in the non-tradable sector, or used overly aggregated data. For policymakers in CEE economies, this finding was relevant in the context of potential euro adoption. The authors show that B–S-driven inflation would, in most cases, remain within the margin allowed by the Maastricht inflation criterion.

The most comprehensive methodological treatment was provided by Blaszkiewicz et al. (2004), who examined nine CEE countries. Before estimating the effects, they tested whether the key assumptions of the B–S model held in these economies. Using advanced panel estimators—such as Group Mean Fully Modified Ordinary Least Squares (FMOLS) and Pooled Mean Group Estimation (PMGE)—they found robust evidence for the "internal" transmission mechanism (the link between relative productivity and the relative price of non-tradables). Their results showed long-run elasticities between 0.35 and 0.56, meaning productivity growth pushed up domestic prices.

However, the authors noted significant differences between countries. In Poland, the impact was strong (coefficients of 1.16 and 1.29), while in Czechia, the elasticities were more moderate (around 0.54–0.61). Crucially, Blaszkiewicz et al. found that while productivity clearly drove domestic price structures (the internal mechanism), its impact on RER (the external mechanism) was less direct. In fact, the relationship with exchange rates only became significant when specific time trends were included. This suggests that while productivity shapes domestic prices, its transmission to international relative prices operates through more complex channels. Their estimated range for B–S-consistent annual inflation (0 to 3%) confirmed the conservative results of previous research.

These studies of transition economies established three key empirical regularities. First, the B–S effect operates in practice but with magnitudes substantially smaller than theory suggests. It typically contributes only 0.2–2.0 percentage points annually to inflation differentials. Second, the internal transmission mechanism (linking productivity to domestic relative prices) is more robust and identifiable than the external mechanism (linking productivity to the RER). The latter remains subject to confounding factors, such as capital flows and corrections of initial currency undervaluation. Third, methodological choices—specifically sectoral definitions, the use of CPI versus GDP weights, and the distinction between domestic and international effects—critically influence estimated magnitudes and explain much of the variance across studies.

These foundational analyses relied on data from the 1990s and early 2000s, a period predating the digital transformation of service delivery. This thesis explores whether these findings and methodology remain applicable in the digital economy, where services are increasingly traded through digital platforms, which fundamentally alters the tradable/non-tradable dichotomy central to the B–S hypothesis.

Furthermore, some economies use deliberate exchange rate undervaluation (currency war) as a policy tool to enhance export and promote economic growth. This is often realised through interventions that keep the exchange rate below its market equilibrium. This tactic has been employed in several developing countries, to maintain an advantage in trade (Ghosh, Ostry, & Tsangarides, 2010). However, such practices can distort the relative price signals, affecting RER and potentially causing misalignments in inflation expectations. This is highly relevant in emerging economies, where exchange rate policies have a more direct effect on projections of economic growth.

1.3.3 Methodological Refinements

The variance in empirical estimates across transition economy studies prompted deeper investigation of measurement and specification issues, leading to significant methodological advances. These refinements address four key challenges: sectoral classification, productivity measurement, structural breaks, and econometric specification.

A key source of divergence across studies is the definition of tradable and non-tradable sectors. As Égert (2002) noted, the common practice of using "industry" as a proxy for the tradable sector is fundamentally flawed. This broad category often includes construction and utilities—activities with very low international tradability. Mihaljek and Klau (2003) addressed this by expanding the tradable sector to include manufacturing, mining, transportation, communications, and tourism, while non-tradable sector included energy, construction, wholesale and retail trade, financial intermediation, real estate, and personal services. This distinction is increasingly important, since the traditional division between tradable and non-tradable sectors becomes less relevant in digital economy.

By using this broader sectoral coverage, their estimates of the "domestic" Baumol–Bowen effect ranged from 0.6 to 2.7 percentage points across countries—substantially lower than in studies that neglected productivity growth in the non-tradable sector. Furthermore, by calculating country-specific shares of non-tradables (which range from 54–60% in Central Europe compared to 76% in the Euro Area) rather than assuming homogeneity, they obtained more precise estimates of the international B–S effect of only 0.2–2.0 percentage points annually.

Blaszkiewicz et al. (2004) provided a formal analysis demonstrating how sectoral misclassification introduces systematic "attenuation bias". They showed that when a defined "tradable" sector contains non-tradable activities, the measured coefficient of productivity differentials is biased toward zero. This mathematical proof explains why many early studies failed to find a significant B–S effect despite visible productivity growth.

A parallel challenge involves the measurement of productivity itself. Due to the difficulties in constructing reliable capital stock data, studies often use average labour productivity (output per worker or per hour) as a proxy for Total Factor Productivity (TFP). As Mihaljek and Klau (2003) and Blaszkiewicz et al. (2004) acknowledge, this substitution is imperfect. Tradable sectors are typically more capital-intensive than service sectors, potentially leading to an overestimation of the B–S effect. Despite this limitation, the practical unavailability of high-quality capital stock data means that labour productivity remains the standard measure in applied work.

The treatment of structural breaks represents another critical methodological challenge. Hoarau (2004) highlighted the importance of accounting for these breaks when testing long-run PPP in developing economies. By using panel stationary tests that allow for multiple structural breaks, he analysed 17 Common Market for Eastern and Southern Africa (COMESA) countries between 1970 and 2000. His findings showed that standard tests overwhelmingly reject PPP, with only 17.6% of countries supporting stationarity. However, when the tests accounted for multiple structural breaks—most of which occurred in the early 1990s following exchange rate reforms—the evidence reversed. This suggests that earlier rejections of PPP likely reflected neglected structural changes rather than genuine lack of long-run equilibrium. Consequently, Hoarau (2004) proposed a “quasi-B–S PPP” concept, where RER reverts to a changing trend rather than a constant one. This adjustment is particularly relevant for transition and developing economies, where policy and structural discontinuities are common.

The econometric toolkit has evolved alongside these measurement refinements. Blaszkiewicz et al. (2004) exemplify the shift toward sophisticated panel methods, using Pedroni panel cointegration tests and estimators such as FMOLS and Dynamic Ordinary Least Squares (DOLS). These methods are designed to handle non-stationary data and provide consistent estimates in cointegrated systems, addressing critical issues such as endogeneity, serial correlation, and cross-sectional dependence, which can bias standard estimators. This evolution is crucial in examining B–S dynamics in the digital economy.

Beyond measurement and estimation refinements, theoretical advances have fundamentally deepened the understanding of the B–S effect. One of the most significant contribution came from Ghironi and Melitz (2005), who recast the effect within a Dynamic Stochastic General Equilibrium (DSGE) framework featuring firm heterogeneity and endogenous trade participation. In their model, the dichotomy between tradable and non-tradable sectors is not assumed a priori. Instead, all goods are potentially tradable.

However, only firms with productivity above a certain threshold find it profitable to export after accounting for fixed and variable trade costs. In this framework, a positive aggregate productivity shock has multiple effects: it raises wages, as in the traditional B–S model, but it also lowers the export productivity threshold (the "cutoff"). This process changes the composition of consumed goods and their average prices, resulting in the RER appreciation and substantial persistence in deviations from PPP.

Ghironi and Melitz also introduced an important distinction between welfare-based price indices and their empirical counterparts. In their framework, the welfare-based price index differs fundamentally from the average price index used to measured CPI due to "product variety effects". This means that while a productivity advantage may raise average prices (leading to CPI-based appreciation), it can simultaneously increase product variety enough that welfare-based prices fall. Their impulse response analysis highlights that standard CPI-based measures may systematically misrepresent welfare implications. This has significant consequences for PPP adjustments used in international income comparisons. This micro-founded approach is particularly relevant for understanding B–S dynamics in the digital era. If digital platforms and lower communication costs dramatically reduce trade participation costs, the B–S mechanism would operate significantly within sectors through firm entry and exit decision. This process could complement, or even substitute, the traditional between-sector channel.

Collectively, these methodological and theoretical refinements have established a sophisticated toolkit for testing the B–S hypothesis, while also revealing how sensitive empirical estimates are to specification choices. The emerging consensus suggests that the effect operates reliably but modestly. Its magnitude depends heavily on sectoral classification, productivity measurement, and the econometric techniques employed. However, this entire methodological framework was constructed for economies where the distinction between tradables and non-tradables was relatively clear, based on physical characteristics and transport costs. Whether these frameworks remain adequate when services become digitally deliverable across borders—fundamentally blurring traditional sectoral boundaries—is a question this thesis investigates.

1.3.4 Recent Evidence from Advanced Economies

Recent empirical work, incorporating data from the 2010s and 2020s, reveals a puzzling pattern that challenges the consensus established by earlier studies. While the standard B–S hypothesis predicts that higher productivity in the tradable sector leads to RER appreciation, several studies of advanced OECD economies find evidence of weakening or even reversed effects.

The findings from Gubler and Sax (2019) provide the most striking evidence of this anomaly. Analysing 13 OECD countries—including major economies such as Germany, France, and the U.S.—over the 1984–2008 period using sectoral TFP data, they document what they term an “opposite Balassa–Samuelson effect”. Specifically, they found a 10% increase in tradable sector productivity is associated with 1.0% to 2.3% RER depreciation, depending on model specifications.

This finding proved robust across alternative samples and productivity measures, including an extended 18-country sample using labour productivity data from 1970 to 2008. Gubler and Sax explore several potential mechanisms for this reversal. For instance, they include home bias in consumption preferences (which improves TOT), skill-biased technological change that differentially affects wage structures across sectors, and deviations from the LOP for tradable goods.

Drawing on their earlier theoretical work (Gubler and Sax, 2014), they demonstrate that when technological progress in tradables is skill-biased, it can reduce the demand for low-skilled labour. If this leads to lower wages for low-skilled workers, it could theoretically reduce production costs in the non-tradable sector, contradicting the wage equalisation assumption. However, their analysis predates the widespread recognition of digital services tradability and does not incorporate measures of digital trade restrictiveness or the development of platform economy.

This analysis opens a critical question: whether the digital transformation of services provides an additional, or even alternative, explanation for this counterintuitive pattern.

Hogen and Kishi (2024) provide robust longitudinal evidence of the B–S effect reversing within a single advanced economy. Using a two-country New Keynesian DSGE model for Japan and the U.S. (1970–2022), they identified a structural break around 1995. During the first phase (1970s to mid-1990s), Japan’s rising relative productivity in tradable sectors—including manufacturing and Information and Communication Technologies (ICT) industries—led to yen appreciation, consistent with classic B–S predictions. However, during the second phase (mid-1990s to 2022), the mechanism reversed entirely. Japan’s relative tradable sector productivity declined compared to the U.S., leading to a sustained real depreciation of yen. Hogen and Kishi link this reversal to the global acceleration of ICT in the late 1990s. They note that Japan’s ICT investment did not keep pace with the U.S., leaving Japan without a leading industry to replace its stagnating machinery sector.

Notably, they also highlight Japan's persistent deficit in its digital service balance of payments as driver of real depreciation. While this analysis innovatively incorporates ICT productivity, it remains limited to a bilateral Japan–U.S. comparison. It does not examine how variation in digital trade policies or service sector tradability moderates this mechanism across a broader set of economies. This gap is addressed in this thesis.

Hassan (2016) provides an important qualification to the "Penn–Balassa–Samuelson" effect by analysing 133 countries. He found the relationship between prices and income to be non-linear and non-monotonic. Specifically, the relationship turns negative for low-income countries while remaining positive for middle- and high-income economies. This suggests that the stage of development fundamentally conditions how B–S mechanism operates.

Wang et al. (2016) extend this analysis by testing the hypothesis separately for 20 developed and 20 developing countries. Strikingly, they find strong evidence for the B–S hypothesis in developed countries, but little to no evidence for developing countries, where cointegration tests failed to identify a stable long-run relationship. They attribute this divergence to violations of core assumptions in developing economies, such as imperfect labour mobility between sectors and the failure of PPP for tradable goods. Together, these studies confirm that the stage of development shapes B–S dynamics—a finding that motivates this thesis's distinction between advanced and emerging European economies. However, neither Hassan (2016) nor Wang et al. (2016) account for variation in digital trade openness, leaving unexplored whether digital transformation creates additional heterogeneity.

These recent studies present a complex and somewhat contradictory picture. While Wang et al. (2016) find that the B–S effect operates primarily in developed economies, Gubler and Sax (2019) document a reversal in precisely those same advanced OECD countries. Hogen and Kishi (2024) offer a potential resolution to this tension by showing that the effect is time-varying: it functioned accordingly to classical predictions until the mid-1990s but reversed thereafter—precisely when the ICT revolution accelerated.

This timing is not coincidental. The emergence of digital technology as a driver of productivity differentials has profoundly altered the sectoral dynamics central to the B–S mechanism. However, a significant gap remains in the literature. None of the studies explicitly tests whether cross-country variations in digital trade policies explains the divergent outcomes observed during this transformation.

Economies that embraced digital services trade openness may have experienced different B–S dynamics than those maintaining regulatory barriers. This hypothesis is directly motivated by Hogen and Kishi's finding that Japan's ICT lag, potentially exacerbated by its digital sector trade deficit, contributed to the B–S reversal. This unexplored connection between digital trade policies and B–S dynamics forms the central research question this thesis investigates.

1.3.5 Synthesis and Research Gaps

The empirical literature established a clear baseline understanding of the B–S effect. Transition economy studies of the 1990s and 2000s confirmed that the hypothesis operates in practice, with productivity differentials contributing 0.2 to 2.0 percentage points annually to inflation differentials in CEE economies (Égert, 2002; Mihaljek and Klau, 2003; Blaszkiewicz et al., 2004). The internal transmission mechanism proved robust, while the external mechanism—linking productivity to RER—operated through more complex, context-dependent channels.

More recent evidence from advanced OECD countries reveals that these dynamics have shifted markedly. Gubler and Sax (2019) document a reversal of the traditional effect in 13 OECD countries, while Hogen and Kishi (2024) traced a specific structural break in Japan's B–S dynamics to the mid-1990s, coinciding with the acceleration of the ICT revolution. Hassan (2016) and Wang et al. (2016) further demonstrated that the relationship is fundamentally conditioned by the stage of development, operating differently across income groups.

Despite these contributions, three critical research gaps remain:

1. **The Role of Digital Transformation:** While Hogen and Kishi (2024) identify ICT productivity as driver of B–S reversal in Japan, no study has explicitly tested whether the broader digital transformation of goods and services—the increasing ability to sell goods and deliver services across borders—explains the weakening or reversal of the effect across a wider set of economies. The timing of empirical anomalies documented by Gubler and Sax (2019) and Hogen and Kishi (2024) coincides with the rise of digital service delivery, yet this connection remains untested.
2. **The Blurring of Service Tradability:** The B–S mechanism traditionally relies on a distinction between tradable and non-tradable sectors. However, as Jensen and Kletzer (2010) demonstrated, digital technology has made a substantial and

growing share of services internationally tradable. Moreover, digitalisation has also increased tradability of goods as platforms such as Shein, Temu, and eBay, have accelerated the cross-border trade. This shift requires a revision of the traditional categorisation of sectors. If the service sector is no longer insulated from international competition, the wage-price transmission mechanism central to the B–S hypothesis may be fundamentally compromised. No existing study directly tests how this changed tradability affects the estimated B–S coefficients.

3. **Current Magnitude and Heterogeneity in the Digital Era:** Existing consensus estimates (of 0.2 to 2.0 percentage points) derive from data predominantly from the 1990s. It is unknown whether this range remains valid for European economies in the post-2014 period, when digital service delivery accelerated. Furthermore, no study examines whether the effect varies with countries' digital trade restrictiveness. Economies with high regulatory barriers may preserve traditional B–S effects, while digitally open economies may experience weakened transmission as their services face international competitive discipline.

This thesis addresses these gaps and makes several contributions to the literature. First, it provides a systematic test of whether digital transformation has altered B–S dynamics using a panel of 26 European economies (2000Q1–2025Q4). Second, it introduces digital economy variables—specifically, the OECD Digital Service Trade Restrictiveness Index (DSTRI) (Ferencz, 2019)—into B–S specifications for the first time. Third, it updates the foundational analyses while testing a specific digital economy mechanism to explain recent anomalies. The following section examines theoretically how digitalisation challenges each core B–S assumption and derives the testable hypotheses that operationalise these contributions.

1.4 Digital Transformation

The previous section reveals several anomalies in recent empirical analyses: Gubler and Sax (2019) found that higher productivity in the tradable sector led to real depreciation in OECD countries, rather than the appreciation predicted by the B–S effect. Hogen and Kishi (2024) showed that the B–S effect in Japan reversed precisely when the ICT revolution accelerated, and Wang et al. (2016) demonstrated that the B–S effect remains valid in developed countries but fails in developing countries, which is the opposite of what the studies of transition economies suggested.

Digital transformation may provide a potential explanation for these anomalies. As services are becoming internationally tradable, the core assumption of the B–S effect—the clear distinction between tradable and non-tradable sectors—may no longer hold. Moreover, digitalisation is also affecting the tradable sector itself, as the rise of online selling platforms leads to lower prices due to increased competition. Consequently, this transformation of both services and goods challenges the traditional boundaries between sectors, and therefore it is important to investigate how these changes affect the B–S mechanism.

1.4.1 The Traditional Dichotomy: Tradable vs. Non-tradable Sectors

The B–S hypothesis depends on the distinction between tradable and non-tradable goods and services. Traditionally, the distinction was clear due to limitations in transportation and communication technologies. The tradable sector produced goods that could be transported and sold across borders, whereas the non-tradable sector provides services that require physical proximity between producer and customer (Balassa, 1964; Samuelson 1964).

Within this framework, prices in the tradable sector are determined by global demand and supply, with arbitrage keeping price differences across countries relatively small. This condition is often associated with the LOP (Isard, 1977). On the contrary, prices in the non-tradable sector reflect domestic costs and competition, since these services cannot be easily traded across borders. However, as digital technologies have advanced, these assumptions are being challenged.

This sectoral classification is central to the B–S mechanism. An increase in productivity in the tradable sector leads to higher wages in that sector. Due to labour mobility within a country (while mobility across countries remains limited) wages also increase in the non-tradable sector to prevent a massive shift of the workforce (Bhagwati, 1984). However, since the productivity in the non-tradable sector does not rise at the same rate, higher wages lead to higher production costs and, consequently, higher prices. As a result, overall inflation increases, and the RER appreciates.

Although this thesis primarily focuses on the relationship between productivity differential and the RER, the wage channel is also examined as an additional mechanism. This allows the empirical analysis to assess whether productivity differentials are transmitted into wage developments, which represents an important intermediate step in the traditional B–S framework.

Digitalisation has profoundly challenged this assumption. Jensen and Kletzer (2010) demonstrated that many services are potentially tradable, as it depends on the task characteristics rather than industry classification. They identified that occupations which do not require physical proximity, such as accounting, consulting, computer programming, or financial analysis, can be performed remotely. Hence, they are deliverable across borders. Their analysis showed that approximately 27% to 38% of U.S. service sector employment was potentially offshorable. That is a much higher proportion compared to the suggestions based on traditional industry classifications.

Recent studies confirm that the potential of the digital economy has already led to actual growth in international trade. Li et al. (2023) provide robust cross-country evidence that the development of the digital economy significantly improves the competitiveness of services exports. Analysing data from 75 countries over the period 2010–2019, which together represent more than 93% of global services exports, the authors find that a 1% increase in digital economy development is associated with a 0.49% rise in services export competitiveness.

This growth in digital trade also extends to supply chains, where digital technologies reduce barriers and enable faster information exchange. Digital supply chains are becoming crucial, as they enable real-time communication and more efficient transportation, enhancing global supply chain efficiency (Queiroz et al., 2021). These advances in supply chain may further alter the traditional B–S mechanism. The increased trade facilitation of goods and services, driven by digital transformation, could lead to new dynamics in international trade and affect the relationship between productivity differentials and the RER.

According to Lin et al. (2023), this effect works through three main channels. First, the category margin, which allows countries to export a wider range of services. Second, the price margin, which increases the technological complexity and value-added of services through knowledge diffusion and innovation. And third, the quantity margin, which increases the volume of existing service exports by reducing trade costs and improving information availability.

Similarly, Jiang and Jia (2022) analyse data from 71 countries between 2005 and 2019, confirming these results, especially for high-income economies. They estimate an elasticity of 0.546, which means that a 1% increase in the level of digitalisation in services is associated with a 0.546% increase in digital service exports. This result is particularly important for European countries, which are the focus of this thesis and where significant investments in digital infrastructure have been made.

1.4.2 Implications for the Balassa–Samuelson Effect: Challenging the Core Assumptions

The B–S hypothesis relies on three core assumptions about economic structure:

1. The economy can be clearly divided into tradable and non-tradable sectors, with the latter insulated from international competition. However, this distinction is increasingly blurred not only between tradable and non-tradable sectors, but also within the tradable sector itself. Digitalisation has intensified price competition especially for non-durable goods, as digital supply chain integration reduces information and transaction costs (Queiroz et al., 2021).
2. Productivity growth is systematically higher in the tradable sector than in the non-tradable sector. However, digital transformation may alter where productivity gains occur, as digitally deliverable services become more scalable and technology-intensive.
3. Perfect labour mobility within countries but not across borders ensures that wage gains in high-productivity tradables spill over to non-tradables, raising their prices and driving aggregate inflation. However, this assumption may not hold anymore, as the increasing possibility of remote work and intensified global competition may weaken wage spillovers to the non-tradable.

These assumptions were broadly consistent with mid-20th-century economic structures—at the time the hypothesis was formulated (Balassa, 1964; Samuelson, 1964). However, digital transformation challenges each of these foundations.

The first assumption of the B–S framework—the clear sectoral distinction—faces the most direct challenge. As previously discussed in the context of task-based tradability the line between sectors has become increasingly blurred (Jensen & Kletzer, 2010). Digitally deliverable services (DDS) accounted for about 63% of global services exports, compared to 48% in 2012 (IMF, OECD, UN, & WTO, 2023). Many services, such as business services, ICT services, financial services, and professional services, which were traditionally classified as non-tradable, are now internationally deliverable through digital platforms. As a result, the effective size of the truly non-tradable sector is shrinking and activities that previously reflected mainly domestic cost conditions are increasingly exposed to international competition.

For example, when Polish accounting firms compete with providers from India through digital platforms, domestic service prices cannot rise in line with wage increases without the risk of losing market share. This weakens the insulation of the non-tradable sector, a key condition of the B–S effect. As the share of internationally tradable services grows, the role of the non-tradable sector as a domestic price anchor becomes less significant.

The second assumption, that productivity growth is concentrated in the tradable sector, has also been challenged. Historically, manufacturing benefited from technological progress, while services showed relatively stagnant productivity. This pattern is known as Baumol's cost disease (Baumol & Bowen, 1965). However, digitalisation has altered this tendency by enabling significant productivity gains in service sectors. Technologies such as cloud computing, artificial intelligence, automation, and digital platforms increase efficiency and allow services to be delivered at grater scale. Consequently, productivity growth is no longer limited to traditional industries but increasingly occurs in DDS.

Hogen and Kishi (2024) illustrate this empirically for Japan. Their study shows that the weakening and eventual reversal of the B–S effect after the mid-1990s was associated with Japan's inability to maintain productivity growth in ICT-intensive sectors relative to the U.S. These results suggest that the direction and strength of the mechanism depend on maintaining productivity advantages in technologically dynamic sectors. When service sectors themselves become engines of productivity growth through digital transformation, this assumption may no longer hold.

The third assumption—perfect labour mobility within countries leading to wage equalisation across sectors—faces more complex challenges. The standard B–S framework assumes that workers can move freely between sectors within a country, which leads to wage equalisation across tradable and non-tradable sectors, while international labour mobility is assumed to be limited. However, digitalisation increasingly blurs this boundary. Through digital platforms and remote work, skilled workers can provide services to foreign employers without physically moving abroad. This creates a form of international labour market integration for certain occupations and weakens the assumption that labour markets operate only at the national level.

Furthermore, as Gubler and Sax (2019) emphasise in their theoretical model, technological progress can be skill-biased. Productivity growth in the tradable sector may increase the demand for high-skilled workers while reducing the demand for low-skilled labour. If the non-tradable sector relies more heavily on low-skilled workers, lower wages for this group may reduce production costs and lower prices in the non-tradable sector. This outcome contradicts the traditional mechanism, in which wage increases in tradables are expected to raise costs and prices in the non-tradables sector.

Taken together, these challenges suggest that the traditional transmission mechanism of the B–S effect has become weaker or more complex in the digital economy. As digitalisation transforms sectoral structures, productivity patterns, and labour market conditions, the relationship between productivity growth, inflation, and the RER may diverge from the predictions of the standard model. These considerations highlight the need to re-examine the relevance of the B–S effect in the digital era.

1.4.3 Digitalisation and the Disruption of the Balassa–Samuelson Transmission Mechanism

Having established that digital transformation challenges the core assumptions of the B–S hypothesis, the following section examines how these challenges disrupt the transitional mechanism. The traditional B–S model relies on a deterministic chain:

1. A productivity shock occurs in the tradable sector.
2. This leads to higher wages in that sector.
3. These gains are transmitted to the non-tradable sector through domestic labour mobility and wage equalisation.
4. This causes non-tradable prices to rise.
5. Consequently, the real exchange rate to appreciate.

Digitalisation systematically disrupts or weakens each link in this chain.

The first link in the transmission mechanism—the productivity shock itself—operates differently in the digital era. The traditional B–S model assumes that productivity shocks occur in geographically fixed tradable sectors, such as manufacturing (Balassa, 1964). However, in the digital economy, productivity gains increasingly derive from intangible capital, including software, algorithms, data, and digital platforms (OECD, 2023). Unlike physical capital, digital technologies exhibit non-rivalry, meaning they can be used simultaneously across multiple locations. For example, a productivity-enhancing algorithm developed in one country can be applied immediately throughout a multinational company's global operations. As a result, the benefits of productivity improvements are distributed across countries rather than remaining concentrated in the domestic economy. This weakens the traditional link between domestic productivity growth in the tradable sector and domestic wage pressures, because the shock is no longer geographically contained.

The second link in the transmission mechanism—wage spillovers from the tradable to the non-tradable sector—also weakens in the digital economy. First, as Gubler and Sax

(2019) suggest, technological change may be skill-biased: productivity growth in digital sectors can increase demand for high-skilled workers while reducing demand for low-skilled workers. If non-tradable sectors rely more heavily on low-skilled labour, wage pressures in these sectors may remain subdued, contrary to the traditional model's assumption. Second, digital platforms enable what Baldwin (2016) terms as "virtual immigration", allowing workers in one country to provide professional services in another without physical relocation. As a result, wage dynamics are increasingly shaped by skill differences and the international contestability of tasks, weakening the assumption of isolated national labour markets.

The third link—the transmission from wages to non-tradable prices—is also weakened as a growing share of services become digitally tradable. In the traditional B–S framework, non-tradable prices are determined domestically and primarily reflect domestic unit labour costs (ULC). However, the "third unbundling" of globalisation, as described by Baldwin (2016), enables the cross-border delivery of services through digital technologies. Consequently, many businesses, IT, and professional services are increasingly exposed to international competition, so domestic service prices are increasingly shaped by global market conditions rather than local wage pressures (Baldwin, 2016).

The fourth link—from relative price changes to aggregate inflation—is also affected. As the share of deliverable services increases, the effective size of the truly non-tradable sector shrinks. Since these activities carry a diminishing weight in overall price indices, even wage-driven price increases in the remaining non-tradable sectors may have a smaller effect on aggregate inflation and, consequently, on RER appreciation. In this sense, the traditional mechanism operates on a narrower base.

Importantly, the strength of these effects may vary across countries depending on their regulatory environment for digital trade. Restrictions, such as data localisation requirements or barriers to foreign digital service providers, may preserve the traditional sectoral distinction and limit the international competition in domestic service sectors. In such cases, the B–S effect may still be observed, although in weaker form. By contrast, countries with more open digital trade regimes are more exposed to the international competition in services, which may further weaken the standard transmission mechanism. This cross-country heterogeneity leads to testable predictions about when and where the B–S effect should weaken.

Overall, these changes suggest that empirical analysis of the B–S effect in the digital era should account for differences in digital integration and regulatory openness.

1.4.4 Regulatory Heterogeneity as a Moderating Variable

As previously discussed, digital transformation challenges and weakens the traditional transmission mechanism of the B–S effect. However, the magnitude of the B–S effect differs across countries. Even though digital technologies make it technically possible to trade several services internationally, national regulations determine whether this potential translates into actual international competition within domestic markets. Therefore, regulatory differences play an important moderating role. Countries with more restrictive digital trade policies may preserve traditional B–S dynamics, whereas more open economies may experience a weaker transmission.

To measure this regulatory variation, this thesis uses the OECD DSTRI, introduced by Ferencz (2019). The DSTRI quantifies regulatory barriers affecting digitally enabled services across five policy areas:

1. Infrastructure and connectivity, such as restrictions on cross-border data flows and data localisation requirements;
2. Electronic transactions, including rules for electronic contracts, signatures, and authentication;
3. Payment systems and limitations on electronic payment methods;
4. Intellectual property rights related to digital content; and
5. Other regulatory barriers, such as licensing requirements and the transparency of regulations affecting digital service providers.

The index ranges from 0 to 1, where 0 indicates a fully open regulatory environment and 1 represents a highly restrictive system. This indicator provides a consistent and comparable measure of digital trade regulations. As the DSTRI covers both OECD and major non-OECD economies, it enables meaningful cross-country comparison within the European sample analysed in this thesis.

The empirical evidence suggests that the effects of digital trade regulation are economically significant. Using a structural gravity model, the OECD (2023) finds that 0.1-point increase in the average DSTRI between two countries raises bilateral trade costs by approximately 15.4%, with a larger effect for emerging economies (9.6%) than for high-income countries (5.2%). These results indicate that regulatory barriers create substantial frictions even when the necessary digital infrastructure is available. Conversely, regulatory liberalisation is associated with strong export gains: a 0.1-point reduction in a country's domestic DSTRI is linked to 145% increase in total exports.

The impact differs across sectors, with the strongest effects observed for DDS, followed by other services, agriculture and food, and manufacturing. Overall, these findings show that differences in digital trade regulation generate significant cross-country variation in the effective tradability of services, even among economies with similar technological capabilities.

Wang, et al. (2024) provide additional evidence. In their study, they examine the mechanisms through which regulatory barriers affect digital trade. Their analysis demonstrates that specific restrictions, such as data localisation requirements, restrictions on cross-border data flows, and discriminatory licensing for foreign providers, significantly reduce the efficiency of digital service exports. Such barriers increase costs and alter market structure and the intensity of the competition. As a result, countries with strict regulations can maintain a degree of insulation for domestic service sectors, even in a highly digitalised environment.

For the B–S effect, these findings have important implications. Regulatory barriers create heterogeneity in the effective tradability of services. Even with similar digital infrastructure and ICT adoption, countries with restrictive digital trade policies may preserve the insulation of domestic service sectors, allowing the traditional B–S mechanism to operate, potentially with lower magnitude. By contrast, in more open economies, service providers face stronger international competition, so productivity-driven wage increases cannot be fully transmitted into prices without risking a loss of market share. As a result, the wage-price transmission weakens, reducing the strength of the B–S effect.

This regulatory dimension introduces an additional policy-related source of cross-country heterogeneity. While previous studies highlight factors such as income level and stage of economic development (Wang et al., 2016; Hassan, 2016), digital trade restrictiveness represents an independent channel through which countries with otherwise similar income characteristics may exhibit different price dynamics. This suggests that empirical analysis in the digital era should account not only for technological development but also for the regulatory environment.

The policy areas identified by Ferencz (2019) as most restrictive (infrastructure and connectivity and electronic transactions) directly determine whether DDS can be traded internationally. Evidence from OECD (2023) confirms that regulatory measures that affect electronic transactions and digital connectivity have the most significant negative impact on trade volumes. This finding supports the theoretical argument that barriers preventing cross-border data flow and delivery of digital services help preserve the non-tradable character of the service sector, maintaining the conditions under which the B–S mechanism can operate.

The resulting testable prediction is clear: the magnitude of the B–S effect should decrease as digital trade openness increases. Countries with low DSTRI scores are expected to exhibit weaker effects, as services sector tradability limits the transmissions from wages to prices. On the contrary, economies with high DSTRI should exhibit stronger B–S effects, since regulatory barriers maintain the insulation of domestic service sectors from global competition. This prediction forms the basis for Hypothesis 2, which will be tested in the following chapters.

2 Objective of the Thesis

The main objective of this master's thesis is to test whether digital transformation has altered the Balassa–Samuelson effect in European countries. The Balassa–Samuelson hypothesis predicts that higher productivity growth in the tradable sector results in real exchange rate appreciation. While this relationship was observed in Central and Eastern European transition economies in the 1990s and early 2000s, the recent evidence from advanced OECD countries suggests that the effect has weakened or even reversed. This thesis investigates whether the increasing tradability of services, driven by digitalisation, explains these shifting dynamics.

Specifically, the thesis addresses four research questions:

1. Has the magnitude of the Balassa–Samuelson effect changed over time?
2. Does digital trade restrictiveness moderate the Balassa–Samuelson effect?
3. Does the effect operate differently across development stages within Europe?
4. Does productivity growth in digitally deliverable services affect prices and exchange rates differently compared to traditional manufacturing productivity?

To answer these questions, the analysis employs panel data for 26 European economies spanning the period 2000Q1–2025Q4. The methodology utilises sectoral productivity measures and regulatory restrictiveness measures from the OECD Digital Services Trade Restrictiveness Index (DSTRI). The sample period is divided to capture both the pre-digital era (2000–2013) and the digital-intensive era (2014–2025), enabling a direct comparison of Balassa–Samuelson dynamics across different technological and regulatory regimes.

3 Methodology and Research Methods

This chapter outlines the empirical framework used to investigate the B–S effect in Europe and to examine whether digital transformation affects it.

3.1 Sample Selection

This thesis examines 26 European countries over the period 2000Q1–2025Q4. The sample includes both advanced and emerging European countries, enabling analysis of heterogeneity across levels of development while maintaining regional coherence and data comparability. The effective number of observations varies across specifications, depending on time specifications and data availability.

Sample Composition

The sample includes both Western European advanced economies and CEE emerging and transition economies, as well as Euro Area countries and Non-Euro Area countries.

Advanced European Economies (15): Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, and Sweden.

Emerging and Transition European Economies (11): Bulgaria, Croatia, the Czech Republic (Czechia), Estonia, Hungary, Latvia, Lithuania, Poland, Romania, the Slovak Republic (Slovakia), and Slovenia.

Euro Area Members (18): Austria, Belgium, Croatia*, Estonia*, Finland, France, Germany, Greece*, Ireland, Italy, Latvia*, Lithuania*, Luxembourg, Netherlands, Portugal, the Slovak Republic*, Slovenia*, and Spain.[1]

Non-Euro Area Countries (8): Bulgaria[2], the Czech Republic, Denmark, Hungary, Norway, Poland, Romania, and Sweden.

This classification captures economic heterogeneity while preserving sufficient observations in each group for comparative analysis.

The analysis spans 2000Q1–2025Q4, covering the wide evolution of digital transformation and structural change in European economies. For contextual purposes, the sample period distinguishes between three phases:

- **Phase 1 (2000–2007):** the emergence of e-commerce and early digital services, characterised by the dot-com boom and subsequent adjustment.

[1] Countries marked with (*) joined the Euro Area during the sample period 2000–2025.
[2] Bulgaria is treated as non-eurozone country as it joined the Euro Area on January 1, 2026, which is outside the sample range.

- **Phase 2 (2008–2014):** the rise of cloud computing infrastructure and mobile internet, alongside the global financial crisis and European sovereign debt crisis.
- **Phase 3 (2015–2025):** the growth of digital platforms and services, including the implementation of major regulatory frameworks as GDPR (2018) and the acceleration of digital adoption during COVID-19 pandemic's (2020–2021).

The 2014 breakpoint for temporal analysis (H1) is motivated by two considerations: the IMF's identification of shifts in digital growth and the availability of OECD DSTRI data from 2014 onward. Accordingly, the empirical analysis distinguishes between pre-digital period (2000–2013) and digital-intensive era (post-2014).

Years 2020–2021 are retained in the analysis rather than excluded, as the COVID-19 pandemic coincided with an acceleration in digital adoption and digital business transformation across countries (Calvino et al., 2024). Year fixed effects help control for common pandemic-related shocks, allowing these observations to be retained without affecting the interpretation of the core explanatory variables.

3.2 Data and Variable Construction

This section describes the process of data collection, the transformation and economic intuition behind each variable selection.

Table 1: Data Sources and Variable Definitions

Variable	Description	Source
Real Exchange Rate	Real effective exchange rate based on CPI	BIS
Productivity Differential	Log ratio of labour productivity (GVA per hours worked), in tradable relative to non-tradable sectors	Eurostat
DSTRI	Annual index of regulatory barriers to digital services trade	OECD
Terms of Trade	Log of TOT (export prices index relative to import prices)	Eurostat
GDP per Capita	Log of GDP per capita	Eurostat
Government Consumption	As a percentage of GDP	Eurostat
Population Growth	Log first difference of interpolated annual population series	Eurostat
Wage	Log of total hourly compensation	Eurostat

Source: Compiled by the author based on BIS, Eurostat, and OECD documentation.

Real Effective Exchange Rate

The dependent variable is the real effective exchange rate (REER), obtained from the Bank for International Settlements (BIS). The BIS REER index is CPI-based and measures relative price competitiveness of each country against a basket of trading partners. In the estimations, the variable is used in logarithmic form, which simplifies coefficient interpretation.

Productivity Differential

The key explanatory variable is productivity differential constructed from sectoral labour productivity data. It is measured as gross value added (GVA) per hour worked. In line with the B–S literature, the variable is intended to capture the productivity advantage of tradables relative to non-tradable activities.

In the baseline specification, the tradable sector includes manufacturing, agriculture, and industry excluding construction (in a robustness specification, agriculture is excluded), whereas the non-tradable sector consists of construction, real estate, wholesale, retail, transport, and accommodation services, ICT, and financial and insurance activities. The productivity differential is defined as the ratio of tradable-sector productivity to non-tradable-sector productivity. A higher value indicates that the tradable sector is relatively more productive than the non-tradable sector. Under the traditional B–S mechanism, this would be expected to contribute to real appreciation.

Because the classification of tradable and non-tradable sectors may be subject to structural changes, alternative specifications are constructed. A specification is designed to reflect the digital era by reclassifying ICT and financial and insurance activities from the non-tradable to the tradable sector in the post-2014 period. In addition, H4 separately examines manufacturing productivity and ICT productivity to compare the behaviour of a traditional tradable sector with a digitally intensive sector.

Wage – Hourly Compensation

To examine the wage-channel component of the B–S mechanism, the analysis also uses total hourly compensation as an additional dependent variable. The wage variable is obtained from Eurostat and is used to assess whether productivity differentials are transmitted into wage developments. This extension is motivated by the theoretical mechanism through which higher productivity in tradable sectors may increase wages, which can then contribute to higher prices in non-tradable sectors and real appreciation. Due to data availability, the wage-channel analysis is based on a smaller sample, as data are missing for Germany and France, while Belgium is missing in 2025Q4.

Digital Services Trade Restrictiveness Index

For H2, the DSTRI enters the specification both as a direct effect and interacted with the productivity differential. The DSTRI measures regulatory barriers to cross-border digital service trade. Higher values indicate greater restrictiveness. It is obtained from OECD and is available for the post-2014 period. The index captures differences in regulatory openness across countries over time, making it suitable for examining whether digital trade regulation alters the relationship between the REER and productivity differential. The DSTRI is originally available annually, for consistency with the quarterly dataset, the index is assumed to be constant within each year.

Terms of Trade

Terms of trade are included as a control variable and measured as the ratio of export prices to import prices. The variable is obtained from Eurostat and is used in logarithmic form. Improvements in the TOT are associated with real appreciation.

GDP per Capita

GDP per capita is included to control for differences in economic development across countries. It is obtained from Eurostat and used in logarithmic form. Higher levels of income are typically associated with higher price levels and real exchange rate appreciation.

Government Consumption

Following De Gregorio and Wolf (1994), government final consumption expenditure is included to control for fiscal policy effects on the REER. The variable is obtained from Eurostat and expressed as a percentage of GDP.

Population Growth

Following Gubler and Sax (2019), population growth is included as a control variable. It is constructed as the log first difference of interpolated population data from Eurostat. As Rose et al. (2009) show, demographic dynamics may influence the REER.

3.2.1 Sample Grouping and Time Classification

Country Group

Countries are classified into two development groups: advanced and emerging. Advanced countries include the 15 high-income countries, while the 11 remaining countries are classified as emerging and transition economies. This classification is time-invariant to maintain a clear group comparison across sample period.

Time Period

For H1, the sample is divided into a pre-digital period (2000–2013) and digital-intensive era (2014–2025) to assess whether the relationship between productivity differential and the REER changes after 2014.

Table 2 reports descriptive statistics for the main variables included in the analysis.

Table 2: Descriptive Statistics

Variable	Obs.	Mean	Std. Dev.	Min	Median	Max
Log REER	2704	4.611	0.101	4.020	4.609	4.914
Prod Diff	2703	–1.089	0.635	–4.138	–1.087	0.492
DSTRI	1104	0.098	0.060	0.000	0.083	0.364
Log TOT	2704	–0.011	0.069	–0.517	–0.005	0.684
Log GDP pc	2704	4.579	0.194	3.560	4.603	5.137
Gov Cons	2704	20.211	3.017	10.600	19.990	28.100
Pop Growth	2574	0.000	0.002	–0.012	0.001	0.008
Log Wage	2495	2.445	0.871	–0.359	2.499	4.096

Source: Autor's calculations based on data from Table 1.

Note: The DSTRI is available only from 2014 onward and therefore has fewer observations. Wage data are missing for Germany and France, and Belgium is missing in 2025Q4.

Table 3 presents the correlation matrix for the key variables in the analysis. The results suggest no evidence of severe multicollinearity. The productivity differential exhibits a weak positive correlation with the RER, while GDP per capita shows a stronger association. This is consistent with the role of income levels in explaining price differences across countries.

Table 3: Correlation Matrix

	Log REER	Prod Diff	Log TOT	Log GDP	Gov Cons	Pop Grow
Log REER	1.000	0.183	0.155	0.410	0.168	0.309
Prod Diff	0.183	1.000	0.212	0.115	0.147	0.240
Log TOT	0.155	0.212	1.000	0.313	0.058	0.180
Log GDP pc	0.410	0.115	0.313	1.000	0.056	0.236
Gov Cons	0.168	0.147	0.058	0.056	1.000	0.037
Pop Growth	0.309	0.240	0.180	0.236	0.037	1.000

Source: Author's calculations based on data sources in Table 1.

Note: Correlations are computed using the full sample. The DSTRI variable is excluded due to its limited availability.

3.3 Empirical Strategy

3.3.1 Baseline Specification

The baseline econometric model employs a two-way fixed effects (FE) panel data model:

$$\log(REER_{it}) = \beta_1\, Prod\_Diff_{it} + \beta_2\, log\_ToT_{it} + \beta_3\, log\_GDP\_pc_{it} + \beta_4\, Gov\_Consumption_{it} + \beta_5\, Pop\_Growth_{it} + \alpha_i + \lambda_t + \varepsilon_{it} \quad (11)$$

where:

- $\log(REER_{it})$ – Log of the real effective exchange rate
- $Prod\_Diff_{it}$ – Productivity differential (tradable/non-tradable)
- log_ToT_{it} – Log of the Terms of Trade
- $log\_GDP\_pc_{it}$ – Log of real GDP per capita
- $Gov\_Consumption_{it}$ – Government consumption (% of GDP)
- Pop_Growth_{it} – Population growth rate (annual %)
- α_i – Country fixed effects
- λ_t – Time fixed effects
- ε_{it} – Error term.

A fixed effects panel OLS model is used to control for heterogeneity across countries. This approach is appropriate, as countries differ in stable characteristics. Controlling for these factors helps isolate the relationship between the explanatory variables and the REER.

Given the mixed order of integration observed in the panel unit root tests, a panel OLS framework with FE is preferred over cointegration-based methods.

Country Fixed Effects

Country FE (α_i) absorb all time-invariant country-specific characteristics that might affect the REER, such as geography, institutional structures, and historical factors. By including country FE, the model identifies coefficients from within-country variation over time rather than from country-cross differences.

Time Fixed Effects

Time FE (λ_t) control for common macroeconomic shocks affecting all countries simultaneously, including global inflationary pressures and international trade conditions. By including these effects, the model isolates country-specific productivity dynamics from global trends.

3.3.2 Research Hypotheses

Based on the theoretical framework, this study tests four hypotheses regarding the B–S effect in the digital era:

Hypothesis 1: Temporal Change

H1: The Balassa–Samuelson effect has weakened in the digital era (post 2014) compared to the pre-digital era (2000–2013).

Digital transformation has increased the tradability of previously non-tradable services through cloud computing, software delivery, and digital platforms. Traditional B–S theory assumes services are non-tradable because they require local presence. However, digital technologies enable cross-border service delivery without physical proximity. If digital services can now be traded internationally, productivity improvements in these sectors face global competition and price arbitrage, reducing their effect on domestic relative prices. This should weaken the traditional productivity–REER relationship, as a larger share of service sector becomes exposed to international competition.

Hypothesis 2: Regulatory Moderation

H2: The Balassa–Samuelson effect is stronger (or less weakened) in countries with more restrictive digital services trade regulation, as measured by the OECD DSTRI.

Regulatory barriers to cross-border digital services trade—including data localisation requirements, restrictions on foreign digital platforms, and strict intellectual property protection—preserve the non-tradability of digital services. In highly regulated environments, digital services remain more sheltered from international competition despite technological capability for cross-border delivery. This maintains the traditional B–S mechanism. Conversely, in open regulatory environments, digital services face global competition, which weakens the productivity–REER relationship. Hence, the DSTRI moderates the relationship between productivity differentials and RER, with regulation acting as a barrier to the tradability-increasing effects of digital technology.

Hypothesis 3: Development Stage Heterogeneity

H3: The Balassa–Samuelson effect differs between advanced and emerging European economies.

The strength of the B–S effect may vary across development stages due to structural differences in markets and institutions. Emerging economies undergoing rapid catch-up may exhibit stronger productivity-driven real appreciation as they industrialise and shift resources from low-productivity agriculture to high-productivity manufacturing. Alternatively, advanced economies may show stronger effects due to more developed financial markets, greater labour mobility across sectors, and deeper integration into global value chains. This hypothesis tests whether the productivity–REER relationship operates uniformly across development levels or exhibits heterogeneity between converging and mature economies.

Hypothesis 4: Sectoral Heterogeneity (ICT vs Manufacturing)

H4: ICT sector productivity has a weaker effect on real exchange rates than manufacturing sector productivity.

Manufacturing has traditionally been the canonical tradable sector, producing physical goods subject to international trade and price arbitrage. ICT services, traditionally non-tradable, have become increasingly tradable through digital platform and remote service delivery. If ICT services now face global competition like manufactured goods, productivity improvements in ICT should no longer generate real appreciation to the same degree as manufacturing productivity gains. The LOP should apply to tradable ICT services, preventing domestic productivity gains from translating into higher relative prices. This hypothesis tests whether the sectoral classification underlying B–S theory remains valid in the digital era, or whether ICT services have fundamentally changed character.

3.3.3 Testing H1: Temporal Change

To test whether the B–S effect has weakened in the digital era, the analysis adopts a split-sample estimation strategy. The baseline two-way FE model is estimated over the full sample period and then separately for the pre-digital and digital-intensive periods. In addition, all specifications are estimated separately for Euro Area and Non-Euro Area countries to account for potential heterogeneity across monetary regimes. The baseline specification is defined as follows:

$$\log(REER_{it}) = \beta_1\, Prod\_Diff_{it} + \beta_2\, log\_ToT_{it} + \beta_3\, Log\_GDP\_pc_{it} + \\ + \beta_4\, Gov\_Consumption_{it} + \beta_5\, Pop\_Growth_{it} + \alpha_i + \lambda_t + \varepsilon_{it}, \quad (12)$$

where:

- α_i – Country fixed effects,
- λ_t – Time fixed effects,
- ε_{it} – Error term.

The model is estimated for three time samples: the full period (2000Q1–2025Q4), the pre-digital period (2000Q1–2013Q4), the digital-intensive era (2014Q1–2025Q4). For each period, the model is estimated separated for Euro Area and Non-Euro Area countries.

In addition to the temporal split, a digital specification is estimated for the post-2014 period. In this specification, ICT and financial and insurance activities are reclassified as tradable sectors, reflecting the increased tradability of digital services.

Evidence in support of H1 would consist of a reduction, disappearance, or reversal of the productivity coefficient in the digital-intensive period relative to the pre-digital period. A weaker, statistically insignificant, or oppositely signed coefficient in the post-2014 era would suggest that the traditional B–S relationship has changed or has become less visible in the digital era.

3.3.4 Testing H2: Regulatory Moderation

Hypothesis 2 examines whether digital services trade regulation moderates the relationship between productivity differentials and the REER. The analysis uses the OECD Digital Trade Restrictiveness Index DSTRI, which measures regulatory barriers affecting cross-border digital service trade. Since DSTRI is available from 2014 onwards, this specification is estimated only for digital-intensive period. The moderation model includes DSTRI both as a direct effect and as an interaction term with productivity differentials:

$$\log(REER_{it}) = \beta_1\, Prod\_Diff_{it} + \beta_2\, DSTRI_{it} + \beta_3\, (Prod\_Diff_{it} * DSTRI_{it}) \\ + X_{it} + \alpha_i + \lambda_t + \varepsilon_{it}, \quad (13)$$

where:

- X_{it} – denotes a vector of control variables,
- β_1 – captures the productivity–REER relationship when DSTRI = 0,
- β_2 – captures the direct effect of digital trade restrictiveness on the REER,
- β_3 – captures how the productivity–REER relationship changes as digital trade restrictiveness increases.

H2 is evaluated based on the coefficient of the interaction term, β_3. A positive and statistically significant β_3 would indicate that higher digital services trade restrictiveness strengthens the productivity–REER relationship. This would be consistent with the idea that regulatory barriers preserve the non-tradability of digital services and therefore maintain the traditional B–S channel. Conversely, a statistically insignificant interaction term would suggest that DSTRI does not systematically moderate the relationship between productivity differentials and the REER.

Given the potential heterogeneity, the H2 model is estimated separately for Euro Area and Non-Euro Area countries. This avoids relying on pooled estimates that may average out opposing relationships across monetary regimes. The model is estimated only for the post-2014 period due to the availability of DSTRI data.

The main H2 specification uses the digital-adjusted productivity differential, as DSTRI specifically measures regulatory barriers to cross-border digital services trade. As a comparison, the model is also estimated using the traditional post-2014 productivity differential.

As a robustness check, the model is re-estimated using one-quarter lag of DSTRI. This specification accounts for possibility that regulatory barriers may affect the relationship between productivity differentials and the REER with a delay rather within the same quarter. The lagged model is used to assess whether the main results are sensitive to the timing of the DSTRI variable.

3.3.5 Testing H3: Development Stage Heterogeneity

Hypothesis 3 examines whether productivity–REER relationship differs between advanced and emerging European economies. The motivation for this test is that the B–S mechanism may operate differently across development stages. Emerging and transition economies may experience stronger productivity-driven real appreciation during the process of catching up, industrialisation, and structural transformation. In contrast, advanced economies may display weaker or different productivity–REER dynamics due to more mature economic structures, deeper financial markets, and stronger integration into European and global value chains. To test this hypothesis, the baseline model is estimated separately for each country group.

Advanced countries:

$$\log(REER_{it}) = {\beta_1}^{A}\, Prod\_Diff_{it} + X_{it} + \alpha_i + \lambda_t + \varepsilon_{it} \tag{14}$$

Emerging countries:

$$\log(REER_{it}) = {\beta_1}^{E}\, Prod\_Diff_{it} + X_{it} + \alpha_i + \lambda_t + \varepsilon_{it} \tag{15}$$

H3 is evaluated by comparing the estimated productivity coefficients across the two development groups. Evidence of development-stage heterogeneity would be indicated by differences in the sign, magnitude, or statistical significance of the productivity coefficient between advanced and emerging economies.

Because the advanced/emerging classification may partly overlap with differences in monetary regimes, the results are interpreted in relation to the Euro Area and Non-Euro Area differences. This helps distinguish whether the observed heterogeneity is more related to development stage or to differences in monetary regimes.

3.3.6 Testing H4: Sectoral Heterogeneity (ICT vs Manufacturing)

Hypothesis 4 examines whether productivity developments in the ICT sector affect the REER differently from productivity gains in manufacturing. Manufacturing is treated as a traditional benchmark tradable sector, while ICT represents a digitally intensive sector whose tradability has increased through digital platforms, remote service delivery, and cross-border provision of services. To test this hypothesis, both sectoral productivity measures are included in the same regression:

$$\log(REER_{it}) = \beta_1\, Prod\_M_{it} + \beta_2\, Prod\_ICT_{it} + X_{it} + \alpha_i + \lambda_t + \varepsilon_{it}, \tag{16}$$

where:

- $Prod\_M_{it}$ – denotes manufacturing productivity,
- $Prod\_ICT_{it}$ – denotes ICT productivity,
- X_{it} – denotes a vector of control variables.

The key comparison lies between the coefficient on manufacturing productivity and ICT productivity. H4 is supported if the coefficient on ICT productivity is smaller than the coefficient on manufacturing productivity, or if ICT productivity is statistically insignificant while manufacturing productivity shows a stronger positive association with the REER. This would indicate that productivity gains in ICT translate less strongly into real appreciation than productivity gains in manufacturing.

To account for potential heterogeneity across monetary regimes, the model is estimated for full sample and separately for Euro Area and Non-Euro Area countries. this allows the analysis to examine whether sectoral productivity effects differ not only across sectors, but also across different monetary regimes.

3.3.7 Additional Wage-Channel Specification

In addition to the REER—based specification, the analysis includes an additional wage-channel specification. This extension examines whether productivity differentials are associated with wage developments, which represents an important transmission channel in the B–S mechanism. In this specification, the dependent variable is logarithm of total hourly compensation, while the main explanatory variable is the productivity differential between tradable and non-tradable sectors. The model is estimated using the two-way FE structure as the baseline REER specification:

$$\log(Wage_{it}) = \beta_1\, Prod\_Diff_{it} + X_{it} + \alpha_i + \lambda_t + \varepsilon_{it} \tag{17}$$

where:

- $\log(Wage_{it})$ – denotes total hourly compensation,
- $Prod\_Diff_{it}$ – Productivity differential (tradable/non-tradable),
- X_{it} – denotes a vector of control variables.

The model is estimated over the full sample period for the full sample and separately for Euro Area and Non-Euro Area countries.

3.4 Robustness Checks

To verify the stability of the estimated coefficients and the reliability of the results, the analysis is supplemented with robustness checks. These checks are designed to evaluate whether the main findings depend on the definition of the tradable sector or the choice of estimation method.

First, for the baseline specification, an alternative definition of the tradable sector is considered by excluding agriculture. Although agriculture is formally tradable, it is often subject to policy support and trade protection (De Gregorio & Wolf, 1994; Gubler & Sax, 2019), which may weaken the standard B–S mechanism. This check evaluates whether the baseline results are sensitive to the inclusion of agriculture in the tradable sector.

Second, the baseline specification is re-estimated using random effects (RE) and first differences (FD). While the FE model focuses exclusively on within-country variation over time and controls for time-invariant unobserved country-specific factors, the RE model combines both within- and between-country variation under the additional assumption that unobserved heterogeneity is uncorrelated with the regressors. Additionally, a FD specification is conducted, removing country-specific effects by analysing period-to-period changes. Comparing results across chosen estimators helps to verify whether the findings are sensitive to the choice of estimation method.

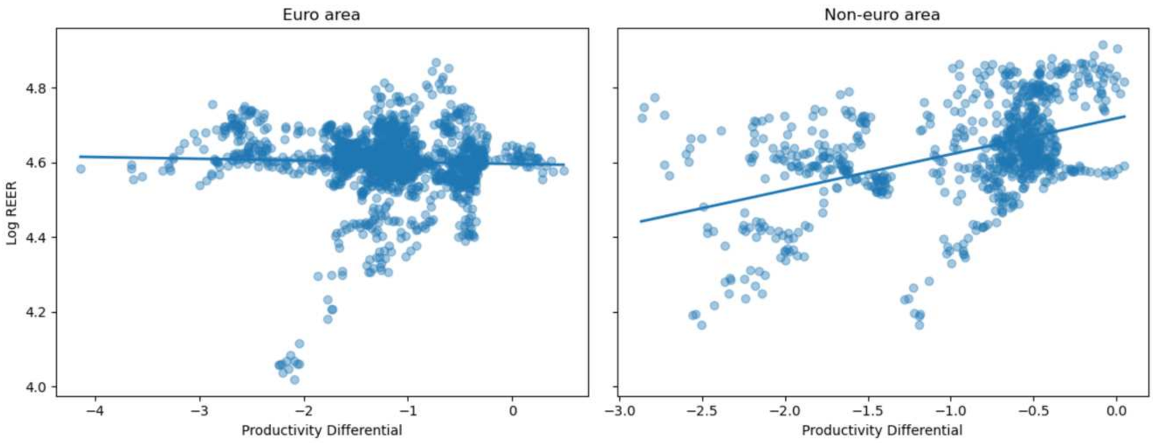
4 Results

This chapter presents the empirical results of the analysis examining the impact of digitalisation on the Balassa–Samuelson effect.

4.1 Preliminary Analysis

To provide a preliminary visual inspection of the relationship between productivity differentials and the REER, Figure 2 presents scatter plots with fitted lines separately for Euro Area and Non-Euro Area countries.

Figure 2: Productivity Differential and REER by Monetary Regime



Source: Author's calculations based on data sources in Table 1.

Figure 2 suggests that the relationship between productivity differential and the REER differs across monetary regimes. In the Euro Area, the fitted line is almost flat and slightly downward-sloping, suggesting a weak or mildly negative unconditional relationship. In contrast, the Non-Euro Area countries display a more positive association. However, the observations remain dispersed in both groups, indicating a relatively weak unconditional relationship.

Panel Unit Root Tests

Table 4 presents the results of panel unit root tests for the variables used in the analysis. The Im–Pesaran–Shin (IPS) and Levin–Lin–Chu (LLC) tests were conducted with a lag order of 4. Both IPS and LLC under both constant and constant-with-trend specifications.

Table 4: Summary of Panel Unit Root Tests Results

Variable	IPS level	IPS Δ	LLC level	LLC Δ	Conclusion
Log REER	–2.725 ***	–17.463 ***	–3.911 ***	–0.029 **	$I(1)$
Prod Diff	–2.278 **	–17.822 ***	–3.472 ***	10.107	$I(0)$
Log ToT	–3.396 ***	–17.465 ***	–1.021	9.745	$I(0)$
Log GDP pc	–3.272 ***	–12.249 ***	4.080	125.136	$I(1)$
Gov Cons	–3.024 ***	–16.628 ***	–3.105 ***	4.283	$I(0)$
Pop Growth	–1.374 *	–18.815 ***	2.616	–1.748 **	$I(0)$
Log Wage	1.778	–12.759 ***	0.484	8.871	$I(1)$–mixed

Source: Author's computation based on data in Table 1.

*Notes: IPS = Im-Pesaran-Shin W_tbar statistic. LLC = Levin–Lin–Chu z-score. H0: unit root exists. Lag order = 4. Results are reported for the constant and trend specification. Δ denotes first difference. Tests conducted in Gretl. Significance levels: * p<0.1, ** p<0.05, *** p<0.01.*

Given the mixed order of integration among variables, the analysis proceeds using a FE panel OLS framework, focusing on within-country variation rather than long-run cointegration relationships.

4.2 Hypothesis 1 – Temporal Change

Hypothesis 1 examines whether the productivity–REER relationship changes in the digital-intensive period. Before estimating the temporal split, the baseline specification is first estimated over the full sample period for the full set of countries and separately for Euro Area and Non-Euro Area countries.

Table 5: Full-period Baseline Results by Monetary Regime

Variable	Full Sample	Euro Area	Non-Euro Area
Prod Diff	0.0237	–0.0159	0.1089
	(0.0328)	(0.0220)	(0.0696)
Log ToT	0.0345	–0.0997	0.0751
	(0.1496)	(0.3553)	(0.1450)
Log GDP pc	0.2447***	0.2935***	0.2772*
	(0.0728)	(0.0893)	(0.1038)
Gov Cons	0.0083	0.0134*	–0.0005
	(0.0057)	(0.0072)	(0.0057)
Pop Growth	6.7060*	4.7967	8.9811
	(4.0119)	(3.3734)	(7.8939)
Observations	2574	1782	792
R^2 (within)	0.1725	0.2700	0.0773
Entity FE	Yes	Yes	Yes
Time FE	Yes	Yes	Yes

Source: Author's calculations based on data sources in Table 1.

*Note: Standard errors in parentheses. Significance levels: * p<0.1, ** p<0.05, *** p<0.01. All models are estimated using two-way fixed effects panel OLS with clustered standard errors.*

Table 5 shows that the productivity differential is statistically insignificant across all full-period specifications. In the full sample, the estimated coefficient is positive but small. Once the sample is split by monetary regime—slightly negative in the Euro Area group and positive in the Non-Euro Area sample. However, none of the estimated coefficients are statistically significant. These results indicate that the baseline specification does not provide robust evidence of the traditional B–S relationship over the full period (2000Q1–2025Q4).

Among the control variables, GDP per capita is positive and statistically significant in all three specifications, indicating that higher income levels are associated with higher REER. Government consumption is positive and marginally significant only in Euro Area sample, while population growth is weakly significant only in the full sample. TOT are not statistically significant in the full-period baseline models.

After establishing the full-period baseline results, the analysis proceeds with the temporal dimension of Hypothesis 1. Table 6 reports the estimates separately for the pre-digital period (pre-2014) and the digital-intensive period (post-2014). Each model is estimated separately for Euro Area and Non-Euro Area countries.

Table 6: Temporal Split Results by Monetary Regime

Variable	Pre-2014		Post-2014	
	Euro Area	Non-Euro Area	Euro Area	Non-Euro Area
Prod Diff	0.0385	0.0374	–0.0602***	0.1996
	(0.0321)	(0.0596)	(0.0229)	(0.1378)
Log ToT	–0.1754	0.0288	–0.0094	0.1962**
	(0.4299)	(0.1754)	(0.1768)	(0.0881)
Log GDP pc	0.2241	0.2143***	0.0616	0.1273
	(0.1400)	(0.0735)	(0.0596)	(0.0977)
Gov Cons	–0.0022	–0.0021	0.0138***	0.0231***
	(0.0080)	(0.0069)	(0.0042)	(0.0085)
Pop Growth	0.6373	–5.5265	9.2046	14.984**
	(2.6832)	(8.1377)	(4.5747)	(6.4015)
Observations	990	440	792	352
R^2 (within)	0.3190	0.3408	0.2843	0.3139
Entity FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes

Source: Author's calculations based on data sources in Table 1.

*Note: Standard errors in parentheses. Significance levels: * p<0.1, ** p<0.05, *** p<0.01. All models are estimated using two-way fixed effects panel OLS with clustered standard errors.*

Table 6 provides more nuanced evidence on the temporal change in the relationship between productivity differentials and the REER. In the Euro Area, the coefficient on the productivity differential is positive but statistically insignificant in the pre-digital era (before

2014). In the post-2014 period, the coefficient becomes negative and statistically significant, which is inconsistent with the traditional B–S assumption of productivity-driven real appreciation. This result suggests that the productivity–REER relationship weakened or changed direction in the Euro Area during the digital-intensive period.

For Non-Euro Area countries, the coefficient remains positive in both periods and becomes larger after 2014. However, the estimates are not statistically significant, making the evidence insufficient to confirm a robust B–S effect outside the Euro Area. Overall, the temporal split suggests that the relationship between productivity differentials and the REER is unstable and differs across monetary regimes.

The control variables also show stronger explanatory power in the post-2014. TOT become positive and statistically significant for Non-Euro Area countries, while government consumption is positive and statistically significant in both Euro Area and Non-Euro Area specifications in the post-2014 period. Population growth is also positive and significant in the Non-Euro Area post-2014 model. These results suggest that macroeconomic and demand-side factors may have become more relevant for the movements of REER in the digital-intensive period than productivity differentials alone.

Table 7: Digital-adjusted Specification Results by Monetary Regime

Variable	Euro Area		Non-Euro Area	
	Traditional	Digital	Traditional	Digital
Prod Diff	–0.0602***	–0.0605***	0.1996	0.2126**
	(0.0229)	(0.0227)	(0.1378)	(0.1071)
Log ToT	–0.0094	–0.0197	0.1962**	0.1884**
	(0.1768)	(0.1673)	(0.0881)	(0.0740)
Log GDP pc	0.0616	0.0677	0.1273	0.1168
	(0.0596)	(0.0566)	(0.0977)	(0.0885)
Gov Cons	0.0138***	0.0125***	0.0231***	0.0176***
	(0.0042)	(0.0042)	(0.0085)	(0.0056)
Pop Growth	9.2046	9.3202**	14.984**	11.653**
	(4.5747)	(4.2951)	(6.4015)	(5.7850)
Observations	792	792	352	352
R^2 (within)	0.2843	0.2948	0.3139	0.3704
Entity FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes

Source: Author's calculations based on data sources in Table 1.

*Note: Standard errors in parentheses. Significance levels: * p<0.1, ** p<0.05, *** p<0.01. All models are estimated using two-way fixed effects panel OLS with clustered standard errors. Traditional refers to the baseline post-2014 sector classification. Digital refers to the digital-adjusted specification in which ICT and financial and insurance activities are reclassified as tradable sectors.*

Table 7 examines whether results are sensitive to the classification of digital sectors. For Euro Area countries, the digital adjusted specification exhibits almost the same result as the traditional post-2014 specification. The coefficient on the productivity differential remains negative and statistically significant, suggesting that the reversed productivity–REER relationship in the Euro Area is not driven by the traditional sectoral classification.

For Non-Euro Area countries, the coefficient remains positive and becomes statistically significant in the digital-adjusted specification. This result is more consistent with the traditional B–S assumption, according to which higher productivity in tradable sector is associated with real appreciation. The contrast between the Euro Area and Non-Euro Area estimates indicates that the relationship between productivity differentials and the REER differs not only in magnitude but also in direction across monetary regimes.

Overall, the digital-adjusted specification reinforces the importance of estimating the models separately by monetary regimes. While the pooled digital specification does not provide a statistically significant result, the split-sample estimates reveal significant but opposite relationships across Euro Area and Non-Euro Area countries.

Taken together, the results provide partial support for Hypothesis 1. The temporal and digital-adjusted specifications reveal important differences across monetary regimes. In the Euro Area, the relationship becomes negative and statistically significant after 2014, suggesting a weakening or reversal of the traditional B–S mechanism. In contrast, Non-Euro Area countries show a positive and statistically significant relationship only in the digital-adjusted specification. These findings suggest that the B–S relationship has not disappeared uniformly but has become more heterogenous across monetary regimes in the digital-intensive period.

4.3 Hypothesis 2 – Regulatory Moderation

Hypothesis 2 examines whether digital services trade restrictiveness moderates the relationship between productivity differentials and the REER. Since the previous results indicate substantial heterogeneity between Euro Area and Non-Euro Area countries, the moderation models are estimated separately for both monetary regimes. The main specification uses digital-adjusted productivity differential from 2014Q1 onward, while the traditional post-2014 productivity differential is included as a comparison.

Table 8: DSTRI Moderation Results by Monetary Regime

Variables	Euro Area		Non-Euro Area	
	Traditional	Digital	Traditional	Digital
Prod Diff	–0.0636***	–0.0637***	0.3547***	0.2779***
	(0.0227)	(0.0218)	(0.1157)	(0.0625)
DSTRI	0.0329	0.0988	0.3017***	0.0493
	(0.0974)	(0.1036)	(0.1107)	(0.1011)
Interaction	0.2572	0.0903	–3.0454***	–2.8698***
	(0.1999)	(0.2679)	(0.8300)	(0.4547)
Log ToT	–0.0340	–0.0434	0.4158***	0.3759***
Log GDP pc	0.0770	0.0862	0.1264	0.1184
Gov Cons	0.0147***	0.0133***	0.0337***	0.0250***
Pop Growth	10.203**	10.370**	19.415***	15.474***
Observations	748	748	264	264
R^2 (within)	0.3284	0.3327	0.3832	0.4695
Entity FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes

Source: Author's calculations based on data sources in Table 1.

*Note: Standard errors in parentheses. Significance levels: * p<0.1, ** p<0.05, *** p<0.01. All models are estimated using two-way fixed effects panel OLS with clustered standard errors. Traditional refers to the baseline post-2014 sector classification. Digital refers to the digital-adjusted specification in which ICT and financial and insurance activities are reclassified as tradable sectors. Productivity differential and DSTRI are mean-centred before constructing the interaction term.*

Table 8 reports the results of the DSTRI moderation models estimated separately for Euro Area and Non-Euro Area countries. since the productivity differential and DSTRI are mean-centred before constructing the interaction term, the coefficient on the productivity differential represents its association with the REER at the average level of DSTRI. The interaction term captures whether this relationship changes as digital services trade restrictiveness increases.

In the Euro Area, the coefficient on the productivity. Differential is negative and statistically significant in both the traditional and digital-adjusted specifications. However, the interaction term between the productivity differential and DSTRI is not statistically significant in either model. This suggest that although the productivity–REER relationship remains negative in the Euro Area, digital services trade restrictiveness does not systematically moderate this relationship.

The results differ for Non-Euro Area countries. In both specifications, the coefficient on the productivity differential is positive and statistically significant, indicating that the relationship between productivity differentials and the REER is more consistent with the traditional assumption of the B–S mechanism. However, the interaction term is negative and statistically significant in both specifications. This indicates that higher digital services trade restrictiveness weakens, rather than strengthens, the positive productivity–REER relationship in the Non-Euro Area countries.

Therefore, H2 is not supported in the expected direction. The results do not show that more restrictive digital services regulation strengthens the B–S channel. Instead, DSTRI has no moderating effect in the Euro Area, while in Non-Euro Area countries higher digital restrictiveness is associated with a weaker productivity–REER relationship. This suggest that digital regulation may constrain the transmission of productivity gains into REER movements rather than preserving the traditional B–S mechanism.

The control variables also point to differences across monetary regimes. TOT are positive and statistically significant only in the Non-Euro Area models, suggesting that external price conditions play a stronger role in REER dynamics outside the Euro Area. Government consumption is positive and statistically significant across all specifications, while population growth is also positive and significant in both Euro Area and Non-Euro Area models. GDP per capita is statistically insignificant in the H2 specifications.

As an additional robustness check, the moderation is re-estimated using a one-quarter lag of DSTRI. The lagged specification does not substantially change the interpretation results. In the Euro Area, the interaction term remains insignificant, while in the Non-Euro Area group it remains negative and statistically significant. This confirms that the main conclusion is not driven by the timing of the DSTRI variable.

Overall, the H2 results suggest that digital services trade regulation does not reinforce the traditional B–S mechanism. Instead, the moderating role of DSTRI appears to be monetary-regime specific.

4.4 Hypothesis 3 – Development Stage Heterogeneity

Hypothesis 3 examines whether the productivity–REER relationship differs between advanced and emerging European countries. Table 9 reports the baseline two-way FE model estimated separately for the two development groups over the full sample period. This specification is used to assess whether the B–S relationship is more visible in economies at different stages of development.

Table 9: Development Stage Heterogeneity Results

Variable	Advanced	Emerging
Prod Diff	0.0470	–0.0151
	(0.0411)	(0.0511)
Log ToT	0.0055	–0.0674
	(0.0524)	(0.3046)
Log GDP pc	–0.1296*	0.0957
	(0.0681)	(0.1607)
Gov Cons	0.0046	0.0032
	(0.0030)	(0.0088)
Pop Growth	4.1525	9.0655*
	(4.2008)	(5.0761)
Observations	1485	1089
R^2 (within)	0.0868	0.2231
Entity FE	Yes	Yes
Time FE	Yes	Yes

Source: Author's calculations based on data sources in Table 1.

*Note: Standard errors in parentheses. Significance levels: * p<0.1, ** p<0.05, *** p<0.01. All models are estimated using two-way fixed effects panel OLS with clustered standard errors.*

Table 9 shows that the productivity differential is not statistically significant in either development group. For advanced economies, the coefficient is positive but statistically insignificant. For emerging and transition economies, the coefficient is slightly negative and statistically insignificant. These results suggest that the baseline productivity–REER relationship is not robustly supported within either advanced or emerging European economies.

The control variables provide only limited additional evidence. In the advanced-economy group, GDP per capita is negative and marginally significant, while the remaining controls are not statistically significant. In the emerging and transition group, population growth is positive and marginally significant, whereas the other control variables do not show statistically significant effects. Overall, the control variables do not alter the main interpretation that productivity differentials do not explain REER movements systematically across development groups.

As a complementary check, an interaction model was estimated to test whether the productivity coefficient differs statistically between advanced and emerging economies. The interaction term is not statistically significant, indicating that the difference between the two development groups is not statistically robust. In addition, an explanatory division of the sample by both development stage and monetary regime does not produce statistically significant productivity coefficients in any of the smaller subsamples. Since the more detailed split substantially reduces the number of countries in each group, it is interpreted only as supplementary evidence.

Therefore, H3 is not supported. The results do not provide evidence that the B–S relationship differs systematically between advanced and emerging European economies. Compared with the monetary-regime heterogeneity observed in H1 and H2, development stage appears to play a weaker role in explaining differences in the productivity–REER relationship within the analysed European sample.

4.5 Hypothesis 4 – Sectoral Heterogeneity

Hypothesis 4 examines whether ICT productivity has a weaker relationship with the REER than manufacturing productivity. Table 10 reports the two-way FE model including both sectoral productivity measures in the same regression. The model is estimated for the full sample and separately for Euro Area and Non-Euro Area countries to account for potential monetary-regime heterogeneity. It captures full sample period, 2000Q1–2025Q4.

Table 10: Sectoral Heterogeneity Results

Variable	Full Sample	Euro Area	Non-Euro Area
Manufacturing Prod	0.2252	–0.6776	1.3523
	(0.6266)	(0.5103)	(1.3078)
ICT Prod	–1.6670**	–0.7420**	–4.9971***
	(0.7211)	(0.3443)	(1.4574)
Log ToT	–0.0213	–0.2844	0.1142
	(0.1466)	(0.3388)	(0.1628)
Log GDP pc	0.2674***	0.3350***	0.1699
	(0.0740)	(0.0874)	(0.1426)
Gov Cons	0.0034	0.0070	0.0033
	(0.0043)	(0.0057)	(0.0058)
Pop Growth	6.4865*	3.0188	14.772
	(3.7625)	(3.3079)	(9.1038)
M – ICT	1.8922	0.0644	6.3494***
	(1.3008)	(0.7486)	(1.9242)
p-value: M = ICT	0.1458	0.9314	0.0010
Observations	2574	1782	792
R^2 (within)	0.2844	0.4000	0.2443
Entity FE	Yes	Yes	Yes
Time FE	Yes	Yes	Yes

Source: Author's calculations based on data sources in Table 1.

*Note: Standard errors in parentheses. Significance levels: * p<0.1, ** p<0.05, *** p<0.01. All models are estimated using two-way fixed effects panel OLS with clustered standard errors. M – ICT reports the difference between the two sectoral productivity coefficients. The p-value tests the null hypothesis that the manufacturing and ICT productivity coefficients are equal.*

Table 10 shows that manufacturing productivity is not statistically significant in the full sample, while ICT productivity is negative and statistically significant. This suggests that

ICT productivity is not associated with real appreciation in the full sample. Instead, higher ICT productivity is associated with a lower REER. However, the coefficient-difference test does not reject equality between the manufacturing and ICT coefficients in the full sample. Therefore, the full-sample results provide only limited evidence of sectoral heterogeneity.

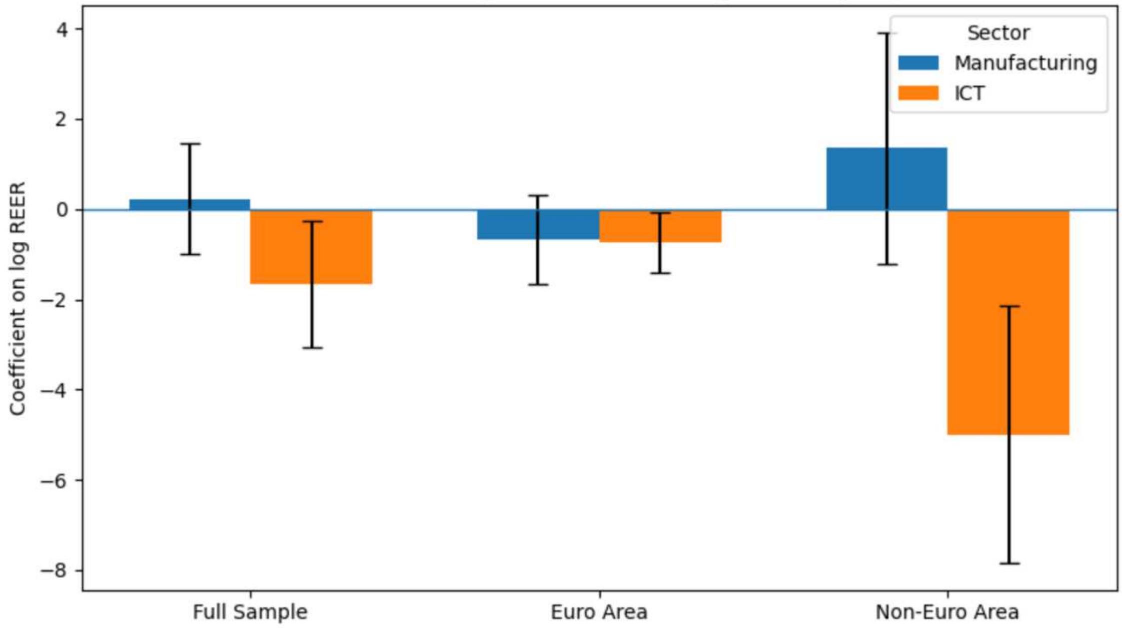
The Euro Area results show similar pattern. ICT productivity is negative and statistically significant, while manufacturing productivity is statistically insignificant. However, the coefficient-difference test again does not indicate statistically significant difference between the two sectoral coefficients. Hence, the Euro Area results do not provide robust support for H4.

The strongest evidence of sectoral heterogeneity appears in the Non-Euro Area sample. In this group, ICT productivity is negative and statistically significant, while manufacturing productivity is positive but statistically insignificant. Importantly, the coefficient-difference test rejects equality between the manufacturing and ICT coefficients. This indicates that the relationship between sectoral productivity and the REER differs significantly between manufacturing and ICT in Non-Euro Area countries.

Overall, H4 is partially supported. The results do not show that manufacturing productivity has a robust positive effect on the REER. However, ICT productivity is consistently negative and statistically significant across specifications, and the difference between manufacturing and ICT productivity is statistically significant in the Non-Euro Area sample. This suggests that ICT productivity has a weaker, and in some specification opposite, association with the REER compared with manufacturing productivity, especially outside the Euro Area.

Figure 3 visualises the sectoral productivity coefficients reported in Table 10. The figure shows that ICT productivity is consistently associated with negative coefficients across the specifications, while the manufacturing productivity coefficient is not statistically significant. The largest difference between the manufacturing and ICT coefficients appears in the Non-Euro Area sample, where the coefficient-difference test indicates a statistically significant gap between the two sectoral productivity measures.

Figure 3: Manufacturing and ICT Productivity Coefficients by Monetary Regime



Source: Author's calculations based on data sources in Table 1.

4.6 Wage Channel Extension

In addition to the REER-based specifications, the analysis examines the wage-channel component of the B–S mechanism. The theoretical mechanism suggests that higher productivity in tradable sectors may increase wages, which can then contribute to higher non-tradable prices and RER appreciation. Therefore, this additional specification uses the logarithm of total hourly compensation as the dependent variable and estimates whether the productivity differential is associated with wage developments. The model is estimated for the full sample and separately for Euro Area and Non-Euro Area countries and over the full sample period.

Table 11: Wage Channel Results by Monetary Regime

Variable	Full Sample	Euro Area	Non-Euro Area
Prod Diff	–0.0391	–0.1264**	0.2076**
	(0.0682)	(0.0557)	(0.1039)
Log ToT	0.5915**	0.5703	0.7828***
	(0.2634)	(0.4598)	(0.2936)
Log GDP pc	1.1207***	1.2619***	0.9175***
	(0.1265)	(0.1390)	(0.1584)
Gov Cons	0.0327***	0.0326**	0.0408***
	(0.0105)	(0.0144)	(0.0088)
Pop Growth	13.1760*	7.3368	12.8960
	(6.9347)	(5.9927)	(11.8290)
Observations	2376	1584	792
R^2 (within)	0.7179	0.6910	0.7747
Entity FE	Yes	Yes	Yes
Time FE	Yes	Yes	Yes

Source: Author's calculations based on data sources in Table 1.

*Note: Standard errors in parentheses. Significance levels: * p<0.1, ** p<0.05, *** p<0.01. All models are estimated using two-way fixed effects panel OLS with clustered standard errors.*

Table 11 reports the results of the wage-channel specification. In the full-sample model, the productivity differential is negative but statistically insignificant, suggesting that there is no robust average relationship between productivity differentials and total hourly compensation across monetary regimes.

In the Euro Area sample, the productivity differential is negative and statistically significant. This finding does not support the traditional wage-channel interpretation of the B–S mechanism, as higher tradable-sector productivity relative to non-tradable-sector productivity is not associated with higher wages. Instead, the negative coefficient is consistent with the broader Euro Area REER results, where the productivity–REER relationship is also weak or reversed.

In contrast, the Non-Euro Area sample shows a positive and statistically significant coefficient on the productivity differential. This suggests that, outside the Euro Area, higher productivity in tradable sectors relative to non-tradable sectors is associated with higher total hourly compensation. The result therefore provides evidence in favour of the wage-transmission channel of the B–S mechanism in Non-Euro Area countries.

The control variables also show several significant relationships. Log GDP per capita is positive and statistically significant across all specifications, indicating that higher-income countries tend to have higher hourly compensation. Government consumption is also positive and statistically significant across all three models. TOT are significant in the full sample and Non-Euro Area sample, while population growth is only weakly significant in the full-sample specification.

Overall, the wage-channel results provide additional support for monetary-regime heterogeneity. The traditional productivity-wage transmission mechanism appears more visible in Non-Euro Area countries, while Euro Area results do not support the expected positive wage-channel relationship. These findings complement the REER results by suggesting that B–S mechanism is more evident outside the Euro Area, particularly when the digital-adjusted specification is considered.

4.7 Robustness Checks

This section reports additional robustness checks used to assess whether the main findings are sensitive to alternative sector definition or estimation methods. First, the baseline specification is re-estimated using an alternative definition of the tradable sector that excludes agriculture. Second, the baseline model is re-estimated using RE and FD as alternative estimators.

4.7.1 Sector definition

A robustness check is conducted by excluding agriculture from the tradable sector. Agriculture is formally tradable however, it is often subject to substantial government intervention, subsidies, and trade protection, which might weaken the standard B–S mechanism. The test suggests that excluding agriculture does not substantially change the interpretation of the main results.

Table 12: Robustness Check: Alternative Sector Definition

Sample	Euro Area	Non-Euro Area
Full Period	–0.0162	0.1121
	(0.0226)	(0.0720)
Observations	1782	792
R^2 (within)	0.2703	0.0761
Pre-digital Period	0.0388	0.0388
	(0.0324)	(0.0621)
Observations	990	440
R^2 (within)	0.3193	0.3419
Digital-intensive Period	–0.0603***	0.2001
	(0.0230)	(0.1373)
Observations	792	352
R^2 (within)	0.2850	0.3147
Controls	Yes	Yes
Entity FE	Yes	Yes
Time FE	Yes	Yes

Source: Author's calculations based on data sources in Table 1.

*Note: Standard errors in parentheses. Significance levels: * p<0.1, ** p<0.05, *** p<0.01. All models are estimated using two-way fixed effects panel OLS with clustered standard errors. The reported coefficients refer to the productivity differential constructed under the alternative sector definition excluding agriculture from the tradable sector.*

Table 12 reports the sector-definition robustness check, where agriculture is excluded from the tradable sector. In the full-sample specification, the productivity differential remains statistically insignificant, indicating that the pooled baseline result is not driven by the inclusion of agriculture. The split-sample results show the same conclusion for the full period and the pre-digital period, as the productivity differential is statistically insignificant in both Euro Area and Non-Euro Area countries.

For the digital-intensive period, the results remain close to the main H1 findings. The Euro Area coefficient is negative and statistically significant, while the Non-Euro Area coefficient is positive but statistically insignificant. Therefore, excluding agriculture does not substantially alter the interpretation of the temporal and monetary-regime heterogeneity results. This suggests that the main findings are not driven by the treatment of agriculture as a tradable sector.

4.7.2 Alternative Estimators

The second robustness check assesses whether the baseline full-sample results are sensitive to the choice of estimator. The model is re-estimated using RE and FD. RE allow the model to use both within-country and between country variation, while FD differences focus on short-run changes by removing country-specific time-invariant components.

Table 13: Robustness Checks: Alternative Estimators Results

Variables	Random Effects	First Differences
Prod Diff	0.0200	-0.0071*
	(0.0308)	(0.0041)
Log ToT	0.0393	0.0563***
	(0.1485)	(0.0123)
Log GDP pc	0.1594**	–0.0058
	(0.0621)	(0.0047)
Gov Cons	0.0065	0.0012**
	(0.0054)	(0.0005)
Pop Growth	8.7153***	0.8964
	(3.0788)	(0.7162)
Observations	2574	2548
R^2 (within)	0.2076	—

Source: Author's calculations based on data sources in Table 1.

*Note: Standard errors in parentheses. Significance levels: * p<0.1, ** p<0.05, *** p<0.01. Random effects and first-difference panel estimators with clustered standard errors at the country level.*

The RE results are broadly consistent with the baseline FE model, as the productivity differential remains statistically insignificant. The FD specification shows a small negative coefficient on the productivity differential, which is statistically significant only at the 10%

level. Overall, the alternative-estimator results suggest that the pooled baseline conclusion is not highly sensitive to the choice of estimator.

As an additional check, the alternative-estimator specifications were also inspected separately for Euro Area and Non-Euro Area countries. The split RE estimates maintain the sign difference observed in the baseline FE results, with a negative productivity coefficient in the Euro Area and a positive coefficient in the Non-Euro Area, although both coefficients remain statistically insignificant. The FD specification shows a negative and statistically significant short-run coefficient for the Euro Area, while the Non-Euro Area coefficient is statistically insignificant. Overall, these results provide mixed but broadly consistent evidence that the weak or reversed productivity–REER relationship in the Euro Area is not driven solely by the FE estimator. However, they do not provide strong additional support for a positive traditional productivity–REER relationship in the Non-Euro Area, which remains more visible in the digital-adjusted specification.

5 Discussion

This chapter discusses the empirical findings in relation to the B–S mechanism, digital transformation, and monetary-regime heterogeneity. The results show that the relationship between productivity differentials and the REER is not uniform across European countries. While the pooled baseline estimates provide limited evidence of a traditional B–S effect, the split-sample results reveal important differences between Euro Area and Non-Euro Area countries. In particular, the evidence suggests that the traditional productivity–REER relationship is weak or reversed in the Euro Area, while it becomes more visible in Non-Euro Area countries when digital tradability is considered. The wage-channel extension further supports this interpretation by showing a positive relationship between productivity differentials and total hourly compensation in Non-Euro Area countries.

5.1 Interpretation of the Main Findings

The main contribution of the empirical results is that they show the B–S mechanism to be more conditional and heterogeneous than a pooled model would suggest. The full-sample baseline estimates provide only limited evidence of a traditional productivity–REER relationship. However, this does not necessarily imply that the B–S mechanism is irrelevant. Rather, the results suggest that the mechanism operates differently across monetary regimes and depends on how tradable and non-tradable sectors are defined in the digital era.

A key interpretation is that pooled estimates mask important differences between Euro Area and Non-Euro Area countries. In the Euro Area, the productivity–REER relationship becomes negative and statistically significant after 2014. This is inconsistent with the traditional prediction that higher productivity in tradable sectors should lead to real appreciation. One possible explanation is that the Euro Area is characterised by a common currency, stronger price integration, and more limited nominal exchange-rate adjustment. As a results, productivity shocks may be absorbed differently than in countries with independent exchange rates. In such an environment, relative price adjustment may be weaker, slower, or influenced more strongly by common monetary conditions and price convergence than by domestic productivity differentials alone.

In contrast, the Non-Euro Area results are more consistent with the traditional B–S logic, but only when digital tradability is considered. The traditional post-2014 specification shows a positive but statistically insignificant productivity coefficient, while the digital-adjusted specification produces a positive and statistically significant coefficient. this suggests that the standard sectoral classification may no longer fully capture the relevant productivity channel in modern economies. Once ICT and financial services are treated as tradable, the productivity differential appears to reflect the structure of increasingly digital and internationally traded services more accurately. Therefore, the digital-adjusted specification does not only act as a robustness check. It helps reveal a relationship that is less visible under traditional classification.

The wage-channel extension strengthens this interpretation. In the traditional B–S framework, productivity gains in tradable sector should be transmitted into wages, which may then raise non-tradable prices and contribute to real appreciation. The results show that this wage transmission is not visible in the pooled sample and is reversed in the Euro Area. However, in Non-Euro Area countries, the productivity differential is positively and significantly associated with total hourly compensation. This suggest that the internal transmission mechanism from productivity to wages is more visible outside the Euro Area. At the same time, the REER effects become statistically significant mainly in the digital-adjusted specification, indicating that the wage channel may be reflected in REER dynamics only when the changing tradability of digital services is properly accounted for.

The Euro Area results are particularly important because they suggest that the traditional B–S transmission mechanism is not clearly visible in either its internal or external dimension. The wage-channel specification shows a negative and statistically significant between the productivity differential and total hourly compensation, which is inconsistent with the expected productivity-to-wage transmission. Similarly, the REER specifications for the post-2014 period show a negative and statistically significant productivity coefficient. this means that higher productivity in tradable sectors relative to non-tradable sectors is not associated with higher wages or real appreciation in the Euro Area sample. A possible explanation is that, within a common currency area, productivity gains may be absorbed through mechanisms other than country-specific nominal exchange-rate movements. The common currency limits nominal exchange-rate adjustment, while common monetary conditions, the ECB's price-stability framework, and stronger cross-country price integration may weaken the link between domestic productivity differentials, wages, and the REER.

The results for digital services trade restrictiveness also point to a more complex mechanism than originally expected. The hypothesis assumed that stricter digital trade regulation could preserve the non-tradability of digital services and therefore strengthen the traditional B–S channel. However, the empirical results do not support this interpretation. In the Euro Area, DSTRI does not significantly moderate the productivity–REER relationship, while in Non-Euro Area countries the interaction is negative and statistically significant. This suggests that higher digital trade restrictiveness may weaken, rather than reinforce, the transmission of productivity gains into REER movements. The negative interaction between the productivity differential and DTSRI suggests that digital services may already behave more like tradable sectors than non-tradable sectors. If this is the case, regulatory barriers do not preserve the traditional non-tradable character of digital services. Instead, they may restrict the ability of digital sectors to scale across borders and translate productivity gains into international competitiveness and REER effects.

Taken together, the H1 and H2 results support the relevance of the digital-adjusted sector classification. The H1 results show that the productivity–REER relationship in Non-Euro Area countries becomes significant only when ICT and financial services are treated as tradable sectors. At the same time, the H2 results suggest that digital services trade restrictions weaken rather than strengthen the productivity–REER relationship. This indicates that digital services may already behave more like tradable sectors, and that regulatory barriers limit their ability to transmit productivity gains into external competitiveness and REER dynamics. Hence, the digital-adjusted specification appears to capture a more realistic sectoral structure in the digital era than the traditional classification.

The development-stage results further suggest that monetary regime differences are more relevant than the advanced/emerging distinction in this sample. Although the B–S mechanism is often associated with catching-up economies, the development-stage split does not produce statistically significant differences in productivity coefficients. This may be because the analysed European countries are relatively integrated and institutionally similar compared to broader global samples. As a result, development stage alone may not capture the most important source of heterogeneity. Instead, the results indicate that the monetary regime and sectoral classification provide more useful dimensions for understanding differences in the productivity–REER relationship.

Finally, the sectoral heterogeneity results suggest that ICT productivity behaves differently from manufacturing productivity. Manufacturing productivity does not show a robust positive effect on the REER, while ICT productivity is consistently negative and statistically significant. This is consistent with the idea that digital services differ from traditional tradable goods. ICT services are characterised by low or near-zero transport costs, scalability, and strong international competition. Productivity gains in ICT may therefore reduce costs and strengthen competitive pressure rather than generate domestic price increases. This helps explain why ICT productivity may be associated with lower REER values rather than real appreciation.

Overall, the findings do not reject the B–S mechanism entirely. Instead, they suggest that the mechanism has become more dependent on monetary regime and sectoral structure. The traditional pooled model provides limited evidence, but the Non-Euro Area wage-channel and digital-adjusted REER results indicate that the mechanism can still operate when modern tradability patterns are taken into account. The Euro Area results, by contrast, suggest that common currency arrangements may weaken or reverse the observable productivity–REER relationship.

5.2 Role of Control Variables

In addition to the main productivity variables, several control variables provide useful insight into the broader determinants of REER movements in the analysed sample. Their behaviour suggests that real exchange rate dynamics are not driven by productivity differentials alone, but also by income levels, external price conditions, fiscal demand, and demographic factors.

GDP per capita is positive and statistically significant in several baseline specifications, especially in the full-period models. This is consistent with the broader price-level convergence argument, according to which higher-income economies tend to exhibit higher relative price levels and stronger RER. However, the significance of GDP per capita becomes less stable in the post-2014 and digital-adjusted specifications. This suggests that income-related fundamentals remain relevant, but their explanatory power may be weaker in the more recent period once monetary-regime differences and digital-sector reclassification are considered.

TOT become more important in the post-2014 period, particularly in the Non-Euro Area specifications. The positive and statistically significant coefficient suggests that improvements in external price conditions are associated with a stronger REER. This is consistent with open-economy macroeconomic theory, where higher export prices relative to import prices can improve external income and strengthen the RER. The stronger role of TOT outside the Euro Area may also reflect the greater exposure of these countries to external price shocks and nominal exchange rates movements.

Government consumption is also positive and statistically significant in several post-2014 and digital specifications. This result is consistent with the idea that higher public expenditure can increase demand for non-tradable goods and services, rising domestic price levels and contributing to real appreciation. This demand-side channel operates independently of productivity differential and may therefore partly obscure the traditional B–S mechanism in some specifications.

Population growth becomes statistically significant mainly in the post-2014 and digital-period models. This may reflect broader structural and demand-side dynamics within the economy. Changes in population growth can affect labour supply, consumption patterns, housing demand, and investment dynamics, all of which may influence domestic prices and the REER. The significance of population growth in some specifications suggest that demographic factors may also contribute to REER movements, particularly in the more recent period.

Taken together, the control variables show that REER dynamics in the analysed European sample are influenced by several macroeconomic and structural factors in addition to productivity differentials. This does not overturn the evidence of a productivity-related mechanism in Non-Euro Area countries, especially in the digital-adjusted and wage-channel results. However, it suggests that the B–S channel operates alongside other forces, such as TOT, fiscal demand, income convergence, and demographic change. These factors may help explain why productivity–REER relationship is weak in the pooled model and more visible only once monetary-regime heterogeneity and digital-sector tradability are considered.

5.3 Explaining Result Heterogeneity

The empirical findings suggest that the Balassa–Samuelson mechanism is weak in the pooled specification, reversed in the Euro Area, and more visible in Non-Euro Area countries when digital tradability is considered. This indicates that the mechanism is not necessarily absent, but rather conditional on monetary regime, sectoral structure, and broader macroeconomic conditions. Several explanations may account for this pattern.

First, the increasing importance of the external and demand-side factors may reduce the relative importance of productivity-based mechanisms. As shown in the results, variables such as TOT, government consumption, and population growth are statistically significant in several specifications. These factors operate through channels that do not rely directly on productivity differentials. For example, TOT reflect external price shocks, government consumption can raise demand for non-tradable goods and services, and population growth may influence labour supply, consumption, housing demand, and investment dynamics. When such forces play a strong role, the transmission of productivity gains into domestic prices and the REER may be weakened or obscured.

Second, structural changes in modern economies alter the traditional distinction between tradable and non-tradable sectors. The classical B–S framework assumes that services are largely non-tradable because they require local presence. However, digital technologies have enabled the cross-border delivery of services, increasing the tradability of sectors such as ICT, finance, and business services. This changes the meaning of the productivity differential itself. If digitally intensive services are increasingly exposed to international competition, productivity gains in these sectors may reduce costs and strengthen competitiveness rather than generate higher domestic prices. This helps explain why digital-adjusted specification produces stronger evidence for the productivity–REER relationship in Non-Euro Area countries.

Third, the Euro Area results may reflect the specific institutional and monetary structure of a common currency area. Since Euro Area countries share a common currency and common monetary policy, country-specific productivity shocks cannot be reflected through independent nominal exchange rate movements. In addition, stronger cross-country price integration, the ECB's price-stability framework, and common monetary conditions may weaken the link between domestic productivity differentials, wages, and the REER. This may explain why the traditional wage channel and REER channel are not clearly visible in the Euro Area sample.

Fourth, the analysed European sample is relatively integrated and institutionally similar compared with broader global samples. Cross-country differences in productivity may therefore be smaller or less directly reflected in relative price movements. In such a setting, the advanced/emerging distinction may not capture the most important source of heterogeneity. Instead, monetary regime and sectoral classification appear to be more relevant for explaining differences in the productivity–REER relationship.

Fifth, measurement issues may also contribute to the observed results. The construction of productivity differentials depends on sectoral classifications that may not fully reflect the evolving structure of modern economies. The digital-adjusted specification addresses this issue by reclassifying ICT and financial services as tradable sectors, but this remains an approximation. If the productivity differential does not accurately capture the true distinction between tradable and non-tradable activities, the estimated relationship between productivity and the REER may be weakened.

Finally, the B–S mechanism may operate gradually and may therefore be difficult to identify in short- and medium-term REER movements. Although the FE specification is appropriate for the structure of the data and focuses on within-country variation over time, productivity-driven price adjustments may occur slowly. As a result, observed REER movements may be more strongly influenced by external price shocks, fiscal conditions, or common monetary developments in the short run. This could reduce the statistical significance of productivity differentials even if the mechanism remains relevant as a longer-term structural process.

In summary, the weak and heterogeneous empirical evidence does not imply irrelevance of the B–S mechanism. Rather, it suggests that the mechanism has become more conditional in modern European economies. Its visibility depends on monetary regime, sectoral classification, digital tradability, and the interaction between productivity-based channels and broader macroeconomic forces.

5.4 Robustness and Reliability of Results

The robustness checks help assess whether the main findings are sensitive to alternative sector definitions or estimation methods. Overall, they do not overturn the central interpretation of the results. Instead, they support the view that the productivity–REER relationship is heterogeneous across monetary regimes and depends partly on how tradable and non-tradable sectors are defined.

The alternative sector-definition check, which excludes agriculture from the tradable sector, produces results that are close to the main H1 findings. In the full-period and pre-digital specifications, the productivity differential remains statistically insignificant in both Euro Area and Non-Euro Area countries. In the digital-intensive period, the Euro Area coefficient remains negative and statistically significant, while the Non-Euro Area coefficient remains positive but statistically insignificant. This suggests that the main interpretation is not driven by the treatment of agriculture as a tradable sector.

The alternative-estimator checks provide more mixed but still informative evidence. In the pooled full-sample specification, the random-effects model confirms the weak baseline result, as the productivity differential remains statistically insignificant. The first-difference model produces a small negative coefficient that is statistically significant only at the 10% level, suggesting a weak short-run relationship rather than a robust alternative pattern.

When the alternative estimators are inspected separately by monetary regimes, the results remain broadly consistent with the main interpretation. The split RE estimates preserve the sign difference observed in the baseline FE results, with a negative productivity coefficient in the Euro Area and a positive coefficient in the Non-Euro Area, although both coefficients are statistically insignificant. The FD specification shows a negative and statistically significant short-run coefficient for the Euro Area, while in the Non-Euro Area coefficient is statistically insignificant. These findings suggest that the weak or reversed productivity–REER relationship in the Euro Area is not driven solely by the FE estimator. At the same time, they do not provide strong additional evidence for a positive traditional productivity–REER relationship in Non-Euro Area countries, which remains more visible in the digital-adjusted specification.

Overall, the robustness checks provide support for the reliability of the main interpretation, but they also show that the result should not be overstated. The evidence does not support a uniform B–S effect across the full sample. Rather, it supports a more conditional interpretation: the relationship between productivity differentials and the REER depends on monetary regime, sectoral classification, and the distinction between traditional and digital-adjusted measures of tradability.

5.5 Limitations

While the empirical analysis provides a consistent evaluation of the relationship between productivity differentials and the REER, several limitations should be considered when interpreting the results.

First, the analysis relies primarily on a FE panel OLS estimation, which focuses on within-country variation over time and controls for unobserved time-invariant heterogeneity. Although this approach is appropriate given the structure of the data and the results of the panel unit root tests, it may not fully capture broader structural relationships that evolve gradually. In particular, if the link between productivity, wages, relative prices, and the REER operates over longer horizons, it may not be fully reflected in the estimated coefficients.

Second, the sample is limited to European countries, which are relatively similar in terms of economic development, institutional frameworks, and market integration compared to broader global samples. This improves comparability across observations, but it may reduce the variation necessary to identify stronger empirical relationships. Extending the analysis to a more diverse set of countries could help assess whether the findings are specific to the European context or more broadly applicable.

Third, while the B–S framework focuses primarily on productivity differentials as a key determinant of the REER dynamics, the literature acknowledges that additional factors, such as capital flows, demand-side pressures, and exchange rate regimes, may also play a role in determining the REER movements. However, these effects are often not explicitly incorporated in empirical models due to data limitations and measurement challenges (Egert, 2002; Mihaljek and Klau, 2003). Consequently, this thesis follows the standard approach in the literature by focusing on productivity variables, while recognising that omitted factors such as capital flows may contribute to unexplained variation in the REER.

Fourth, the digital services trade restrictiveness analysis is limited by the frequency and availability of the DSTRI data. The DSTRI variable is available only from 2014 onward and is originally reported annually. This is not necessarily problematic, as regulatory frameworks typically change slowly and may remain stable for several quarters or even years. However, it means that the variable captures broader differences in the regulatory environment rather than short-term quarterly changes. As a result, the H2 results should be interpreted as evidence of how relatively more or less restrictive digital trade environments affect the productivity–REER relationship, rather than as precise short-run effects of regulatory changes.

Fifth, the wage-channel extension is based on a smaller sample due to missing data. Total hourly compensation data are unavailable for Germany and France, while Belgium is missing in 2025Q4. This reduces the number of observations and means that the wage-channel results may not fully represent the entire country sample used in the REER-based analysis. Nevertheless, the wage specification provides useful additional evidence on the internal transmission mechanism of the B–S framework.

Sixth, the construction of productivity differentials depends on sectoral classifications that may not fully capture the changing structure of modern economies. The digital-adjusted specification reclassifies ICT and financial services as tradable sectors, which is theoretically motivated by the increased cross-border tradability of digital services. However, this classification remains an approximation. Some activities within ICT and finance may still be domestically oriented, while some traditionally non-tradable services may also have become more internationally tradable over time.

Finally, the empirical analysis does not fully capture all channels through which digitalisation may affect REER dynamics. Digital transformation may influence productivity, wages, prices, competition, market structure, and cross-border service delivery simultaneously. These mechanisms are difficult to separate empirically with aggregate sectoral data. Therefore, the findings should be interpreted as evidence on broad productivity–REER patterns rather than as a complete identification of all digitalisation channels.

Overall, these limitations suggest that the results should be viewed as a part of a broader set of factors influencing REER dynamics. The analysis provides evidence that the B–S mechanism has become more heterogeneous across monetary regimes and sectoral classifications, but further research with more detailed sectoral, firm-level, or longer-horizon data would be useful to examine the underlying mechanisms in greater depth.

5.6 Comparison with Existing Literature

The empirical findings of this thesis can be better understood when placed in the context of the existing literature on the B–S effect. While the traditional B–S framework predicts a positive relationship between productivity differentials and the RER, empirical evidence across studies remains mixed.

Table 14: Summary of Empirical Evidence on the Balassa–Samuelson Effect

Study	Sample	Period	Finding
Égert (2002)	CEE countries	1990s	Positive but limited effect
Mihaljek & Klau (2003)	Central Europe vs Euro Area	1990s–2000s	Small effect
Hassan (2016)	Global sample	1980s–2010s	Mixed/non-linear
Wang et al. (2016)	Developed vs developing countries	Late 20th – early 21st century	Only in developed countries
Gubler & Sax (2019)	OECD countries	1970–2008	Negative effect

Source: Author's compilation based on Egert (2002), Gubler & Sax (2019), Hassan (2016), Mihaljek & Klau (2003), Wang et al. (2016)

As shown in Table 14, the empirical evidence on the B–S effect is far from uniform. Earlier studies often identify a positive relationship between productivity differentials and real exchange rates, but the magnitude of the effect is frequently limited. For example, Égert (2002) finds a positive but limited effect for Central and Eastern European countries, while Mihaljek and Klau (2003) show that productivity differentials explain only a limited share of inflation and real exchange rate dynamics. This is consistent with the pooled baseline results of this thesis, where the productivity differential is not statistically significant and therefore does not provide strong evidence of a uniform B–S effect across the full European sample.

At the same time, the results of this thesis furthermore support the more recent view that the B–S mechanism may be heterogeneous rather than uniform. Hassan (2016) finds mixed and non-linear evidence, while Wang et al. (2016) show that the effect may differ across levels of development. In this thesis, the advanced/emerging distinction does not explain the heterogeneity strongly, but the Euro Area and Non-Euro Area split reveals important differences. This suggests that in the European context, monetary regime may be a more relevant source of heterogeneity than development stage alone.

The findings also relate to Gubler and Sax (2019), who document a reversed B–S effect in advanced OECD economies. The negative and statistically significant Euro Area coefficients in the post-2014 and digital-adjusted specifications are consistent with the idea that productivity gains may not always lead to real appreciation. In highly integrated economies, productivity improvements may be reflected in lower costs, stronger competition, or common price dynamics rather than higher domestic prices and REER appreciation.

The sectoral heterogeneity results contribute to the literature by highlighting the role of digital transformation and changing tradability. Traditional B–S models are based on a clear distinction between tradable goods and non-tradable services. However, the results of this thesis suggest that this distinction has become less stable in the digital era. ICT productivity is associated with negative REER coefficients, while the digital-adjusted specification strengthens the positive productivity–REER relationship in Non-Euro Area countries. This supports the idea that digital services increasingly behave like tradable sectors and that standard sector classifications may no longer fully capture the relevant productivity channel.

Taken together, the comparison with the existing literature suggests that that the findings of this thesis are consistent with the broader evolution of B–S evidence. The traditional positive relationship between productivity differentials and RER is not uniformly observed. Instead, the effect appears to be weaker, more conditional, and more dependent on institutional setting, monetary regime, and sectoral structure. The contribution of this thesis is therefore to show that digital tradability and monetary-regime heterogeneity are important for understanding the B–S mechanism in contemporary European economies.

5.7 Policy Implications

The findings of this thesis carry several policy implications. First, the results suggest that productivity growth alone may not be sufficient to explain or influence RER dynamics in a uniform way across European economies. The effect of productivity differentials depends on monetary regime, sectoral structure, and the extent to which digital services are treated as tradable. Therefore, policies aimed at improving external competitiveness should not rely exclusively on broad productivity-enhancing measures but should also consider the institutional and sectoral context in which productivity gains occur.

Second, the distinction between Euro Area and Non-Euro Area countries is relevant for policy interpretation. In Non-Euro Area countries, the results provide stronger evidence that productivity gains can be transmitted into wages and, when digital tradability is considered, into REER dynamics. This suggests that productivity-enhancing policies in tradable and digitally tradable sectors may have clearer implications for competitiveness outside the Euro Area. In the Euro Area, by contrast, the productivity–wage and productivity–REER channels are weaker or reversed, suggesting that common monetary conditions, price integration, and the absence of country-specific nominal exchange rate adjustment may reduce the direct impact of domestic productivity differentials on RER movements.

Third, the results highlight the importance of updating sectoral classifications in policy analysis. Digital transformation has increased the tradability of services such as ICT and financial services. If policymakers continue to treat these sectors as purely non-tradable, they may underestimate their role in external competitiveness and real exchange rate dynamics. Policies related to digital infrastructure, cross-border service provision, data regulation, and digital trade barriers can therefore influence how productivity gains are transmitted into wages, prices, and international competitiveness.

Finally, the findings suggest that digital regulation should be designed carefully. The negative interaction between productivity differentials and digital services trade restrictiveness indicates that regulatory barriers may weaken the ability of digital productivity gains to translate into external competitiveness and REER effects. This does not mean that digital regulation should be removed entirely, as regulation may serve important objectives related to data protection, consumer rights, and market stability. However, overly restrictive digital trade barriers may limit the benefits of productivity growth in increasingly tradable digital sectors.

Conclusion

This thesis examined the relationship between productivity differentials and the real exchange rate movements within the framework of the Balassa–Samuelson hypothesis, with a particular focus on European economies and the role of digital transformation. The objective was to assess whether productivity differentials remain relevant for explaining real exchange rate dynamics, whether the strength of the Balassa–Samuelson mechanism has changed in the digital era, and whether this relationship differs across monetary regimes, development groups, and sectors.

The empirical findings suggest that the Balassa–Samuelson mechanism is not uniform across the analysed European countries. The pooled baseline results provide only limited evidence of a traditional productivity–REER relationship, as the productivity differential is statistically insignificant in the full-sample specification. However, the split-sample results reveal important heterogeneity between Euro Area and Non-Euro Area countries. In the Euro Area, the productivity–REER relationship becomes negative and statistically significant in the post-2014 period, suggesting a weakening or reversal of the traditional mechanism. In contrast, Non-Euro Area countries show a more positive relationship, which becomes statistically significant when ICT and financial services are reclassified as tradable sectors.

These findings indicate that the digital-adjusted sector classification is important for understanding the Balassa–Samuelson mechanism in the digital era. The results suggest that traditional sectoral classifications may no longer fully capture the relevant productivity channel, as digitally intensive services have become increasingly tradable through cross-border delivery, digital platforms, and international competition. The DSTRI moderation results further support this interpretation. Rather than strengthening the traditional Balassa–Samuelson channel, higher digital services trade restrictiveness weakens the productivity–REER relationship in Non-Euro Area countries, suggesting that digital services may already behave more like tradable sectors.

The wage-channel extension provides additional insight into the transmission mechanism. In the full sample, the productivity differential is not significantly associated with total hourly compensation. In the Euro Area, the relationship is negative and statistically significant, which does not support the traditional productivity-to-wage transmission. However, in Non-Euro Area countries, the productivity differential is positively and statistically significantly associated with wages. This suggests that the internal wage channel of the Balassa–Samuelson mechanism is more visible outside the Euro Area. Together with the digital-adjusted REER results, this provides evidence that the mechanism may still operate in Non-Euro Area countries when modern tradability patterns are considered.

The analysis of development-stage heterogeneity does not provide strong evidence that the productivity–REER relationship differs systematically between advanced and emerging European economies. This suggests that, within the analysed European sample, monetary regime and sectoral classification are more relevant sources of heterogeneity than the advanced/emerging distinction. The sectoral analysis further shows that ICT productivity behaves differently from manufacturing productivity. Manufacturing productivity does not show a robust positive effect on the REER, while ICT productivity is consistently negative and statistically significant. This supports the view that digital services differ from traditional tradable sectors, as productivity gains in ICT may reduce costs and increase competitive pressure rather than generate domestic price increases and real appreciation.

Overall, the findings do not reject the Balassa–Samuelson mechanism entirely. Instead, they suggest that the mechanism has become more conditional and heterogeneous in modern European economies. The traditional pooled model provides limited evidence, but the Non-Euro Area wage-channel and digital-adjusted REER results indicate that the mechanism can still operate when digital tradability is taken into account. The Euro Area results, by contrast, suggest that common currency arrangements, price integration, and common monetary conditions may weaken or reverse the observable productivity–REER relationship.

The contribution of this thesis lies in providing updated empirical evidence on the Balassa–Samuelson effect using recent data for 26 European countries over the period 2000Q1–2025Q4. By incorporating monetary-regime heterogeneity, digital-adjusted sector classification, sectoral productivity differences, and a wage-channel extension, the thesis contributes to the ongoing debate on the relevance of traditional exchange rate theories in contemporary digital and integrated economies. The results highlight that productivity-based mechanisms remain relevant, but their impact depends on institutional context, sectoral structure, and the changing tradability of services.

In conclusion, the findings of this thesis suggest that real exchange rate dynamics in modern European economies are increasingly complex and cannot be fully explained by a uniform productivity-based mechanism. The Balassa–Samuelson effect remains relevant, but its visibility depends on monetary regime, sectoral structure, and the changing tradability of digital services. As economies become more integrated and digitalised, understanding how productivity, wages, regulation, sectoral composition, and external conditions jointly shape real exchange rate movements remains an important area for future research.

Resumé

Táto diplomová práca sa zaoberá testovaním Balassa-Samuelsonovho efektu v období digitalizácie. Balassa-Samuelsonov efekt predpokladá, že rast produktivity v sektore obchodovateľných tovarov a služieb vedie k apreciácii reálneho výmenného kurzu. Tento mechanizmus však vychádza z viacerých kritických predpokladov, ktorých platnosť môže byť ovplyvnená digitálnou transformáciou. Preto sa v táto práca zameriava na otázku, či je Balassa-Samuelsonov efekt v období digitalizácie stále empiricky pozorovateľný a či sa jeho intenzita v porovnaní s predchádzajúcim obdobím zmenila.

Na pochopenie vzťahu medzi produktivitou a reálnym výmenným kurzom je potrebné vychádzať zo základných teoretických konceptov, najmä parity kúpnej sily a reálneho výmenného kurzu. Parita kúpnej sily predstavuje referenčný rámec, podľa ktorého by mali byť cenové hladiny medzi krajinami po prepočte na spoločnú menu rovnaké. Inými slovami, rovnaký kôš tovarov by mal mať rovnakú cenu v rôznych krajinách. Tento princíp vychádza zo zákona jednej ceny, podľa ktorého by mali byť obchodovateľné statky predávané za rovnakú cenu na medzinárodných trhoch.

Z makroekonomického hľadiska zohráva reálny výmenný kurz dôležitú úlohu, keďže ovplyvňuje exportnú výkonnosť, investície a celkový ekonomický rast. Podhodnotený reálny výmenný kurz môže podporiť konkurencieschopnosť a rast exportu, zatiaľ čo nadhodnotený kurz môže mať opačný efekt. Odchýlky od rovnovážnej úrovne reálneho výmenného kurzu sú preto dôležitým indikátorom makroekonomickej rovnováhy.

Na uvedené teoretické východiská nadväzuje Balassa-Samuelsonov efekt, ktorý predstavuje jedno z hlavných vysvetlení rozdielov v cenových hladinách medzi krajinami a vývoja reálneho výmenného kurzu. Tento efekt vychádza z predpokladu, že rozdiely v produktivite medzi obchodovateľným a neobchodovateľným sektorom vedú k systematickým rozdielom v cenách a následnej apreciácii meny v produktívnejších ekonomikách.

Základným mechanizmom je vyšší rast produktivity v obchodovateľnom sektore, ktorý umožňuje firmám vyplácať vyššie mzdy. Vzhľadom na mobility práce medzi sektormi sa rast miezd prenáša aj do neobchodovateľného sektora, kde však produktivita rastie pomalšie. To vedie k rastu cien neobchodovateľných statkov a k celkovému zvýšeniu cenovej hladiny v ekonomike. Keďže ceny obchodovateľných statkov sú determinované medzinárodnou konkurenciou, hlavný cenový tlak sa prejavuje práve v neobchodovateľnom sektore, čo vedie k reálnej apreciaácii meny.

Balassa-Samuelsonov efekt zároveň poukazuje na obmedzenia parity kúpnej sily, keďže rozdiely v cenových hladinách medzi krajinami nie sú spôsobené len kurzovými odchýlkami, ale najmä štrukturálnymi rozdielmi v produktivite. Tento mechanizmus je obzvlášť relevantný pre konvergujúce ekonomiky, kde dochádza k rýchlejšiemu rastu v porovnaní s vyspelými krajinami.

Empirické štúdie však ukazujú, že sila tohto efektu je v praxi obmedzená a závisí od viacerých faktorov, ako sú definícia sektorov, spôsob merania produktivity či použité ekonometrické metódy. Výsledky výskumov naznačujú značnú heterogenitu medzi krajinami a poukazujú na to, že tradičný Balassa-Samuelsonov mechanizmus nemusí fungovať rovnako v rôznych ekonomických podmienkach.

Novšie prístupy zároveň zdôrazňujú, že globalizácia a digitalizácia môžu meniť základné predpoklady Balassa-Samuelsonovho efektu. Najmä rast obchodovateľnosti služieb a rozvoj digitálnych technológií stierajú hranice medzi obchodovateľným a neobchodovateľným sektorom, čím môžu oslabovať tradičný transmisný mechanizmus medzi produktivitou, cenami a reálnym výmenným kurzom.

Rozvoj digitálnych technológií a online platforiem výrazne zvýšil obchodovateľnosť služieb, ktoré boli tradične viazané na domáci trh. V dôsledku toho sa ceny a mzdy v týchto sektoroch čoraz viac formujú na globálnej úrovni, čo môže oslabiť štandardný transmisný mechanizmus Balassa-Samuelsonovho efektu. Zisky nadobudnuté zvýšením produktivity v digitálnych sektoroch sa nemusia premietať do rastu domácich cien rovnakým spôsobom ako v tradičných odvetviach, čo môže viesť k slabšiemu alebo dokonca opačnému vzťahu medzi produktivitou a reálnym výmenným kurzom.

Empirické dôkazy v existujúcej literatúre naznačujú, že Balassa-Samuelsonov efekt je heterogénny a môže závisieť od viacerých faktorov, predovšetkým od úrovne ekonomického rozvoja, sektorovej štruktúry a miery digitálnej otvorenosti ekonomiky. V niektorých vyspelých krajinách bol dokonca zaznamenaný opačný vzťah, kde rast produktivity v obchodovateľných sektoroch vedie k reálnej depreciácii.

Dôležitú úlohu môžu zohrávať aj regulačné faktory, ktoré môžu obmedzovať medzinárodnú obchodovateľnosť digitálnych služieb. Krajiny s vyššími bariérami v oblasti digitálneho obchodu si môžu zachovať tradičný Balassa–Samuelsonov mechanizmus, zatiaľ čo otvorenejšie ekonomiky môžu vykazovať jeho oslabenie.

Tieto zistenia naznačujú, že v podmienkach digitalizovanej ekonomiky sa vzťah medzi produktivitou a reálnym výmenným kurzom stáva komplexnejším a menej jednoznačným.

Tradičný model preto nemusí plne zachytávať dynamiku moderných ekonomík, čo vytvára priestor pre ďalší empirický výskum.

Na základe týchto teoretických východísk je možné formulovať empirickú otázku, či sa tento mechanizmus prejavuje aj v súčasných európskych ekonomikách a do akej miery je ovplyvnený procesom digitalizácie. Práve tento aspekt predstavuje kľúčový prínos práce, keďže existujúca literatúra sa prevažne zameriava na obdobia pred nástupom digitalizácie.

Empirická analýza je založená na panelových dátach pre 26 európskych krajín za obdobie 2000 – 2025 s kvartálnou frekvenciou. Vzorka zahŕňa vyspelé aj rozvíjajúce sa ekonomiky, čo umožňuje analyzovať heterogenitu naprieč rôznymi úrovňami ekonomického rozvoja. Z časového hľadiska je analyzované obdobie rozdelené na pred-digitálne obdobie (2000 – 2013) a obdobie intenzívnej digitalizácie (od roku 2014), čo umožňuje testovať zmeny v mechanizme Balassa-Samuelsonovho efektu v čase.

Závislou premennou je reálny efektívny výmenný kurz, ktorý zachytáva cenovú konkurencieschopnosť ekonomiky voči zahraničiu. Kľúčovou vysvetľujúcou premennou je diferenciál produktivity medzi obchodovateľným a neobchodovateľným sektorom, konštruovaný na základe sektorových údajov o produktivite práce. Okrem toho model zahŕňa aj kontrolné premenné, ako sú čisté výmenné relácie, HDP na obyvateľa, vládna spotreba a rast populácie, ktoré môžu ovplyvňovať vývoj reálneho výmenného kurzu.

Na testovanie hypotéz je použitý panelový regresný model s fixnými efektmi, ktorý umožňuje kontrolovať nepozorované rozdiely medzi krajinami v čase. Tento prístup identifikuje vzťahy na základe zmien v rámci jednotlivých krajín, čím eliminuje vplyv charakteristík nemenných v čase, ako sú geografické či inštitucionálne faktory.

Zvolený metodologický prístup je vhodný najmä v kontexte európskych krajín, ktoré sa síce líšia inštitucionálne, no vykazujú vysokú mieru ekonomickej integrácie. Zároveň však tento prístup môže obmedzovať schopnosť zachytiť dlhodobé rovnovážne vzťahy.

Analýza zahŕňa viacero rozšírení základného modelu. Na testovanie časovej zmeny efektu je použité rozdelenie vzorky na pred-digitálne a digitálne obdobie. Ďalej je skúmaná úloha regulačných faktorov prostredníctvom indexu digitálnych obchodných bariér (DSTRI), ktorý umožňuje analyzovať, či otvorenosť digitálnych trhov ovplyvňuje vzťah medzi produktivitou a reálnym výmenným kurzom. Heterogenita efektu je testovaná aj podľa úrovne ekonomického rozvoja a sektorovej štruktúry, pričom sa osobitne porovnáva vplyv produktivity vo výrobnom sektore a v ICT sektore.

Dôležitým rozšírením empirickej stratégie je aj rozdelenie vzorky podľa menového režimu. Modely sú odhadované osobitne pre krajiny eurozóny a krajiny mimo eurozóny, keďže spoločná mena môže ovplyvňovať spôsob, akým sa produktivitné zmeny premietajú do cien, miezd a reálneho efektívneho výmenného kurzu. Okrem toho je doplnená aj analýza mzdového kanála, ktorá skúma, či sa produktivitný diferenciál premieta do celkovej hodinovej kompenzácie. Tento krok umožňuje overiť vnútorný transmisný mechanizmus Balassa-Samuelsonovho efektu, podľa ktorého by vyššia produktivita v obchodovateľnom sektore mala viesť k rastu miezd a následne k tlaku na ceny neobchodovateľných statkov a služieb.

Stabilita výsledkov je overená pomocou testov robustnosti, ktoré zahŕňajú alternatívne špecifikácie modelu, ako sú model s náhodnými efektmi a model prvej diferencie. Tieto prístupy umožňujú overiť, či sú výsledky citlivé na zvolenú metodológiu.

Empirické výsledky naznačujú, že vzťah medzi produktivitným diferenciálom a reálnym efektívnym výmenným kurzom nie je v analyzovanej vzorke európskych krajín jednotný. V spoločnej, agregovanej vzorke poskytuje základný model iba obmedzenú podporu tradičnému Balassa-Samuelsonovmu mechanizmu, keďže koeficient produktivitného diferenciálu nie je štatisticky významný. Tento výsledok však neznamená, že mechanizmus je úplne irelevantný. Skôr poukazuje na to, že združený model môže zakrývať rozdiely medzi krajinami eurozóny a krajinami mimo eurozóny.

Tento výsledok je dôležité interpretovať opatrne. Nevýznamný koeficient v spoločnej vzorke nemusí znamenať, že Balassa-Samuelsonov mechanizmus v súčasných európskych ekonomikách vôbec neexistuje. Skôr naznačuje, že jeho pôsobenie nemusí byť rovnaké vo všetkých krajinách a že agregovaný model môže zakrývať rozdiely vyplývajúce z menového režimu, sektorovej štruktúry a miery obchodovateľnosti digitálnych služieb. Z tohto dôvodu sú výsledky interpretované nielen na úrovni celej vzorky, ale aj osobitne pre eurozónu a krajiny mimo eurozóny.

Rozdelenie vzorky podľa menového režimu ukazuje výraznejšiu heterogenitu. V krajinách eurozóny sa vzťah medzi produktivitným diferenciálom a reálnym efektívnym výmenným kurzom po roku 2014 stáva negatívnym a štatisticky významným. Tento výsledok je v rozpore s tradičným predpokladom Balassa-Samuelsonovho efektu, podľa ktorého by vyššia produktivita v obchodovateľnom sektore mala viesť k reálnej apreciácii. V prostredí spoločnej meny môže byť tento mechanizmus oslabený alebo obrátený v dôsledku spoločných menových podmienok, cenovej integrácie a obmedzenej možnosti krajín prispôsobovať sa prostredníctvom vlastného nominálneho výmenného kurzu.

Naopak, v krajinách mimo eurozóny je vzťah medzi produktivitným diferenciálom a reálnym efektívnym výmenným kurzom viac v súlade s tradičnou logikou Balassa-

Samuelsonovho efektu. V tradičnej post-2014 špecifikácii je koeficient pozitívny, ale štatisticky nevýznamný. Po úprave sektorovej klasifikácie, v ktorej sú ICT a finančné služby zaradené medzi obchodovateľné sektory, sa však tento vzťah stáva pozitívnym a štatisticky významným. Tento výsledok naznačuje, že digitálne intenzívne služby sa v súčasnej ekonomike môžu správať viac ako obchodovateľné sektory a že tradičné delenie medzi obchodovateľnými a neobchodovateľnými sektormi už nemusí plne zachytávať relevantný transmisný mechanizmus.

Výsledky analýzy regulačnej moderácie prostredníctvom indexu DSTRI nepotvrdzujú pôvodný predpoklad, že vyššia reštriktívnosť digitálneho obchodu posilňuje tradičný Balassa-Samuelsonov kanál. V eurozóne interakčný efekt medzi produktivitným diferenciálom a DSTRI nie je štatisticky významný. V krajinách mimo eurozóny je však interakčný efekt negatívny a štatisticky významný. To naznačuje, že digitálne obchodné bariéry môžu skôr oslabovať schopnosť produktivitných ziskov premietať sa do medzinárodnej konkurencieschopnosti a pohybov reálneho efektívneho výmenného kurzu. Tento výsledok podporuje interpretáciu, že digitálne služby sa už v značnej miere správajú ako obchodovateľné sektory.

Analýza podľa úrovne ekonomického rozvoja neposkytuje silnú podporu hypotéze, že Balassa-Samuelsonov efekt sa systematicky líši medzi vyspelými a rozvíjajúcimi sa európskymi ekonomikami. Koeficienty produktivitného diferenciálu nie sú štatisticky významné ani v jednej z týchto skupín. V rámci analyzovanej európskej vzorky sa preto ako dôležitejší zdroj heterogenity javí menový režim a sektorová klasifikácia než samotné rozdelenie krajín podľa úrovne ekonomického rozvoja.

Sektorová analýza ukazuje, že produktivita v ICT sektore sa správa odlišne od produktivity vo výrobnom sektore. Produktivita vo výrobnom sektore nemá robustný pozitívny vplyv na reálny efektívny výmenný kurz, zatiaľ čo produktivita v ICT sektore vykazuje negatívny a štatisticky významný vzťah. Tento výsledok môže odrážať špecifický charakter digitálnych služieb, ktoré sa vyznačujú nízkymi alebo takmer nulovými nákladmi cezhraničného poskytovania, vysokou škálovateľnosťou a silnou medzinárodnou konkurenciou. Produktivitné zisky v ICT sektore sa preto nemusia premietať do rastu domácich cien, ale skôr do nižších nákladov a vyššieho konkurenčného tlaku.

Doplňujúca analýza mzdového kanála poskytuje ďalší pohľad na vnútorný mechanizmus Balassa-Samuelsonovho efektu. V tradičnom rámci by rast produktivity v obchodovateľnom sektore mal viesť k rastu miezd, ktoré sa následne môžu preniesť do cien neobchodovateľných statkov a služieb. Výsledky však ukazujú, že tento kanál nie je viditeľný v spoločnej vzorke a v eurozóne má dokonca negatívny vzťah. V krajinách mimo eurozóny je však vzťah medzi produktivitným diferenciálom a celkovou hodinovou kompenzáciou pozitívny a štatisticky významný. To naznačuje, že vnútorný transmisný mechanizmus od produktivity k mzdám je zreteľnejší mimo eurozóny.

Celkovo možno konštatovať, že výsledky tejto práce neodmietajú Balassa-Samuelsonov efekt úplne, ale ukazujú, že jeho platnosť je v súčasných európskych ekonomikách podmienenejšia a heterogénnejšia. Tradičný agregovaný model poskytuje len obmedzené dôkazy, avšak výsledky pre krajiny mimo eurozóny, najmä pri digitálne upravenej sektorovej klasifikácii a mzdovom kanáli, naznačujú, že mechanizmus môže byť stále relevantný. V eurozóne sa naopak zdá, že spoločná mena, vyššia cenová integrácia a spoločné menové podmienky môžu oslabovať alebo obracať pozorovateľný vzťah medzi produktivitou, mzdami a reálnym efektívnym výmenným kurzom.

Pri interpretácii výsledkov je však potrebné zohľadniť aj určité obmedzenia. Analýza je založená na európskej vzorke krajín, ktoré sú relatívne integrované a inštitucionálne podobné, čo môže znižovať variabilitu potrebnú na identifikáciu silnejších vzťahov. Index DSTRI je dostupný až od roku 2014 a zachytáva skôr širšie regulačné prostredie než krátkodobé kvartálne zmeny. Mzdová analýza je zároveň založená na menšej vzorke z dôvodu chýbajúcich údajov pre niektoré krajiny. Napriek týmto obmedzeniam práca prináša aktuálny pohľad na Balassa-Samuelsonov efekt v období digitalizácie a ukazuje, že jeho skúmanie si vyžaduje zohľadniť menový režim, digitálnu obchodovateľnosť služieb a sektorovú heterogenitu.

Zistenia tejto práce preto poukazujú na potrebu aktualizovať tradičné interpretácie Balassa-Samuelsonovho efektu v podmienkach digitalizovanej a integrovanej ekonomiky. Rastúca obchodovateľnosť digitálnych služieb, rozdiely medzi menovými režimami a sektorová štruktúra zohrávajú dôležitú úlohu pri vysvetľovaní toho, ako sa produktivitné zmeny premietajú do miezd, cien a reálneho výmenného kurzu. Práca tak prispieva k diskusii o tom, že tradičné produktivitné mechanizmy zostávajú relevantné, ale ich vplyv závisí od inštitucionálneho, sektorového a digitálneho kontextu

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AI Prompts

"Help me transform the verbal explanation of the Balassa–Samuelson mechanism from Balassa (1964) into formal equations."

"Summarise the main findings of studies by Égert (2002), Mihaljek and Klau (2003), Hassan (2016), Wang et al. (2016), and Gubler and Sax (2019) regarding the Balassa–Samuelson effect."

"Explain the advantages of using a fixed effects panel model for analysing productivity differentials and real exchange rates."

Appendices

Appendix A: Panel Unit Root Tests Results

This appendix reports the full results of IPS and LLC panel unit root tests under different specifications.

Variable	IPS (c) level	IPS (c) Δ	IPS level (ct)	IPS Δ (ct)	LLC (c) level	LLC (c) Δ	LLC (ct) level	LLC (ct) Δ	Conclusion
Log REER	–1.181	–18.801 ***	–2.725 ***	–17.463 ***	–1.683 **	–2.730 ***	–3.911 ***	–0.029 **	*I*(1)
Prod Diff	–2.950 ***	–18.852 ***	–2.278 **	–17.822 ***	–4.495 ***	5.477	–3.472 ***	10.107	*I*(0)
Log ToT	–3.593 ***	–19.185 ***	–3.396 ***	–17.465 ***	–3.616 ***	5.567	–1.021	9.745	*I*(0)
Log GDP pc	0.570	–14.297 ***	–3.272 ***	–12.249 ***	–1.925 **	97.469	4.080	125.136	*I*(1)
Gov Cons	–2.519 ***	–18.249 ***	–3.024 ***	–16.628 ***	–1.622 *	1.015	–3.105 ***	4.283	*I*(0)
Pop Growth	–3.898 ***	–20.404 ***	–1.374 *	–18.815 ***	0.260	–4.241 ***	2.616	–1.748 **	*I*(0)
Log Wage	5.171	–14.531 ***	1.778	–12.759 ***	–0.619	5.150	0.484	8.871	*I*(1)–mixed

Source: Author's computation based on data in Table 1.

*Notes: IPS = Im-Pesaran-Shin W_tbar statistic. LLC = Levin–Lin–Chu z-score. H0: unit root exists. Lag order = 4. (c) denotes constant specification, (ct) denotes constant and trend specification. Δ denotes first difference. Tests conducted in Gretl. Significance levels: * p<0.1, ** p<0.05, *** p<0.01. Log Wage is conducted for 24 countries over 2000Q1–2025Q3 due to data availability.*