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LONG-RUN GROWTH AND PRICE CONVERGENCE

Implications of a Two-Sector Neoclassical Growth Model and Application to the Slovenian Case

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Abstract

A simple two-sector neo-classical growth model is implemented to examine the real economy and price dynamics, and the implied Harrod-Balassa-Samuelson (H-B-S) effects, in a country converging towards the industrial leader. The price convergence patterns and the H-B-S effects depend upon which sector, the tradable or the non-tradable, ends up converging first. In particular, if the tradable sector catches up first with the industrial leader's productivity, the theory predicts a temporary, but potentially sizeable over-shooting in the price level of the converging country. In this case H-B-S effect is negative in the last stage of the convergence process. The model is parameterized to simulate the convergence scenarios of the Slovenian economy. Given the current convergence pattern, it may take roughly twenty five years until catching up in tradable sector and most likely more in the non-tradable sector productivity. The H-B-S effect is evaluated to lay between 1 and 1.5 percentage points, but might more than double in case of an accelerated growth. Finally, while the H-B-S implications for the conflict among Maastricht criteria (necessary to be met during the ERM2 euro adoption program) are well known, we note that H-B-S effect potentially also increases the deflation probability occurrence in some stable nominal exchange rate configurations.

Key words: real convergence, Harrod-Balassa-Samuelson effect, relative prices

Povzetek

Enostaven dvosektorski neoklasični model gospodarske rasti je uporabljen v analizi konvergence realne ekonomije in censke dinamike, in posledičnega efekta Harrod-Balassa-Samuelson (H-B-S), v državi ki dohiteva industrijsko (naj)razvitejše gospodarstvo. Vzorec censke konvergence in efekt H-B-S je odvisen od tega, kateri sektor, menjalni ali nemenjalni, prvi zaključi s konvergenco. Če menjalni sektor prvi dohiti produktivnost v razvitejši državi, teorija napoveduje začasen, vendar potencialno precejšen presežek ravni cen v konvergenčni ekonomiji. V takem primeru je efekt H-B-S negativen v zadnjem obdobju procesa konvergence. Parametre, ki predstavljajo modelsko ekonomijo smo določili tako, da je možno prikazati različne vzorce konvergence za slovensko gospodarstvo. Če bi se nadaljeval dosedanji konvergenčni vzorec, bi menjalni sektor potreboval še kakšnih petindvajset let dokler da bi dohitel produktivnost razvitejšega gospodarstva, nemenjalni sektor pa še dosti dlje. Efekt H-B-S je ocenjen na 1 do 1,5 odstotne točke, lahko pa se več kot podvoji v primeru pospešene gospodarske rasti. Četudi so neskladja med maastrichtskimi kriteriji (katerih izpolnjevanje pogojuje uspešno sodelovanje v ERM2 za prevzem eura) v primeru efekta H-B-S znana, pa tukaj opozorimo, da efekt H-B-S lahko tudi poveča verjetnost nastopa deflacije v primeru stabilnega nominalnega deviznega tečaja.

Ključne besede: realna konvergenca, efekt Harrod-Balassa-Samuelson, relativne cene

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1. INTRODUCTION

Theoretical and empirical research has provided strong arguments that countries at different development levels converge in revenue per capita. Most of the recent research convincingly argues that this convergence is mainly due to the catching up in productivity, that is to technological progress.[2] However, when the technological progress differs across sectors of an economy, it also implies movements in the relative price of the goods they produce. The Harrod-Balassa-Samuelson effect is the tendency for countries with higher productivity in tradable goods, compared to non-tradable goods, to have higher price levels. Its obvious corollary is that countries characterized by a faster growth in tradable relative to the non-tradable goods productivity experience real appreciation. This is an often encountered stylized fact in countries on their long-run growth path and catching up in output per capita with the industrial leader. The Slovenian economy, together with other Central and Eastern European countries, often labeled "convergence countries", is not an exception to this rule.

Because these productivity growth processes determine the behavior of the equilibrium real exchange rate, they convey implications for the long-run monetary policy design. In particular, as they represent movements in real economy and relative prices, these processes are money-neutral in the long-run, leaving it to monetary policy, again in the long-run, to impact only nominal values of the macroeconomic variables and the inflation rates. Also, in a stable nominal exchange rate environments, the real appreciation in turn translates into higher inflation rates. Anticipating and quantifying different long-run growth and price convergence patterns is therefore crucial for the appropriate monetary policy conduct.

In this paper we pursue two objectives. First, we examine the predictions of the standard neo-classical growth theory, extended to tradable and non-tradable production sectors, for the convergence production technology driven convergence process, over very long horizons. We are especially interested in the implied dynamics of the real economy equilibrium, the price level and the inflation. Second, we intend to focus in particular to the possible convergence path of the Slovenian economy towards a stylized industrial leader country. In addition, we use a selection of scenarios to analyze alternative convergence patterns, in particular when some growth parameters are altered or the initial conditions differ. We quantify these effects over the entire convergence horizon.

To evaluate the long-run convergence dynamics, we use a simple version of a two-sector neo-classical static general equilibrium growth model. The model is expanded so that it can account for the movements in relative prices, here due exclusively to H-B-S effects. The two-sector production side is completed by the specification of the consumer's preference structure to jointly determine the demand for goods and the sectoral expenditure and labor allocation shares, given the equilibrium relative price. To compare the convergence country with the industrial leader, specified as the other country composing the world economy, we assume that the law of one price holds for tradable goods, but not for non-tradable. The H-B-S effect arises from the differences in the domestic relative price movements, generated by the differences in the sectoral technological progress, the imperfect substitutability between the two types of goods and the equalization of the production factor prices across sectors. The model is parameterized so that it enables to simulate various convergence paths of the Slovenian economy towards the industrial leader. Finally, the convergence process is driven by the catching up in the convergence country's sectoral technology level. The technology level growth rate is exogenous and independent in both sectors, and continues to grow at the pace of the industrial leader when it attains its sectoral productivity level.

[2] See Prescott and Parente (2000) for a good example.

We show that the theory does not predict a monotonous price convergence to be the only one consistent with a monotonous convergence process in technology. If the convergence country tradable sector reaches the industrial leader's productivity before the non-tradable sector, its price level increases above that of the industrial leader. This effect is the largest at the moment of the tradable sector catching up in productivity, after what the price level decreases towards the industrial leader's price level. This implies a negative H-B-S effect in the last stage of the convergence process. If, conversely, the non-tradable sector first catches up with the industrial's leader productivity, the theory predicts a monotonous convergence in prices. The other principal growth or convergence effects arising from the general equilibrium analysis, assuming a higher tradable than non-tradable sector productivity growth and sectoral equality of production factor prices, can be summarized as follows. The relative price of the non-tradable goods versus the tradable goods price increases. The consumption share of the non-tradable goods decreases, but their expenditure share increases. To partly offset the increasing productivity gap between the sectors, the labor is reallocated to the non-tradable sector. These effects imply an over time intensifying H-B-S effect, given the increasing high-inflation non-tradable share in consumer's expenditure. Also, for more and more productive resources are allocated to the sector characterized by a lower productivity growth, the overall real output growth may (slightly) decrease over very long horizons.

In the case of Slovenia, given the current trends in sectoral productivity growth, we expect the tradable sector to reach the industrial leader's productivity in roughly twenty five years, while the non-tradable sector may well take significantly more time. The implied H-B-S effect lays between 1 and 1.5 percentage points and may increase by another half of a percentage point until the end of the 2020-ies, when it is expected to be maximal. After that moment, when the tradable sector is expected to have caught up in productivity, the H-B-S effect should be slightly negative in order to decrease the implied price level over-shooting, evaluated to around ten percent at its maximum. A significantly faster growth rate due to the tradable sector productivity, say 6.5 percents on a yearly basis, may halve the time needed by the tradable sector to converge, but the corresponding H-B-S effect increases to roughly 3 percentage points.

Two additional findings should be emphasized. First, the tradable sector productivity is probably the dominant factor in explaining the differences across countries at different development level. But the major differences across developed countries may well be attributable to non-tradable sector productivity. In general, the quantitative simulations of the model economy indicate the predominance of the tradable sector in the real growth process, but also the relevance and a large impact, over very long periods, on price level of the non-tradable sector productivity. The international competition, a fast technology adoption, etc. result in a very fast convergence in the tradable sector productivity (manufacturing), which has been in turn at the origin of the "growth miracles" observed in last century, for example in East Asia. Nevertheless, the differences in the non-tradable sector productivity account in the long-run for potentially high price level differentials, generating the dispersion in output per capita in purchasing power parity standards across developed countries. This result is partly due to the fact that there may be little difference in the non-tradable sector productivity across countries but a very large one in the tradable sector productivity, when productivity is measured in quantities and not in value added.

Second, the H-B-S implications for the inconsistency among Maastricht criteria are often exposed. In addition, we show that the H-B-S effect may also imply other monetary policy issues, namely an increased probability of the deflation occurrence in some economic arrangements with fixed or stable nominal exchange rates. Two cases are presented here. The first case is the convergence period after the tradable sector productivity has reached that of the industrial leader. It is shown here that this part of the convergence process is consistent with a negative H-B-S effect *vis-a-vis* the industrial leader. If the country maintains stable (or appreciating) nominal exchange rate against a low inflation industrial leader the occurrence of a deflation is much more probable, given the cyclical movements in the inflation. We argue that the Japanese economy may be subject to this case. The second case is the participation of a developed country together with the converging countries to a low average inflation common currency area. The development level in the euro area is characterized by a high diversity, and this diversity is expected to increase with the accession of the Central and Eastern European countries. That leads to an important part of the euro area experiencing a positive H-B-S effect *vis-a-vis* the most developed countries. If the monetary authority in the euro area keeps as the objective a very low inflation target, this implies an even lower equilibrium inflation in the more developed countries, the obvious example being Germany. That in turn increases the probability of the deflation occurrence in these countries. If the deflation *per se* goes along with real costs these cases represent issues of concern for the monetary policy design.

The H-B-S effect is first presented in the seminal contributions by Balassa (1964) and Samuelson (1964). The appreciation of the real exchange rate in the transition economies is examined for example in Halpern and Wyplosz (1997), Čihak and Holub (2001), Jazbec (2001), Mihaljek (2002) and Kovacs (2003). These authors amended the analysis with some transition-specific features: sectoral labor transition, government sector, product quality, sectoral mark-ups, etc and typically attributed to H-B-S effect less than 2 percentage points on a yearly basis. The available estimates for Slovenia report a moderate H-B-S effect. Rother (2000) 1.5 –2 percentage points, Jazbec (2001) 1-1.5, Žumer (2002) none for the 1993-96 period and 1.4 percentage points for 1997-2001 and Kovacs (2003) 0.7 for the 1992-2001 period.

The introduction is followed by three sections and a conclusion. Section 2 introduces the model framework used in the analysis. Section 3 presents the data and the calibration of the model's parameters. The main results are outlined in section 4, where also a robustness analysis and a discussion of interesting aspects arising from the results are provided. The last section concludes and suggests some directions for further research.

2. A SIMPLE TWO-SECTOR GROWTH MODEL FRAMEWORK

In this section a simple two-sector open economy growth model is developed. We upgrade a standard neoclassical growth model with three additional ingredients. First, the economy composes of two sectors producing two different goods, the tradable goods linked to international competition and the non-tradable only subject to domestic demand and supply conditions. Second, the introduction of the demand side of the economy makes endogenous the shares of both sectors in consumption, expenditure (GDP) and labor. Third, the model economy evolves in an international environment so that a convergence process towards a stylized industrial leader country can be easily studied.

The section is divided in four parts, the first three dealing with the one country equilibrium and the fourth introducing the open economy relationships. First we present the production side of the economy and derive the relative price of the non-tradable good in terms of tradable. Next is presented the demand side and the computation of the sectoral shares in consumption, expenditure and labor allocation. Both sides of the economy are assembled to determine the equilibrium GDP in section three. The final section provides the expressions for the relative price level, inflation and the purchasing power parity (PPP) output measure in order to compare two countries with different development level.

2.1. One Country: Production and Relative Price

We start by introducing the supply side of the economy and deriving the resulting relative price between the tradable and non-tradable goods within a country. We assume an economy with two sectors characterized with standard Cobb-Douglas production functions and labor-augmenting technological progress. The production *Y* in the tradable sector *T* and the non-tradable *N* at time *t* depends upon the production factors capital *K* and labor *L* used and the available sector specific level of technological progress *A* in the following way.

$$Y_{T,t} = K_{T,t}^{1-\mu_{LT}} \left(A_{T,t}\, L_{T,t}\right)^{\mu_{LT}}$$
$$Y_{N,t} = K_{N,t}^{1-\mu_{LN}} \left(A_{N,t}\, L_{N,t}\right)^{\mu_{LN}}$$

Recall that with a Cobb-Douglas production technology, the exponent on the production factor represents its share in the output revenue. μ_{LX} is therefore interpreted as the labor share in the sector *X* production or equivalently its labor intensity. The choice of the labor-augmenting technological process is dictated by the necessity for the model to account for the empirical regularities in economic growth.[3]

In the case of the above production technology, the optimality conditions for efficient production are found by maximizing the producer's objective, i.e. her intertemporal profits:

$$\max_{\{K_{T,t},L_{T,t}\}_{t=0}^{t=\infty}} \Pi_T = \sum_{t=0}^{t=\infty} \left(\frac{1}{1+r_t}\right)^t \left[K_{T,t}^{1-\mu_{LT}} \left(A_{T,t}\, L_{T,t}\right)^{\mu_{LT}} - w_t\, L_{T,t} - r_t\, K_{T,t}\right]. \tag{1}$$

This is done by appropriately choosing the capital and labor inputs. w_t and r_t are respectively the wage and the interest rate necessary to reward the labor and capital inputs at time *t*. Taking the derivatives of the objective (1) with respect to these factor inputs yields the standard result that firms maximize their profits by equalizing the marginal productivity of the production factors to their price at each point of time:

$$\mu_{LT}\, A_{T,t}\, K_{T,t}^{1-\mu_{LT}} \left(A_{T,t}\, L_{T,t}\right)^{\mu_{LT}-1} = w_t \tag{2}$$
$$\left(1-\mu_{LT}\right) K_{T,t}^{-\mu_{LT}} \left(A_{T,t}\, L_{T,t}\right)^{\mu_{LT}} = r_t \tag{3}$$

The producers in the non-tradable sector undertake a similar optimization procedure. In what follows we take the tradable good as a numeraire and define p_t as a price of the non tradable good. This is therefore at the same time the relative price between the tradable and non-tradable goods. Before proceeding, an additional assumption is to be made.

[3] The long-run economic growth regularities, or stylized facts, are first reported in Kaldor (1963). The most important other stylized facts are the long-run stationary growth rate and interest rate and the equal growth in the output per capita, capital stock per capita and in the real wage. The only Cobb-Douglass production function specification consistent with these stylized facts is the labor augmenting technological progress specification, which in turn motivates its usage in this work. See, for example, Barro and Sala-I-Martin (1995) p. 54.

<u>Assumption 1</u>: The factor prices are equal across sectors.

By assumption 1, the wages w_t and the real interest rate r_t are equal in both sectors. This is motivated by the factor mobility between different sectors in the economy.

The firm's problem in the non tradable sector can then be written as follows:

$$\max_{\{K_{N,t},L_{N,t}\}_{t=0}^{t=\infty}} \Pi_N = \sum_{t=0}^{t=\infty}\left(\frac{1}{1+r_t}\right)^t \left[p_t\, K_{N,t}^{1-\mu_{LN}}\left(A_{N,t}\, L_{N,t}\right)^{\mu_{LN}} - w\, L_{N,t} - r\, K_{N,t}\right]$$

The corresponding first order conditions are:

$$p_t\, \mu_{LN}\, A_{N,t}\, K_{N,t}^{1-\mu_{LN}}\left(A_{N,t}\, L_{N,t}\right)^{\mu_{LN}-1} = w_t \tag{4}$$

$$p_t\left(1-\mu_{LN}\right)K_{N,t}^{-\mu_{LN}}\left(A_{N,t}\, L_{N,t}\right)^{\mu_{LN}} = r_t \tag{5}$$

From the optimality conditions (2) to (5) we now compute the relative price p_t between the goods produced in both sectors. Combining the optimality conditions for capital (3) and (5) obtains the factor demands for capital in both sectors:

$$K_{T,t} = \left(\frac{\mu_{LT}}{r_t}\right)^{\frac{1}{\mu_{LT}}} A_{T,t}\, L_{T,t} \tag{6}$$

$$K_{N,t} = \left(\frac{p_t\, \mu_{LN}}{r_t}\right)^{\frac{1}{\mu_{LN}}} A_{N,t}\, L_{N,t} \tag{7}$$

The above results are the standard results given the choice of the labor augmenting Cobb-Douglas technology. Observe that the capital stock increases at the same rate as the technological progress. Equalizing the left-hand-side of the optimality conditions for labor in both sectors (2) and (4) yields the following expression for the relative price:

$$p_t = \frac{\mu_{LT}\, A_{T,t}\, K_{T,t}^{1-\mu_{LT}}\left(A_{T,t}\, L_{T,t}\right)^{\mu_{LT}-1}}{\mu_{LN}\, A_{N,t}\, K_{N,t}^{1-\mu_{LN}}\left(A_{N,t}\, L_{N,t}\right)^{\mu_{LN}-1}}$$

Replacing in the above expression for $K_{T,t}$ and $K_{N,t}$ using the demands (6) and (7) for these factors and solving for p_t yields the expression for the relative price of the goods produced in the two sectors:

$$p_t = \frac{\mu_{LT}\, A_{T,t}^{\mu_{LT}}\left(\left(\frac{\mu_{LT}}{r_t}\right)^{\frac{1}{\mu_{LT}}} A_{T,t}\, L_{T,t}\right)^{1-\mu_{LT}} L_{T,t}^{\mu_{LT}-1}}{\mu_{LN}\, A_{N,t}^{\mu_{LN}}\left(\left(\frac{p_t\, \mu_{LN}}{r_t}\right)^{\frac{1}{\mu_{LN}}} A_{N,t}\, L_{N,t}\right)^{1-\mu_{LN}} L_{N,t}^{\mu_{LN}-1}} = \frac{\mu_{LT}\, A_{T,t}\left(\frac{\mu_{LT}}{r_t}\right)^{\frac{1-\mu_{LT}}{\mu_{LT}}} \underbrace{L_{T,t}^{\mu_{LT}-1-\mu_{LT}+1}}_{1}}{\mu_{LN}\, A_{N,t}\left(\frac{\mu_{LN}}{r_t}\right)^{\frac{1-\mu_{LN}}{\mu_{LN}}} \underbrace{L_{N,t}^{\mu_{LN}-1-\mu_{LN}+1}}_{1}}\; p_t^{\frac{-1+\mu_{LN}}{\mu_{LN}}}$$

$$p_t = \left(\frac{\mu_{LT}\, A_{T,t} \left(\frac{\mu_{LT}}{r_t} \right)^{\frac{1-\mu_{LT}}{\mu_{LT}}}}{\mu_{LN}\, A_{N,t} \left(\frac{\mu_{LN}}{r_t} \right)^{\frac{1-\mu_{LN}}{\mu_{LN}}}} \right)^{\mu_{LN}} = \Phi(r_t, \mu_{LT}, \mu_{LN}) \left(\frac{A_{T,t}}{A_{N,t}} \right)^{\mu_{LN}} \tag{8}$$

This expression shows that the relative price depends in a non linear way of the relative productivity of the two sectors and of the scaling factor Φ depending on the production labor intensities in the two sectors and the real interest rate. In correspondence with the long-run economic growth stylized facts, these are assumed to remain invariant through time so that Φ is treated as a constant. Note that the more the non-tradable sector is labor intensive, the more the relative difference in productivity is transmitted in the relative price p_t.[4]

2.2. One Country: Demand Side and Sectorial Shares

In this step, we specify the demand side of the economy in order to determine how the consumers allocate their consumption expenditure over time and across tradable and non-tradable goods. A typical consumer in the model economy maximizes a standard constant elasticity of substitution (CES) intertemporal utility function:

$$U(C_{T,t}, C_{N,t}) = \sum_{t=0}^{\infty} (\beta)^t \left[\gamma^{\frac{1}{\theta}} C_{T,t}^{\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}} C_{N,t}^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}} \tag{9}$$

The intertemporal utility (9) increases in consumption of both the tradable and the non-tradable good at any period *t*. With the instantaneous utility discount factor β between 0 and 1, the consumer values more the consumption in periods close to the present than far away in the future. The elasticity of substitution parameter θ, always positive, indicates how much the consumer is willing to substitute the consumption of one good with the other when its relative price increases by on percent. The higher is the elasticity of substitution, the higher is the reaction in the quantities to a relative price change. Finally, the preference parameter γ lying between 0 and 1 indicates how much weight the consumer puts on the consumption of the tradable good, the weight 1 - γ being consequently that of the non-tradable good.

The consumer is constrained in each period by her wealth. She must typically decide how much of her wealth to consume in the current period and how much to save (invest) for the consumption in future periods. In this work we are neither interested in the consumption-saving decision, nor the intertemporal substitution problems. We rather focus on the consumption choice among tradable and non-tradable goods within the period, given the relative price p_t and the consumption expenditure Z_t. That enables to reduce the budget constraint to the following form:

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[4] In case of the total factor productivity (TFP) specification of the production function $Y_{T,t} = A_{T,t}^{TFP} K_{T,t}^{1-\mu_{LT}} L_{T,t}^{\mu_{LT}}$ the resulting expression is slightly different: $p_t = \Phi'(r_t, \mu_{LT}, \mu_{LN}) \frac{A_{T,t}^{TFP \frac{\mu_{LN}}{\mu_{LT}}}}{A_{N,t}^{TFP}}$, where A^{TFP} is the TFP level of technology.

$$C_{T,t} + p_t\, C_{N,t} = Z_t$$

To solve for the optimal consumption of the two types of goods, the representative consumer solves the Lagrangian *L*:

$$\underset{\{C_{T,t},C_{N,t}\}_{t=0}^{\infty}}{L} = \sum_{t=0}^{\infty} \beta^t \left[\left(\gamma^{\frac{1}{\theta}} C_{T,t}^{\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}} C_{N,t}^{\frac{\theta-1}{\theta}} \right)^{\frac{\theta}{\theta-1}} + \lambda_t \left(Z_t - C_{T,t} - p_t\, C_{N,t} \right) \right],$$

where λ_t is the Lagrange multiplier on the budget constraint equal to the marginal utility of wealth. The first order conditions for the optimal consumption of the two goods are obtained by taking the derivative of the Lagrangian with respect to the quantities to be consumed:

$$\frac{\partial L}{\partial C_{T,t}} = \beta^t \gamma^{\frac{1}{\theta}} C_{T,t}^{\frac{\theta-1}{\theta}-1} \frac{\theta-1}{\theta} \frac{\theta}{\theta-1} \left(\gamma^{\frac{1}{\theta}} C_{T,t}^{\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}} C_{N,t}^{\frac{\theta-1}{\theta}} \right)^{\frac{\theta}{\theta-1}-1} - \lambda_t = 0$$

$$\frac{\partial L}{\partial C_{N,t}} = \beta^t (1-\gamma)^{\frac{1}{\theta}} C_{N,t}^{\frac{\theta-1}{\theta}-1} \frac{\theta-1}{\theta} \frac{\theta}{\theta-1} \left(\gamma^{\frac{1}{\theta}} C_{T,t}^{\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}} C_{N,t}^{\frac{\theta-1}{\theta}} \right)^{\frac{\theta}{\theta-1}-1} - \lambda_t\, p_t = 0$$

After simplification of these first order conditions we get the following expressions:

$$\beta^t \gamma^{\frac{1}{\theta}} C_{T,t}^{\frac{\theta-1}{\theta}-1} \left(\gamma^{\frac{1}{\theta}} C_{T,t}^{\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}} C_{N,t}^{\frac{\theta-1}{\theta}} \right)^{\frac{\theta}{\theta-1}-1} = \lambda_t$$

$$\frac{1}{p_t} \beta^t (1-\gamma)^{\frac{1}{\theta}} C_{N,t}^{\frac{\theta-1}{\theta}-1} \left(\gamma^{\frac{1}{\theta}} C_{T,t}^{\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}} C_{N,t}^{\frac{\theta-1}{\theta}} \right)^{\frac{\theta}{\theta-1}-1} = \lambda_t$$

Equalizing the right-hand-side of these two equations yields:

$$\beta^t \gamma^{\frac{1}{\theta}} C_{T,t}^{\frac{\theta-1}{\theta}-1} \left(\gamma^{\frac{1}{\theta}} C_{T,t}^{\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}} C_{N,t}^{\frac{\theta-1}{\theta}} \right)^{\frac{\theta}{\theta-1}-1} = \frac{1}{p_t} \beta^t (1-\gamma)^{\frac{1}{\theta}} C_{N,t}^{\frac{\theta-1}{\theta}-1} \left(\gamma^{\frac{1}{\theta}} C_{T,t}^{\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}} C_{N,t}^{\frac{\theta-1}{\theta}} \right)^{\frac{\theta}{\theta-1}-1}$$

Simplifying and rearranging this expression gives a simple expression of the relative consumption of quantities of both goods in terms of the relative price, the elasticity of substitution and the relative weight in the consumer's preferences:

$$\frac{C_{N,t}}{C_{T,t}} = p_t^{-\theta} \frac{1-\gamma}{\gamma} \tag{10}$$

The relative consumption expression (10) shows that the representative consumer in the economy consumes proportionally less non-tradable good when its relative price is higher and increasingly so with higher substitution possibilities. Only with $\theta = 0$, i.e. no possibility to substitute between the two goods, the price has no effect on the relative quantities consumed. As expected, the larger the preference weight of the tradable good, the larger is its share in consumption. Note that with the relative price p_t equal to 1, the relative quantities consumed correspond exactly to the relative weights of the two types of goods in the consumer's preferences.

From (10) it is straightforward to compute the weights of the two goods in the composite consumption bundle. Since the weights sum to 1 and the consumption quantities are proportional to the consumption shares of the two goods in the composite consumption bundle, one can write:

$$\frac{C_{N,t}}{C_{T,t}} = p_t^{-\theta}\,\frac{1-\gamma}{\gamma} = \frac{\omega_{N,t}}{\omega_{T,t}}$$

$$\omega_{T,t} = \frac{\gamma}{\gamma + (1-\gamma)\,p_t^{-\theta}}$$

$$\omega_{N,t} = 1-\omega_{T,t} = \frac{(1-\gamma)\,p_t^{-\theta}}{\gamma + (1-\gamma)\,p_t^{-\theta}}$$

These weights are again dependent only on the relative price, the elasticity of substitution and of the consumer's preferences weights of the two types of goods. Given the CES utility specification, these weights are independent of the consumer's expenditure level. The consequent share in total expenditure can be found by multiplying both composite consumption shares by their price, respectively 1 for tradable and p_t for non tradable good, and dividing by the total expenditure:

$$\Omega_{T,t} = \frac{\omega_{T,t}}{\omega_{T,t} + p_t\,\omega_{N,t}} = \frac{\gamma}{\gamma + (1-\gamma)\,p_t^{1-\theta}} \tag{11}$$

$$\Omega_{N,t} = 1-\Omega_{T,t} = \frac{p_t\,\omega_{N,t}}{\omega_{T,t} + p_t\,\omega_{N,t}} = \frac{(1-\gamma)\,p_t^{1-\theta}}{\gamma + (1-\gamma)\,p_t^{1-\theta}} \tag{12}$$

The shares in the consumption expenditure depend on the same elements as the share in the composite consumption and are independent of the consumption expenditure level. All these values may however vary through time, in particular when the relative price among the tradable and the not-tradable goods vary.

Finally, we determine the dynamics of the labor allocation across sectors. We start by demonstrating that growth in each sector is proportional to the growth of labor augmenting technology process and the available labor production factor. Replacing for the sectoral capital stocks (6) and (7) in sectoral production function, one can compute the expression for output in both sectors:

$$Y_{T,t} = K_{T,t}^{1-\mu_{LT}}\left(A_{T,t}\,L_{T,t}\right)^{\mu_{LT}} = \left(\left(\frac{\mu_{LT}}{r_t}\right)^{\frac{1}{\mu_{LT}}} A_{T,t}\,L_{T,t}\right)^{1-\mu_{LT}} A_{X,t}^{\mu_{LT}}\,L_{X,t}^{\mu_{LT}} = \left(\frac{\mu_{LT}}{r_t}\right)^{\frac{1-\mu_{LT}}{\mu_{LT}}} A_{T,t}\,L_{T,t} \tag{13}$$

$$Y_{N,t} = K_{N,t}^{1-\mu_{LN}} \left(A_{N,t} L_{N,t}\right)^{\mu_{LN}} = \left(\left(\frac{p_t \, \mu_{LN}}{r_t} \right)^{\frac{1}{\mu_{LN}}} A_{N,t} L_{N,t} \right)^{1-\mu_{LN}} A_{N,t}^{\mu_{LN}} L_{N,t}^{\mu_{LN}} = \left(\frac{p_t \, \mu_{LN}}{r_t} \right)^{\frac{1-\mu_{LN}}{\mu_{LN}}} A_{N,t} L_{N,t} \quad (14)$$

To proceed, we need an additional assumption about how the other GDP components compose of the tradable and non tradable goods:

<u>Assumption 2:</u> *The tradable and non-tradable sector goods weights in GDP are the same as in consumption.*

If the weights in the overall production are the same as for consumption, one can easily compute the labor allocation across both sectors and consequently the entire economic equilibrium. To compute the labor shares we take the advantage of the fact that the relative sectoral GDP is proportional to the relative consumption expenditure. This is in turn equal to the ratio of the expenditure shares, since with CES utility the consumption is homothetic in both types of goods and the relative shares represent the case where the revenue Z_t = 1. Formally, we therefore solve (for example) the following expression:

$$\frac{Y_{N,t}}{Y_{T,t}} = \frac{C_{N,t}}{C_{T,t}} = p_t^{-\theta} \frac{1-\gamma}{\gamma} = \frac{\left(\frac{p_t \, \mu_{LN}}{r_t} \right)^{\frac{1-\mu_{LN}}{\mu_{LN}}} A_{N,t} L_{N,t}}{\left(\frac{\mu_{LT}}{r_t} \right)^{\frac{1-\mu_{LT}}{\mu_{LT}}} A_{T,t} L_{T,t}}$$

Using in addition the normalization $L_T + L_N = 1$ allows to derive the expression for the demand for labor in both sectors:

$$L_{T,t} = \frac{1}{p_t^{-\theta} \frac{1-\gamma}{\gamma}} \times \frac{\left(\frac{p_t \, \mu_{LN}}{r_t} \right)^{\frac{1-\mu_{LN}}{\mu_{LN}}} A_{N,t}}{\left(\frac{\mu_{LT}}{r_t} \right)^{\frac{1-\mu_{LT}}{\mu_{LT}}} A_{T,t}} \left(1 - L_{T,t}\right)$$

Finally, solving for $L_{T,t}$ and $L_{N,t}$ gives:

$$L_{T,t} = \left(\frac{1}{p_t^{-\theta} \frac{1-\gamma}{\gamma}} \times \frac{\left(\frac{p_t \, \mu_{LN}}{r_t} \right)^{\frac{1-\mu_{LN}}{\mu_{LN}}} A_{N,t}}{\left(\frac{\mu_{LT}}{r_t} \right)^{\frac{1-\mu_{LT}}{\mu_{LT}}} A_{T,t}} \right) \times \left(1 + \frac{1}{p_t^{-\theta} \frac{1-\gamma}{\gamma}} \times \frac{\left(\frac{p_t \, \mu_{LN}}{r_t} \right)^{\frac{1-\mu_{LN}}{\mu_{LN}}} A_{N,t}}{\left(\frac{\mu_{LT}}{r_t} \right)^{\frac{1-\mu_{LT}}{\mu_{LT}}} A_{T,t}} \right)^{-1} \quad (15)$$

$$L_{N,t} = 1 - L_{T,t} = \left(1 + \frac{1}{p_t^{-\theta} \frac{1-\gamma}{\gamma}} \times \frac{\left(\frac{p_t \, \mu_{LN}}{r_t}\right)^{\frac{1-\mu_{LN}}{\mu_{LN}}} A_{N,t}}{\left(\frac{\mu_{LT}}{r_t}\right)^{\frac{1-\mu_{LT}}{\mu_{LT}}} A_{T,t}} \right)^{-1} \tag{16}$$

It appears then that sectoral allocation of labor depends on the relative level of technology in both sectors, the elasticity of substitution among the two types of goods, their weight in the preference specification, their shares in production in both sectors and the relative price.

2.3. One Country: Equilibrium Real GDP

We now have all the necessary elements to compute the equilibrium real GDP. The real aggregate output is defined as the sum of sectoral outputs in terms of the tradable good, deflated by the price adjustments:

$$Y_t = \frac{Y_{T,t} + p_t \, Y_{N,t}}{1 - \omega_{N,t}\left(p_t - 1\right)} = \frac{\left(\frac{\mu_{LT}}{r_t}\right)^{\frac{1-\mu_{LT}}{\mu_{LT}}} A_{T,t} \, L_{T,t} + p_t \left(\frac{p_t \, \mu_{LN}}{r_t}\right)^{\frac{1-\mu_{LN}}{\mu_{LN}}} A_{N,t} \, L_{N,t}}{1 - \omega_{N,t}\left(p_t - 1\right)} \tag{17}$$

The obtained expression is the GDP per capita, since the total population is normalized to 1. In (14), the value in terms of the tradable good is deflated to take into account the variations in the relative prices in the aggregate production. The sectoral outputs $Y_{T,t}$ and $Y_{N,t}$ are then replaced with (13) and (14). Finally the real GDP obtains by replacing for labor with (15) and (16) and for the relative price with (8). Observe that the model economy is fully specified by the sectoral technology levels, the specification of the production functions and the preferences.

2.4. Open Economy Relationships

We assume that the world composes of two countries, the industrial leader, denoted by a superscript *, and the convergence country. The convergence country behaves as a price taker. The standard open economy assumption is that the international competition enforces the law of one price to hold for tradable goods, so that $p_{T,t}$ is constrained in the following way:

$$p_{T,t} = p^*_{T,t} \, e_t \, ,$$

where e_t is the nominal exchange rate and higher e_t stands for depreciation. Other price indexes obtain from the following definitions:

$$p^*_{N,t} = p^*_t \, p^*_{T,t} \text{ and } p^*_{CPI,t} = \omega^*_{T,t} \, p^*_{T,t} + \left(1 - \omega^*_{T,t}\right) p^*_{N,t}$$
$$p_{N,t} = p_t \, p_{T,t} \text{ and } p_{CPI,t} = \omega_{T,t} \, p_{T,t} + \left(1 - \omega_{T,t}\right) p_{N,t}$$

The inflation rate in the convergence country and the industrial leader is respectively the growth rate of $p_{CPI,t}$ and $p^*_{CPI,t}$. For the international comparison of the price level we use the ratio real exchange rate (RER) defined as:

$$\mathrm{RER}=\frac{\left(p_{T,t}/e_t\right)^{\Omega_{T,t}}\left(p_{N,t}/e_t\right)^{\Omega_{N,t}}}{p_{T,t}^{*\,\Omega_{T,t}^{*}}\;p_{N,t}^{*\,\Omega_{N,t}^{*}}}=\frac{p_{T,t}^{\Omega_{T,t}}\left[p_t\,p_{T,t}\right]^{\Omega_{N,t}}\Big/e_t}{p_{T,t}^{*\,\Omega_{T,t}^{*}}\left[p_t^{*}\,p_{T,t}^{*}\right]^{\Omega_{N,t}^{*}}}=\frac{p_{T,t}/e_t}{p_{T,t}^{*}}\,\frac{p_t^{\,\Omega_{N,t}}}{p_t^{*\,\Omega_{N,t}^{*}}}=\frac{p_t^{\,\Omega_{N,t}}}{p_t^{*\,\Omega_{N,t}^{*}}} \qquad (18)$$

Note that the RER depends only on the relative price and the differential in the expenditure share. This is logical since the law of one price holds for tradables. The country with lower price level is the country with lower relative price, that is the country with the lower relative tradable to non-tradable productivity ratio, as can be seen from (8).

Finally, straightforward definitions yield the nominal (single currency) GDP per capita ratio and the GDP per capita ratio in PPP standards. To obtain the GDP per capita in PPP standards we multiply the nominal GDP (expenditure) per capita ratio by the RER to correct it for the price level differences.

$$\text{GDP p.c. ratio}=\frac{\left(p_{T,t}/e_t\right)Y_{T,t}+\left(p_{N,t}/e_t\right)Y_{N,t}}{p_{T,t}^{*}\,Y_{T,t}^{*}+p_{N,t}^{*}\,Y_{N,t}^{*}} \qquad (19)$$

$$\text{GDP p.c. PPP}=\text{GDP p.c. ratio}\times\frac{1}{\mathrm{RER}} \qquad (20)$$

We presented a simple framework based on a two sector neo-classical growth model in the view to study the convergence dynamics of a convergence economy towards the industrial leader. The model is assumed to represent the money-neutral real long-run general equilibrium of the economy. Explicit forms for the dynamics of all macroeconomic elements that we want to study are provided: the GDP convergence, intra-economy relative price, the endogenous price index and its weights, etc. In the following sections we apply the model to formulate the predictions of the underlying theory about real output and price convergence and about the implied the H-B-S effect.

3. MODEL CALIBRATION

The calibration of the model parameters is carried out so that the model replicates a set of economic growth stylized facts and some relevant data moments. The convergence country is catching up with the industrial leader by experiencing a higher sectoral productivity growth. Since the two countries are characterized by the same preference structure and production technology and differ only in the level of technological development, they become exactly similar when their technology levels in both sectors end up converging. Here we review the criteria we follow in attributing values to the model parameters.

Table 1 summarizes the parameter values and the necessary initial conditions in the baseline convergence scenario of the Slovenian economy towards its most developed counterparts. The characterization the industrial leader is in most respects inspired by the EU(15) or German economy.

Table 1: Parameter values in the baseline scenario

		Industrial leader	Convergence country
Preferences	weight T: γ	0.74	0.74
	substitution θ	0.3	0.3
	real interest rate r	0.01	0.01
Technology	labor share T: μ_{LT}	0.45	0.45
	labor share N: μ_{LN}	0.76	0.76
Initial conditions	p	endogenous	endogenous
	p_T	normalization to 1	endogenous
	p_N	endogenous	endogenous
	A_T	normalization to 1	0.3
	A_N	normalization to 1	0.8
Growth rates p.q.	$A_{t,T}/A_{t-1,T}$ -1	0.008	0.017
	$A_{t,N}/A_{t-1,N}$ -1	0.001	0.002
	$p_{t,T}/p_{t-1,T}$ -1	0.002	endogenous

The parameters in table 1 fully characterize the solution of the model presented in the previous section. The functional specification of the preferences and the production technology are the same in both countries. Some of the presented parameters are endogenous to the model, meaning that they are determined by the model equations when the other parameters are known. To find a unique numerical solution to the model, a set of free parameters has to be normalized. Since the real variables in the typical economic model are homogenous of degree zero with respect to the prices, i.e. only the relative prices are determined within the model, one price can be set exogenously for the solution to all prices to be found. The choice here was to normalize to 1 the initial value of the industrial leader tradable price p_T. We also chose to normalize to 1 the initial value of the labor augmenting technology level in the industrial leader. This can be done because the production of all types of goods is a continuous flow and can be always normalized so that the production technology level for producing any good at a particular date is exactly 1.[5] Note also that the growth rates in the labor augmenting technology level are constant through time for both sectors and in both countries. When the technology level in one sector catches up with that of the industrial leader, it continues to grow at the growth rate of the industrial leader. The rest of this section discusses the numerical values of free parameters.

3.1. Technology and Preferences

Given the CES functional specification of the preferences, the preferences are determined by the weight attributed to the consumption of tradable goods γ, the marginal rate of substitution parameter θ between tradable and non-tradable goods and, implicitly, the real interest rate. The weight γ is chosen so that the expenditure share in the industrial leader corresponds to roughly 40%, which is the share of industrial goods in the consumption bundle in Germany in the nineties. This implies γ to be set to 0.74. The long-run marginal rate of substitution θ is supposed low, which enables the non-tradable goods producers to significantly increase their relative prices, when the overall revenue increases and the

[5] This is not to say that such a normalization choice doesn't impose constraints on other parameter values, in particular the preference weight of the tradable and non-tradable goods. But, since any type of good can be redefined to be for example as a multiple of that same good, the preference weight γ of this good has also to be redefined in correspondence. The parameter γ is thus not directly interpretable in this model (and does of course not correspond to the expenditure share unless the substitution parameter is set to 1).

technology growth is higher in the tradable sector. Also, the lower the substitution parameter, the lower the labor force flow out of the tradable sector to the non-tradable given the higher tradable sector technology growth. The parameter θ is therefore chosen so that the model reproduces an empirically plausible labor force substitution towards the non-tradable sector during a long period. Over the last fifty years, the labor force share in the manufacturing decreased in most developed countries from around 40% to around 20%, with nevertheless high differences across countries. Its current level is between 15% in the US and around 25% in Germany and in Japan.[6] To be consistent with this long-run process, given the long-run growth performance of these countries, we set θ to 0.3. This generates over the next fifty years a decrease in the industrial leader tradable share in labor from roughly 25% to 15%. The final parameter is the long-run real interest rate, set to 1% on a quarterly basis, in line with the literature applying the variants of the neoclassical growth model.[7]

The two time and country invariant parameters in the specification of the production technology are the labor shares in production in tradable and non-tradable sectors. They are chosen so that the overall labor share in the industrial leader economy is two thirds, consistent with the standard long-run stylized fact reported for example in Cooley (1997). The other constraint on the numerical values of these parameters is the share of tradable sector in the industrial leader country's labor force. We approximate it by the share of the manufacturing in the labor force, i.e. roughly 25%. These two constraints are sufficient to pin down the values of the two parameters to 0.45 for the labor share in the tradable and 0.76 for the labor share in the non-tradable sector production.

3.2. The Industrial Leader and the Convergence Country

To completely characterize the growth and price equilibrium process in the industrial leader country, the constant technology growth rates in both sectors and the tradable inflation (or some other price growth) must be specified. The technology growth in both sectors is parameterized so that the long-run real aggregate growth of the industrial leader country is 2% per year. In addition, the difference in the technology growth in both sectors is an important determinant of the relative price change, in turn implying the differential in the aggregate inflation rate and the inflation in the tradable sector. Over the nineties, the overall CPI inflation was on average 1.7% on a yearly basis, while the inflation in the tradable sector, measured by the producer price index (PPI) amounted for only 0.8% over the period. To satisfy the constraint on the aggregate real growth and the constraint on the aggregate and tradable inflation differentials, the quarterly growth rates are set to 0.008 in the tradable and 0.001 in the non-tradable sector. The tradable inflation is simply 0.002, the PPI inflation on a quarterly basis. With the initial normalization to 1 of the sectoral technology levels as well of the price of the tradable good, the model solution is completely specified and the equilibrium path of the industrial leader can be computed.

The convergence country parameters to be specified are its initial sectoral technology levels and the corresponding technology growth rates. We express the initial sectoral technology levels relative to those of the industrial leader. As is apparent from expression for the relative price (8) and the price level ratio (real exchange rate) across countries (18), the lower is the productivity difference with the industrial leader in the non-tradable sector with respect to the tradable, the higher is the difference in the relative price level among the two countries. By the same time, the model should accurately replicate the initial output per capita difference (measured in the same currency). This implies the initial conditions 0.3 of the industrial

[6] See for example figure 4.7 p. 225 in Obstfeld and Rogoff (1996).

[7] See Cooley (1997).

leader's productivity in tradable and 0.8 of the industrial leader's productivity in the non tradable sector.[8]

From the initial sectoral technology levels, the convergence country catches up with the technology level the industrial leader in both sectors independently. To calibrate the values of the technology growth rates in both sectors, the same strategy is used as in the case of the industrial leader. The long-run aggregate GDP growth in the convergence country slightly exceeds 4% on a yearly basis and the CPI – PPI differential amounts for between 0.18 and 2.6%.[9] The sectoral growth rates satisfying these constraints are 0.017 in the tradable and 0.002 in the non-tradable sector.

The calibration procedure results in a quite plausible parameterization of the model. The data replicating performance of the model is further discussed along the baseline scenario analysis, which also covers the last decade so that some results can be compared to the available evidence. To assess the sensitivity to the preference and technology parameter changes we provide a robustness analysis at the end of the next section.

4. RESULTS

This section presents the details of the equilibrium convergence process generated by the model economy and some insightful alternative convergence scenarios. The parameter values obtained in section 3 are used in the baseline simulation of the convergence process. Note again that the convergence process arises from the sectoral convergence in productivity. When the convergence country technology level in some sector catches up with the level in the industrial leader, the productivity increases at the same rate as in the industrial leader for the remaining time. That implies that eventually both countries become exactly the same as the technology end up converging in both sectors. Some parameters describing the convergence process may change over time, potentially strongly altering the convergence process in some dimension. To evaluate the impacts of these convergence parameter changes, additional experiments are conducted with the model economy. The third part of this section presents a robustness analysis with respect to the model parameters describing the preferences and technology. The section ends with a discussion of some interesting implications of the results.

4.1. The Baseline Convergence Pattern

The catching up period of the convergence country lasts until 2026 for the tradable and 2048 for the non-tradable sector. The baseline scenario assumes that the convergence country and the industrial leader (i.l.) present the same characteristics over the whole convergence period as over the last decade. Figure 1 shows the convergence in real output and the implied growth rates on a yearly basis.[10] The sectoral convergence end dates are identified by the sectoral growth rates decreasing to the levels of the industrial leader. The dark shaded area covers the period where none of the sectors ended convergence, over light gray period only the tradable sector caught up and the in white area both sectors reached

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[8] The Eurostat figures for 1992 are 32% for the current price output ratio and 58% for the output ratio in PPP standards with respect to the EU(15). The model counterparts are respectively 32.0% and 59.8%.

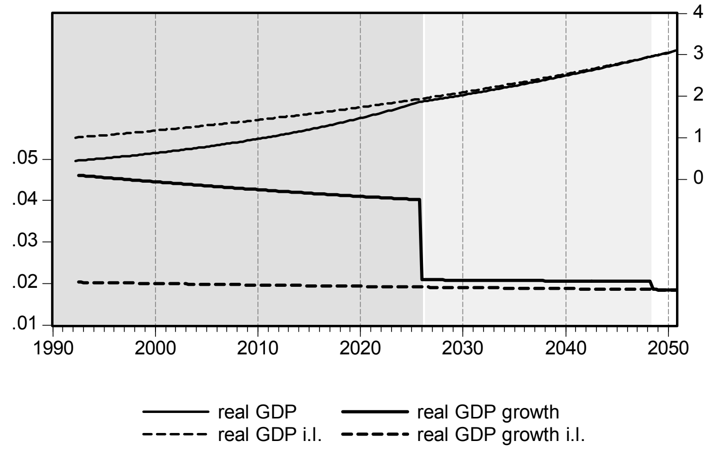
[9] These figures somewhat depend on the estimation period. The GDP growth over the available period is roughly 4.2% but the estimate is strongly decreased by the inclusion of the recent downturn in economic activity that may only be cyclical. The CPI – PPI inflation differential decreases over time, but seems to stabilize after few years at around 2 percentage points.

[10] For simplicity, yearly growth rates are computed by taking four times the quarterly growth rates.

the industrial leader's productivity. Over the sixty years simulation period, the industrial leader slightly more than triples its output, starting with 1 in the beginning of the nineties. The convergence country starts in 1992 with a real output level of roughly 0.45 (i.e. 45% of the i.l.) and then catches up progressively with the industrial leader's long-run equilibrium growth path. In 2001, the convergence country reaches about 66% of the industrial leader's real GDP per capita level and 71% in PPP standards, which is consistent with the empirically observed figures.[11]

The real GDP growth rate in both countries is slightly, but continuously decreasing over time, even with constant sectorial technology growth rates. To preserve the optimal production of the tradable and non-tradable goods, given the specification of the preferences, the economy is comepelled to allocate ever more labor force to the non-tradable sector, which is increasingly relativelly less productive.

Figure 1: Convergence in real in GDP



The most important part of the convergence process completes when the tradable sector converges. To match the available evidence on growth and price convergence, the non-tradable sector productivity must be rather close across countries. One can also note, by observing the growth rates, that the real GDP growth rate is mostly determined by the growth in the tradable sector. In effect, close to no difference arises when only the non-tradable sector keeps converging (here growing twice as fast as in the industrial leader).

The convergence in the sectoral technology level is presented on figure 2. When the technology level in a sector catches up, it continues to grow at the same growth rate as in the industrial leader. The technology growth rates in the convergence country are initially those arising form the calibration procedure. They equal the industrial leader's values after convergence in tradable in 2026 and non-tradable in 2048.

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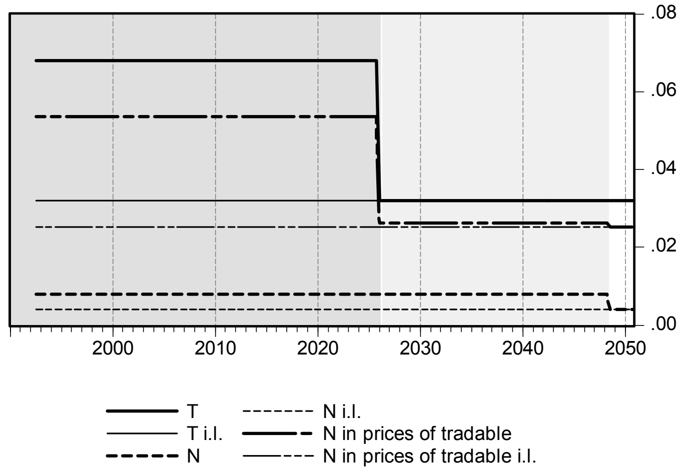
[11] See for example Eurostat, comparison in PPP standards. One can see from (18) and (20) that the difference in the model specified real GDP per capita and the GDP per capita in PPP standards arises from the consumption bundle differences (and slight difference in the deflator). Output per capita ratio in current prices with respect to the EU 15 was 32% in 1992 and 45% in 2001. The model predicts respectively 32 and 44%.

Figure 2: Sectoral technology growth rates



The technology growth in the non-tradable sector is much closer to the tradable when expressing the growth rate in terms of the tradable good, since it includes the significant relative price increase. The technology growth in terms of the tradable good is 5.36% instead of 0.8% in the convergence country and 2.53% instead of 0.4% in the industrial leader. This generates the significant relative price increase of the non-tradable good with respect to the tradable. Most of the growth in the non-tradable sector is in value and not in quantities. The mirror image of this is that most of the development differences (which may be quite high – more than 10 times!) arise from the differences in technology the tradable sector.

Figure 3: Price levels

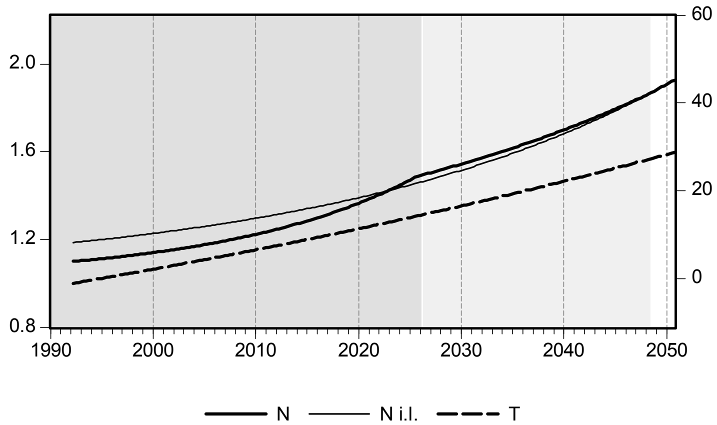
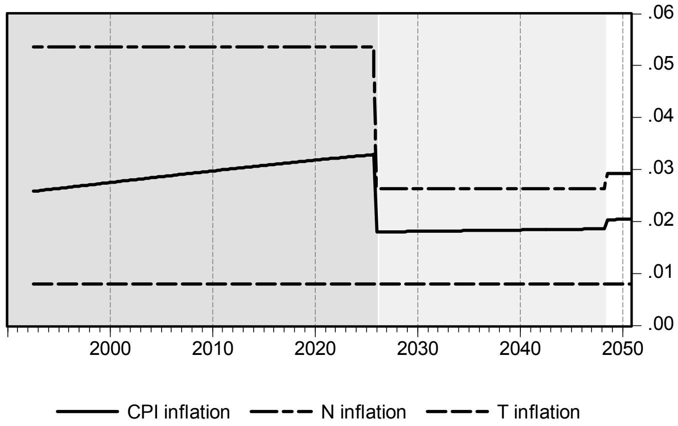


Figure 3 shows the evolution of the sectoral price levels in the convergence country and the industrial leader, expressed in the industrial leader's currency. Due to the law of one price, the price of the tradable good is the same across countries. The price of the non-tradable good is on the contrary initially much lower in the convergence country, reflecting lower relative price (of the non-tradable good in terms of tradable) in the convergence country. As the tradable sector productivity catches up with the industrial leader's at the faster pace than the non-tradable sector productivity, the relative price grows faster in the convergence country and so does the price level. Interesting enough, if the tradable sector ends up converging before the non-tradable, the sectoral productivity ratio is higher in the convergence country, in turn implying a higher relative price and a higher non-tradable price level! The convergence country non-tradable price level peaks respectively to the industrial leader at the date of convergence of the tradable sector, when the sectoral productivity ratio difference between the two countries is the highest. After that, only the non-tradable sector keeps converging, now decreasing the convergence country sectoral productivity ratio relative to the industrial leader. The relative price in the convergence country now decreases respectively to the industrial leader, and so does the non-tradable goods price level. The process lasts until the convergence in the non-tradable sector, after what both economies are exactly similar.

The price convergence pattern can also be described in terms of the inflation rates. The implied inflation paths are diplayed on figure 4. The inflation rate in the non-tradable sector (corrected for the exchange rate differentials) is the same across countries. Conversely, the non-tradable sector price inflation evolves in correspondence to the variations in the relative price. During the fast tradable sector productivity growth the non-tradable inflation is high, roughly 5.5% p.a., while it is arround 3% in the industrial leader. After the convergence in the tradable productivity, the non-tradable inflation strongly decreases and stabilizes at level (slightly) inferior to the industrial leader.The relative price increase in the convergence country is indeed lower than in the industrial leader, because higher productivity growth in the non-tradable sector in the convergence country alows for lower wage pressures on prices.

Figure 4: Sectoral and aggregate inflation

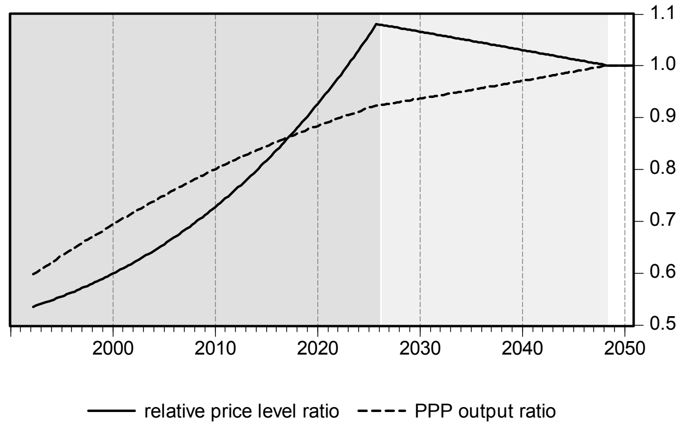


While the sectorial inflation is constant as long as the technological progress increases at constant rates, the overall CPI inflation on the contrary increases over time. Similarly, the H-B-S effect may increase over time. The reason for this is that the share of the non-tradable goods in the consumption expenditure increases. The H-B-S effect may therefore be at its maximum just before the economy ends up converging in the tradable sector technology. In this technology convergence context, the inflation could increase from roughly 2.5% to more than 3% due to the effect of the reallocation in the consumer expenditure between the two sectors.

After the convergence in the tradable sector, the convergence country inflation is actually smaller than in the industrial leader, implying in turn a negative H-B-S effect. This is due to the the smaller non-tradable inflation and induces the normal equilibrium process needed to equate the price levels in both countries.

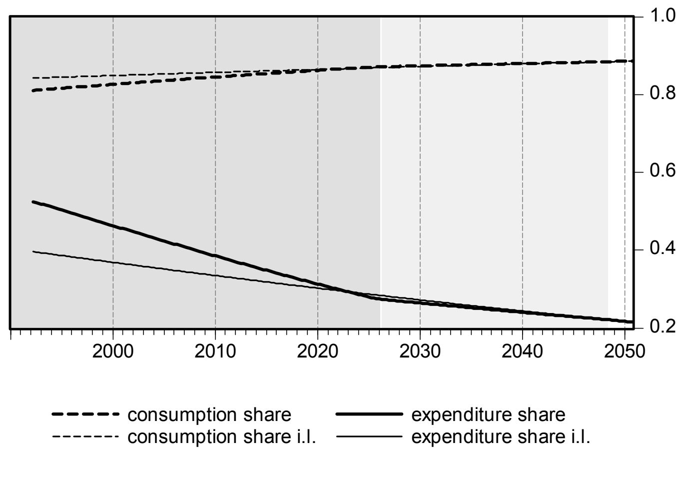
An insightful aspect of the catching up process is the convergence in PPP output measure together with the price level ratio (RER), as represented on figure 5. The price level first increases moderately, but then converges faster and even overshoots the industrial leader's price level. In effect, higher non-tradable price level implies higher overall price level.[12] In the Slovenian economy convergence case, the predicted future over-shooting in price level is less than 10%.

Figure 5: PPP output and relative price levels



The represented output ratio in PPP standards is (slightly) different than the real GDP ratio. It shows a much smoother output convergence process than the real GDP measure, and much less sensitive to the sectoral convergence. Although the real GDP is close to identical after the tradable sector converged (see figure 1), it is not the case of the output in PPP standards. This is mainly because different deflators are used. The PPP price level, the geometric mean deflator weighted by expenditure embodied in the RER, captures somewhat better the real value of consumption than the standard real GDP (here the same as consumption) deflator. While initially the PPP standard output ratio is well above the real GDP ratio, the situation reverses when the RER exceeds one. This is again because the PPP price level depreciates the consumption value more severely when the price dispersion is higher, i.e. when the relative price is higher.

Figure 6: Tradable share in consumption and expenditure (GDP)

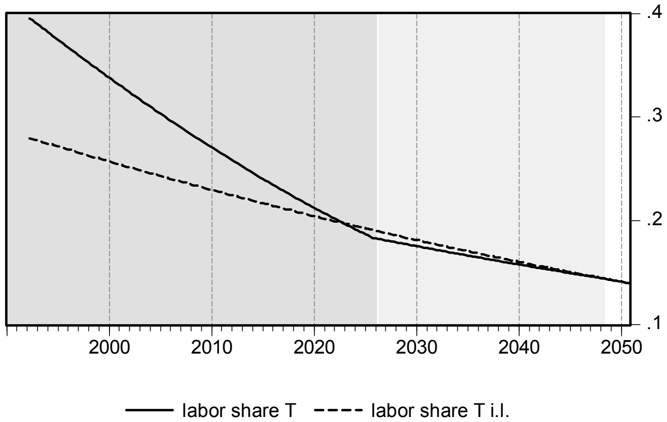


[12] At simulated expenditure weights.

The share of tradable goods in consumption slightly increases over time, while their share in expenditure (GDP) decreases, as a result of significant relative price growth. From figure 6 it appears that the consumption share of the tradable goods remains very stable over the period and is very similar in both countries. The moderate substitution of the tradable goods arises from the low elasticity of substitution between the two types of goods. Conversely, the low elasticity of substitution implies a relatively more important response of the tradable share in the expenditure. The model specification predicts that the latter should decrease from more than a half to 46% in 2000 and to only 22% in 2050.

Figure 7 represents the flow of the labor force from the tradable into the non-tradable sector due to the differences in sectorial productivity growth. Since there is a low substitution in the consumption share of non-tradable goods with the tradable goods, the labor share of the non-tradable sector must increase to offset the increase in the productivity differences across the two sectors. The tradable share is initially higher in the convergence country because it is characterized by a higher productivity gap in the tradable sector with respect to the industrial leader than in the non-tradable sector. With the faster convergence in the tadable sector, this situation progressivelly changes and even temporary reverses. The reason it reverses is that the relative price is temporarily higher in the convergence country respectively to the industrial leader, to induce the optimal production level in the convergence country non-tradable sector. After the end of the convergence process in the tradable sector, the tradable sector share converges towards that of the industrial leader and finaly equals the latter when both sectors end up converging.

Figure 7: Tradable share in the labor allocation



Because this study focuses on the equilibrium price evolution and the H-B-S effect given the underlying real convergence processes, a useful check of the model's predictive capability is to compare the predicted inflation evolution to the actual. For the overlapping period between the simulation exercise and the available data period, this comparison is represented on figure 8 for the aggregate inflation and on figure 9 for the sectoral inflation.[13]

The model-predicted aggregate inflation replicates fairly well the CPI inflation in the post-independence period. During the whole period of available data, the model simulates relativelly accurately the evolution of the long-run inflation trend. Recall that the calibration imposed the tradable price inflation in the industrial leader and ensured that the average

[13] The figures present the deseasonalized quarterly inflation rates on the yearly basis. The nominal exchange rate growth rate, needed to relate the domestic inflation to the foreign, is the Hodrick-Prescott filtered quarterly growth rate on the yearly basis. The out-of-sample projection for the nominal exchange rate is only indicative.

differential in the tradable price and CPI inflation in the convergence country corresponds to its empirical counterpart. The rest of the index (the sectorial weights, the relative price, the international constraint on the price of the tradable good, etc.) is determined within the model.[14]

Figure 8: Slovenian inflation and the long-run model prediction

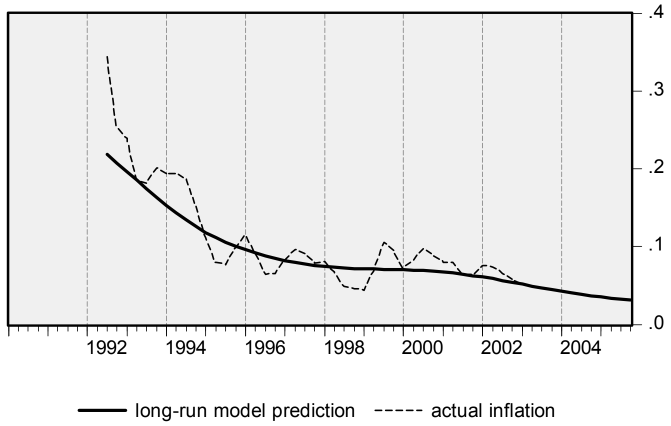
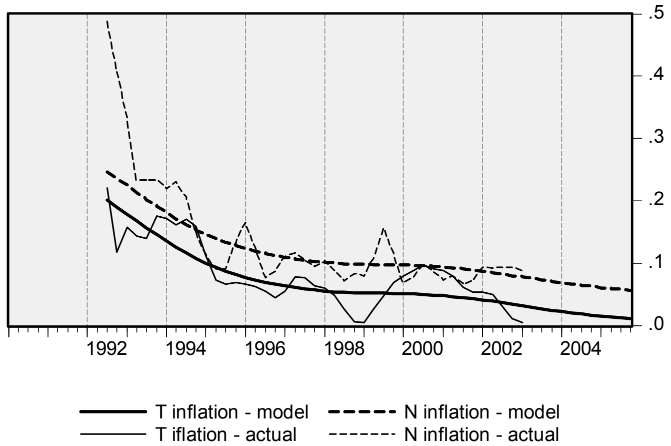


Figure 9: Sectoral inflation and the long-run model prediction



The model also replicates satisfactorilly well the evolution of the sectorial inflation indexes.[15] The model predicts a parallel long-run evolution ot the two inflation rates since, from (8), the constant growth rates in technological progress imply a constant growth rate in the relative price. That feature comes from the complete long-run monetary neutrality that characterises the neoclassical growth model. A corollary of the monetary neutrality is that nominal echange rate doesn't impact the real economy or the relative prices in the long-run, whathever the monetary shocks to the economy. This in turn implies a long-run nominal

[14] Remark that figure 8 simply represents the sum of the aggregate theoretical CPI inflation form figure 4 and the nominal exchange rate trend. Logically, since industrial leader inflation and the domestic inflation in foreign currency are (close to) constant, the major part of the long-run inflation dynamics is determined by the empirical exchange rate trend. Of course, this is a long-run equilibrium relationship that *a priori* tells little or none about causality. From this analysis, it is indeed not possible to say anything about what is (are) the driving force(s) of the inflation in Slovenia as long as the exchange rate is an endogenous variable.

[15] The tradable price inflation is represented by the PPI. The non-tradable goods inflation is constructed so that the CPI inflation obtains using PPI for tradable inflation and applying model predicted expenditure weights.

exchange rate pass-through to the price level (and all individual prices!) equal to exactly one. Since the sectorial inflation differential equals the percentage change in the relative price, by definition, the monetary neutrality requires the latter to be constant if the former grows at a constant rate. At first sight, this long-run prediction seems to have a remarkable empirical support. Observe that the parallel evolution of the two inflation rates, that is their constant absolute difference, is not linked to the absolute level of inflation and is therefore expected to persist in the future.

Initial conditions and growth rates yield relatively good results in predicting the real output and price convergence over the last decade. The model generates for the year 2000 a RER of 66%, a nominal GDP per capita ratio of 45% and a GDP per capita in PPP standards of 71%. This is in almost exact correspondence with the evidence. The model also accounts fairly well of the aggregate and sectoral inflation rates. If the current growth parameters prevail in the future, the convergence in productivity may last for roughly another 25 years in the tradable sector and some twenty years more in the non-tradable sector. Until the convergence completes in the tradable sector, a long-run equilibrium inflation rate between 2.7 and 3.5 percents p.a. is consistent with this specification of the model. It may slightly increase over time, at the order of magnitude of a half of percentage point. The implied H-B-S effect lays between 1 and 1.5 percentage points p.a.. After the convergence of the tradable sector productivity, the inflation decreases to slightly less than the level of the industrial leader. When both sectors end up converging, both economies are exactly similar in per capita terms and price evolution.

In what follows, we assume that the model economy represents a satisfactory approximation to the long-run convergence process. We simulate it in a selected set of alternative convergence scenarios in order to gain insight on what may be the qualitative and quantitative implications of various changes in the characterization of the long-run convergence process.

4.2. Alternative convergence scenarios

We select five alternative convergence scenarios: faster technology convergence in the tradable sector, faster technology convergence in the non-tradable sector, lower initial technology level in the non-tradable sector, no convergence in non-tradable sector and a two step convergence in the non-tradable sector. Studying these alternative convergence paths is useful to get insight on the risks regarding the output and price convergence, when some important parameter describing the convergence process changes. Only the principal characteristics of the new convergence path are presented, but a more detailed description can be found in table 2.

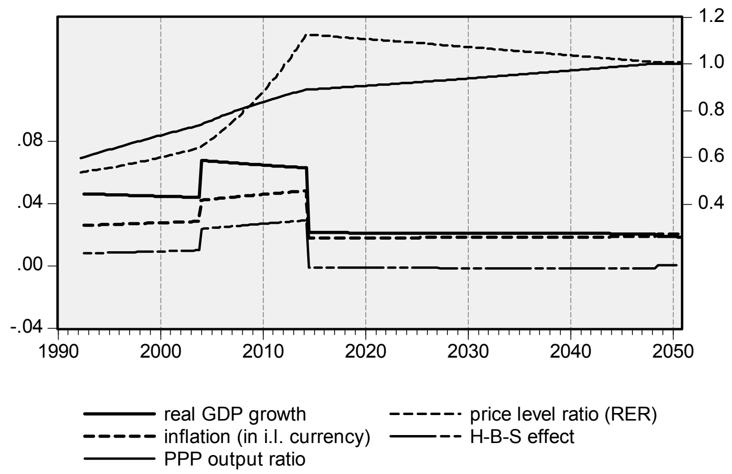
The first alternative growth scenario is a faster convergence in the tradable sector. Technically, this is simulated by increasing the quarterly growth rate from 1.7% to 2.7% until it ends up converging to the industrial leader’s level. Figure 10 describes the principal characteristics of the new convergence path.

Table 2: Scenario analysis

	Convergence					Real GDP					Inflation				
	Sectoral convergence					Growth rate					Inflation				
	PPP output convergence					real GDP level					Relative price change				
	Relative prive level										Harrod - Balassa - Samuelson				
	2000	**2010**	**2025**	**2040**	**2050**	**2000**	**2010**	**2025**	**2040**	**2050**	**2000**	**2010**	**2025**	**2040**	**2050**
Baseline	tradable in 2026, both in 2048					0.045	0.043	0.040	0.021	0.018	0.070	0.030	0.033	0.018	0.020
	0.69	0.80	0.92	0.97	1.00	1.00	1.55	2.87	3.98	4.87	0.046	0.046	0.046	0.018	0.021
	0.60	0.73	1.06	1.03	1.00						0.009	0.011	0.013	-0.002	0.000
Faster T	tradable in 2014, both in 2048					0.045	0.065	0.021	0.021	0.018	0.070	0.046	0.018	0.018	0.020
	0.69	0.84	0.92	0.97	1.00	1.00	1.78	2.93	3.99	4.88	0.046	0.076	0.018	0.018	0.021
	0.60	0.88	1.09	1.04	1.01						0.009	0.027	-0.002	-0.002	0.000
Faster N	non tradable in 2019, both in 2026					0.045	0.046	0.039	0.019	0.018	0.070	0.027	0.034	0.020	0.020
	0.69	0.83	1.00	1.00	1.00	1.00	1.58	3.00	4.05	4.87	0.046	0.040	0.049	0.021	0.021
	0.60	0.70	0.98	1.00	1.00						0.009	0.008	0.015	0.000	0.000
Lower initial N	tradable in 2026, both after 2050					0.044	0.042	0.040	0.020	0.020	0.071	0.030	0.033	0.018	0.019
	0.63	0.72	0.81	0.86	0.89	0.95	1.46	2.70	3.73	4.58	0.046	0.046	0.046	0.018	0.018
	0.65	0.80	1.19	1.16	1.12						0.010	0.011	0.014	-0.002	-0.002
No convergence in N	tradable in 2033, both never					0.045	0.039	0.036	0.017	0.016	0.070	0.033	0.037	0.022	0.023
	0.69	0.77	0.79	0.74	0.71	1.00	1.51	2.66	3.46	4.08	0.046	0.052	0.052	0.024	0.024
	0.60	0.76	1.23	1.33	1.39						0.009	0.014	0.017	0.002	0.002
Two step conv. in N	tradable in 2026, both after 2050					0.045	0.039	0.036	0.017	0.028	0.070	0.033	0.037	0.022	0.012
	0.69	0.77	0.79	0.74	0.88	1.00	1.51	2.66	3.46	4.55	0.046	0.052	0.052	0.024	0.006
	0.60	0.76	1.23	1.33	1.14						0.009	0.014	0.017	0.002	-0.009

The significantly higher technology convergence in the tradable sector accelerates its convergence, the real GDP growth, the inflation and the corresponding H-B-S effect, which may be now close to 3%. The tradable convergence ends in 2014 instead of 2026. This translates into much higher real GDP growth, 6.5% instead of 4.3% on a yearly basis, during the tradable convergence period. The relative price increases by 7.6% on a yearly basis, in comparison to the 4.6% in the baseline. The long-run theoretical H-B-S effect rises from 1.1% to 2.7% implying a significantly higher inflation, 4.6% instead of 3.0%.[16] The overall price level overshoots the price level in the industrial leader by more than 10% and then slowly decreases towards the latter during the non-tradable sector convergence. As in the baseline, and for the same reason, during this last convergence stage the H-B-S effect is slightly negative, implying a slightly lower inflation in the convergence country.

Figure 10: Faster convergence in T productivity



In the second alternative convergence scenario, we analyze a faster catching up in the non-tradable sector technology. The quarterly growth rate in the non-tradable production technology is doubled, from 0.002% to 0.004% starting with 2004. The new convergence characteristics are depicted on figure 11.

When the non-tradable productivity converges prior to the tradable sector productivity, the price level no more over-shoots and both the price level and the real GDP converge monotonously to the industrial leader's values. As a corollary, even if the real GDP growth is faster, the equilibrium inflation rate and the H-B-S effect are inferior to the baseline. The twice faster convergence in the non-tradable sector makes it reach the industrial leader technology level in 2019 instead of 2048, so that the whole economy ends the convergence process in 2026, when the tradable sector technology also catches up. Faster non-tradable technology growth increases the real GDP growth, but decreases the inflation rate and the H-B-S effect. Since the ratio of tradable to non-tradable productivity now never exceeds that in the industrial leader, the relative price in the convergence country, and therefore its price level, always remain below the industrial leader's values. The effects on the real growth rate and inflation are quantitatively small, because the model's parameterization predicts modest

[16] Note that this scenario resembles closely the recent Irish convergence path. It is difficult to say whether the Slovenian economy, in many respects similar to the Irish, can achieve such a growth performance in the future. One engine of such change in the natural growth path may be connected with the entry into the EU, improving the growth channels of trade, competition, technology adoption, etc. Note that that type of structural change may in turn endanger the "nominal convergence criteria" necessary to fulfill to enter the euro-zone, given the predicted increase in the H-B-S-type effects.

level and growth rate differences in the non-tradable technology across countries. The H-B-S effect and inflation decrease by around 0.3 percentage points on a yearly basis. Nevertheless, small real growth and inflation impacts on a yearly basis translate in important level effects in the longer periods. While real GDP level may differ by few percents relative to the baseline, the price levels may differ by more than ten 10%, exerting considerable impact on output ratio in PPP standards. More extreme cases are considered in the fourth and fifth convergence scenarios, leading to even higher, but plausible differences in levels.

Figure 11: Faster convergence in N productivity

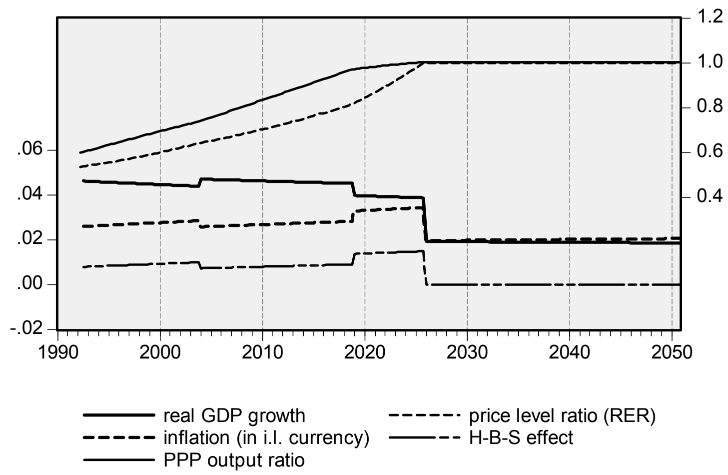
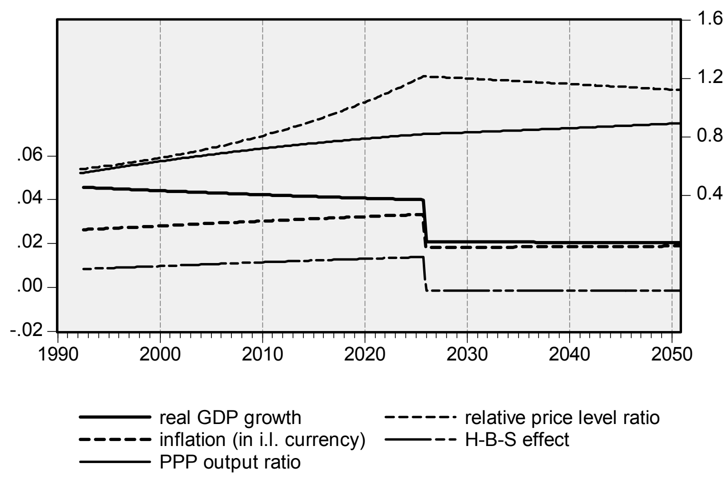


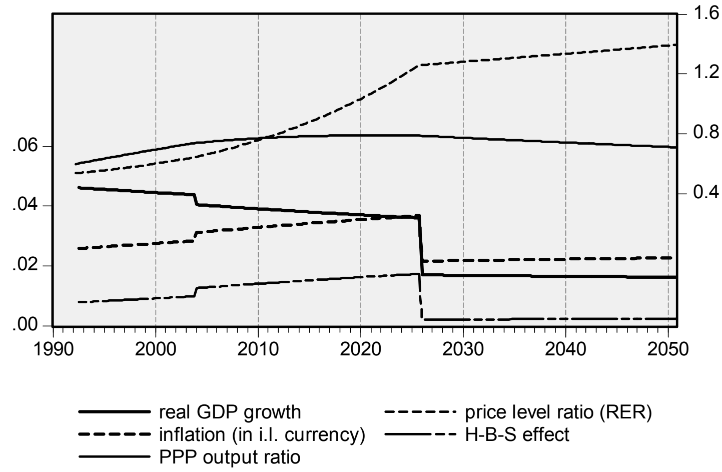
Figure 12: Lower initial productivity in sector N



We consider in the third scenario how different initial conditions impact the convergence pattern, setting the initial technology level gap in the non-tradable sector to 30% instead of 20% of the level in the industrial leader. As expected, there is no impact on the growth rates and inflation, but quite a sizeable effect on the price and output levels. Figure 12 displays these impacts.

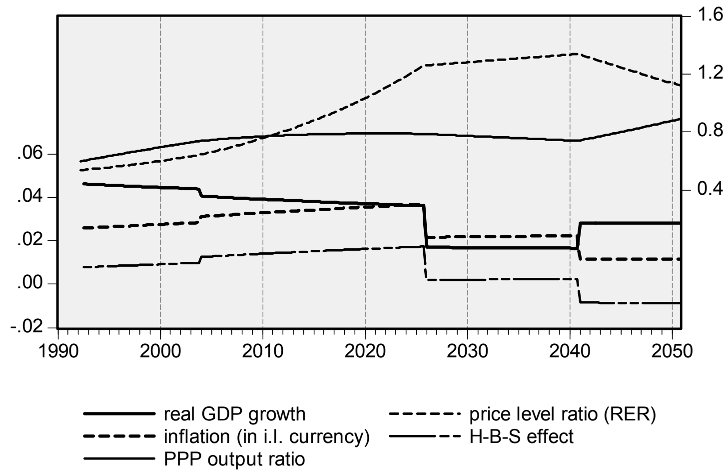
Since the productivity level in the non-tradable sector is lower, so is the aggregate output. Conversely the price level ratio (RER) to the industrial leader is higher, initially 65% instead of 60%. The convergence country relative price is higher than before since the convergence country relative sectoral productivity is lower, in turn implying higher overall price level. This further decreases the output ratio measured in PPP. The initial non-tradable sector productivity level is so low, that the convergence continues after 2050, given the unchanged baseline growth rates. Another interesting feature to remark is that the higher initial price level remains above the baseline during the whole convergence period. It even exceeds the industrial leader price level by more than 20% at its maximum!

Figure 13: No convergence in sector N productivity



Finally, we examine two more extreme, but still plausible and very illustrative, convergence patterns in relation with the non-tradable productivity level evolution. In the fourth convergence scenario, the converging economy non-tradable sector technology level doesn't grow. The fifth scenario is similar to the fourth, but after some period the tradable sector productivity restarts converging, in a sustained pace.

Figure 14: Two-step convergence in sector N



When the coutry's non-tradable sector stagnates, the price level ratio to the industrial leader keeps increasing, while the output ratio ends up decreasing over time. Always rising tradable to non-tradable productivity ratio increases the relative price and consequently the price level ratio to the industrial leader (RER). This process continues also after the convergence in the tradable sector, since the non-tradable sector technology in the industrial leader keeps growing. Higher relative price growth implies higher equilibrium inflation and higher H-B-S effect by 0.3 to 0.4 percentage points. Note that in this equilibrium path, a higher inflation and H-B-S effect arise together with a lower GDP growth, which is the mirror image of the second alternative growth scenario. All these convergence features generate after about fifty years a price level ratio (RER) as high as 1.4 with repect to the industrial leader, even though the starting point is at 0.7.

The last convergence scenario shows the importance of policies enhancing the non-tradable sector productivity catching up for the convergence country's welfare. After a stagnation period in the non-tradable technology, as in the previous scenario, the non-tradable sector resumes with an intense catching up process after 2040. This results in a significant increase in real GDP growth and a significant decrease in inflation and the H-B-S effect. This effect is similar to the effect in the second scenario, but the technology growth rate in the non-tradable sector is now 0.008 per quarter, as compared to 0.002 in the baseline or 0.004 in the second alternative scenario. The inflation and the H-B-S effect decrease by close to one percentage point on a yearly basis, the inflation being nearly halved with respect to the industrial leader. The growth rate is also higher by one percentage point. The overall price level ratio sharply decreases and the PPP standards output ratio sharply increases. Nevertheless, the preceding stagnation in the non-tradable productivity made the economy lag so much behind the industrial leader, that the convergence ends only after the horizon of 2050. If available, a policy reform that would result in a higher non-tradable technology catching up, would directly generate a faster real GDP growth. But it could also significantly decrease the H-B-S effects on inflation and generate over longer period a much lower price level, therefore further increasing the output and welfare.

Overall, the alternative scenarios we studied show the predominance of the tradable sector in the real growth process, but also the relevance and a large impact on price level of the non-tradable sector. The quantitative results of these scenarios again indicate that plausible aggregate real growth and price dynamics require much lower differences in the non-tradable level of technology than in the tradable, and a far lower growth rate in the former than in the latter. This seems to confirm the presumption from the calibration. Nevertheless, over longer periods, high welfare importance of non-tradable development has been emphasized. In the second and the fourth scenarios the relative price level decreased with respect to the situation with lower non-tradable technology growth, in turn increasing the welfare and output. In the case of the faster convergence of the tradable sector, the convergence country experiences an over-shooting in the price level with respect to the industrial leader, which is followed by a lower inflation than in the industrial leader and a negative H-B-S effect. In addition, if non-tradable productivity growth is low, more resources, labor and capital, are allocated to the less efficient sector, because of the low elasticity of substitution between the two goods, further decreasing the real growth in the economy.

Even though the tradable sector level of technology may be the dominant factor explaining the differences across countries at different development level, the major differences across developed countries may well be attributable to the non-tradable sector productivity. The international competition or a fast technology adoption – for example – result in a very fast convergence in the tradable sector technology (manufacturing). The accelerated tradable sector productivity growth is probably at the origin of the "growth miracles", the extremely fast convergence of some development countries towards the industrial leader. But the "barriers to riches" from Parente and Prescott (2000), i.e. the rigid and monopolistic structure preventing from the adoption of efficient technologies and improving productivity, may well become the "barriers among riches" for the developed countries, where such a market structure characterizes the non-tradable sector. In that interpretation, an important part of the differences across developed countries results in the differences of the non-tradable sector productivity.[17]

4.3. Robustness

The interest of a robustness analysis is in evaluating the sensitivity of the results to variations in the parameters of the underlying economic structure, the technology and the preferences. We also describe qualitatively how the changes in these parameters impact the macroeconomic dynamics. The experiments are reported in table 3. The experiments consist in altering the value of the parameter and compute the new equilibrium, *ceteris paribus*. To be illustrative, the results are only presented for particular dates: 2000, 2025 and 2050. We first compare to the baseline scenario the change in labor intensity, then the change in the marginal elasticity of substitution and finally in the weights of tradable and non-tradable goods in the consumer's preferences.

A higher labor intensity in non-tradable versus the tradable sector is not needed for an economy to experience a positive H-B-S effect. We examine the situation in which both sectors characterize by the same labor intensity, equal to 0.66 instead of 0.45 and 0.76 for respectively the tradable and the non-tradable sector. From equation (8), since the capital share in the non-tradable sector production has increased, the wage equalization across sectors is less transmitted to the relative prices when the labor augmenting productivity ratio increases. The lower relative price generates less labor transfer to the non-tradable sector. The corresponding H-B-S effect is roughly halved and the inflation rate reduced (in both the convergence country and the industrial leader) by a half of a percentage point. But the convergence country still experiences a positive H-B-S effect. Equation (8) clearly shows that only the non-tradable sector labor intensity matters for the relative price growth. Nevertheless, both the tradable and non-tradable sector labor intensities intervene in the relative price level. Because more production factors are allocated to the sector with higher productivity growth, the real GDP growth, and consequently the real GDP level, is significantly higher than in the baseline growth path. Finally, observe that the sectoral expenditure share and the sectoral labor allocation are the same. Equations (11) and (15) imply $L_{T,t}$ to equal $\Omega_{T,t}$ when μ_{LN} equals μ_{LT}. Since this is inconsistent with evidence, the tradable sector expenditure share being in general more important than the tradable sector labor share, it indicates that the tradable sector is less labor intensive than the non-tradable (which also is often empirically evidenced).

The ability to substitute between the tradable and the non-tradable goods generates huge output and price level effects in the long-run. The third and the fourth row in table 3 report the changes in the model economy when the elasticity of substitution θ is set respectively to 0 and 1. θ equal to zero implies that there is no possibility to substitute among the two goods, so that the optimal consumption share of both goods is constant and always equal to their weight in the consumers preferences, γ for the tradable and $1-\gamma$ for the non-tradable goods. As a consequence of the invariant demand for the non-tradable goods, a persistently higher proportion is allocated to the less productive non-tradable sector, decreasing significantly the potential output and growth. While the relative price between the two types of goods remains unchanged relative to the baseline, because of the same the level of technology in both sectors, the sectoral expenditure share changes significantly in favor of

[17] Recall again the example of Japan. In this interpretation one must distinguish between real output in PPP standards and the output "in dollars", since countries with lower non-tradable development will be characterized by higher price level and therefore higher development in dollars. It is nevertheless interesting to note, that its residents will have high purchasing power abroad and therefore an (illusive?) perception of wealth.

the non-tradable. Since its weight in the expenditure rises, so does the inflation rate and the H-B-S effect.

When θ equals 1, there is a high possibility to substitute the consumption of the relatively more and more expensive non-tradable good by consuming more of the non-tradable goods. Now the consumer's optimal choice allows for more resources to be allocated to the more productive tradable sector. The real growth and the output level are nearly 150% (2.5 times!) higher than in the zero substitution case. The labor and expenditure shares are constant through time, the latter equal to its sectoral weight in consumer's preferences. This is because all price increases are offset one to one by a decrease in the quantities consumed. It is implausible that the θ is higher than one. In this case, not only would the tradable share in consumption increase over time, but also its share in the expenditure and labor. This would further enhance the potential output and growth, because the resources are more efficiently used. As the non-tradable share in expenditure would become less and less important, and so its weight in the price level, the price level may even be decreasing (depending on the nominal anchorage of the economy), potentially implying a negative inflation rate.

The last experiment examines the impact of the tradable and non-tradable weight in the consumer's preferences. The tradable sector weight γ is set to 0.4 instead of 0.74 and consequently the non-tradable sector weight is augmented from 0.26 to 0.6. For the consumers value more the non-tradable good relatively to the baseline, its share in the consumption increases. The relative price does not change, since it is determined by the production technology, so that with higher consumption share also the expenditure share increases. The implied inflation rate and the H-B-S effect are therefore larger than in the baseline. To produce more non-tradable goods, more factors and resources are allocated to the less productive non-tradable sector. This reduces the output level and the output growth.

We observe that alterations in the parameters defining the underlying economic structure, the preferences and the production technology, significantly impact the results. If these parameters were purely calibrated, that may question the plausibility of the results. Nevertheless, the fact that (huge) changes in these parameters produce a (huge) change in the dynamics of the model economy, enables for a fairly good identification of their values. We took advantage of that in attributing the parameter values so that key data moments are replicated by the model economy. Although a more accurate estimation of their values is in order, the parameterization proposed in this paper is probably fairly close to the "true values". This inspires confidence in the reported results, not only qualitatively but also quantitatively.

Table 3: Robustness analysis

	Real GDP			**Inflation**			**Sectoral shares**		
	Growth rate			Inflation			Consumption		
	Level			Relative price change			Expenditure (GDP)		
				Harrod - Balassa - Samuelson[1]			Labor		
	2000	**2025**	**2050**	**2000**	**2025**	**2050**	**2000**	**2025**	**2050**
	0.0445	0.0403	0.0185	0.0703	0.0327	0.0204	0.8260	0.8699	0.8854
Baseline	1.0000	2.8744	4.8689	0.0456	0.0456	0.0213	0.4630	0.2796	0.2169
				0.0091	0.0133	0.0000	0.3379	0.1869	0.1409
	0.0587	0.0555	0.0254	0.0602	0.0205	0.0146	0.7199	0.7757	0.7968
Labor intensity: $\mu_{LT} = \mu_{LN} = 0.66$	1.0000	4.1750	8.2882	0.0396	0.0396	0.0185	0.7832	0.6437	0.5740
				0.0043	0.0068	0.0000	0.7832	0.6437	0.5740
	0.0331	0.0265	0.0119	0.0809	0.0471	0.0273	0.7400	0.7400	0.7400
Sustitution: $\theta = 0$	1.0000	2.0825	3.0447	0.0456	0.0456	0.0213	0.3407	0.1418	0.0926
				0.0136	0.0210	0.0000	0.2343	0.0891	0.0570
	0.0653	0.0671	0.0317	0.0536	0.0089	0.0083	0.9400	0.9800	0.9876
Sustitution: $\theta = 1$	1.0000	5.2507	11.9137	0.0456	0.0456	0.0213	0.7400	0.7400	0.7400
				0.0020	0.0005	0.0000	0.6276	0.6276	0.6276
	0.0330	0.0324	0.0154	0.0839	0.0426	0.0243	0.5266	0.6103	0.6440
Preference weight: $\gamma = 0.4$	1.0000	2.2592	3.5452	0.0456	0.0456	0.0213	0.1680	0.0833	0.0609
				0.0172	0.0185	0.0000	0.1068	0.0511	0.0370

1. Difference in foreign currency price inflation.
All growth rates are on a yearly basis.

4.4. Discussion

This framework on the basis of a two sector neo-classical growth model provides a surprisingly complete insight in the alternative growth and price convergence process patterns. Even with a simplistic representation of the economy, quantitative results appear fairly plausible and in line with the growth evidence in many countries. Some points are worth discussing further in detail.

First, the deviations from the law of one price are frequent also in the tradable sector. These are in general due to natural or government imposed trade barriers, transport costs, noncompetitive market structures, etc. Note that these elements are merely level and not growth effects, i.e. they produce a price level differentials but not inflation differentials (as long as they remain unchanged and are proportional to the price). The quantitative results in inflation and H-B-S effect we present in this work are therefore robust to this type of differential.

The interpretation we favor is that non-tradable goods (services, etc) are also included in the tradable goods prices, preventing the law of one price to hold for tradables. All goods contain a tradable and non-tradable component and to disentangle the two components is in general difficult or impossible. This allows for a reinterpretation of the model associating the tradable sector price with tradable component and the non-tradable good price with the non-tradable component of the good. In this perspective, the law of one price holds only for the tradable component of the goods price.[18]

Second, the H-B-S effect is not implied by a possible monopolistic structure of the production in the non-tradable sector. The H-B-S effect is defined as a tendency for countries with higher productivity in tradable goods relative to non-tradable goods to have higher price levels. As is apparent form the model specification, the effect obtains also in the case of intra-sectoral perfect competition (which is actually way this model is specified – no individual producer in the non-tradable sector can charge a higher than the equilibrium price!). The monopolistic structure exists only at the sectoral level and arises from the consumer's preferences. It is the fact that the representative consumer is willing to consume both types of goods that allows the non-tradable sector producers to increase their relative price. Blaming the monopolistic structure of the non-tradable sector for the H-B-S effect therefore is not a pertinent criticism.[19]

Third, this model shows that the theory clearly does not imply a monotonous convergence in price level during the real convergence process. As a corollary, it does not imply a positive H-B-S effect during the whole convergence period. We show that if the tradable sector productivity converges prior to the tradable sector productivity, the sectoral productivity ratio is higher in the convergence country than in the industrial leader, implying a higher relative price and consequently a higher price level. The over-shooting in the price level during the convergence proces is not just a theoretical artifact. Take the example of Japan. It

[18] Nevertheless, such a reinterpretation may bear some quantitative implication for the results. There is no guarantee that the aggregate tradable and non-tradable share remain close to the ones this model is (in part) calibrated to replicate. We conjecture, however, that using PPI as the tradable price leads to this bias in the obtained results being quantitatively small. Future work may investigate in that direction.

[19] This is of course not to say that the monopolistic structures, often encountered in the non-tradable sector, should not be an economic policy concern! We just point to the fact that the theory predicts the relative price increases (aside from some second order effects) to be similar whatever the competitiveness in the non-tradable sector. In effect, since the monopolistic structure generates a level and not a growth effect, the inflation differential is not altered at the margin. In other words, amending the model with a monopolistic structure in the non-tradable sector would only increase the non-tradable price by a constant mark up. See Dixit and Stiglitz (1977) for an example of the monopolistic structure included in a comparable class of models.

experiences a significantly higher price level than the US, but characterizes at the same time by a lower productivity than the US.[20] Since the productivity in the manufactoring (tradable sector) is cetrainly not inferior to that in the US (most often the converse is reported), the difference in the price level comes from the underdevelopement in the non-tradable sector. Rapidly growing countries like Finland and Ireland or some Asian countries similarly display high price levels, respectivelly to the industrial leader, and high nominal GDP. Such a convergence scenario also seems plausible in the case of Slovenia, since the convergence in the non-tradable sector productivity is expected to last for longer time than the tradable sector productivity. The relative price level or the RER is the higher when the tradable sector productivity catches up with that of the industrial leader. After that, the convergence country price level decreases relatively to the price level in the industrial leader implying for the rest of the convergence process a negative H-B-S effect.

Fourth, the H-B-S effect has interesting implications for the conduct of monetary policy. The model implies the monetary neutrality, i.e. any amount of money or any nominal exchange rate do not alter the real economic equilibrium. The real equilibrium, described by the production and the relative prices, is fully defined by the preferences and technology. Unless these can be altered by the monetary policy, there is no possibility to deviate from equilibrium production and the relative price in the long-run. Similarly, the trend in the relative price is a consequence of the underlying real equilibrium convergence process. We discuss two implications of the H-B-S effect that arise from the monetary neutrality and the real equilibrium dynamics generated by the convergence process.[21]

The H-B-S effect may implicate a long-run real equilibrium that is in conflict with the Maastricht criteria on exchange rate and inflation.[22] We showed, along with other work, that a corollary of the real convergence process is a higher equilibrium inflation (expressed in the same currency) in countries where the productivity in the tradable sector relative to the non-tradable sector increases faster. There is no long-run possibility for the monetary authorities to act against such an equilibrium inflation, except by nominally appreciating the currency. The Maastricht criteria must be fulfilled during the country's participation to the ERM2 program in order to adopt the euro.[23] The accession countries are obviously expected to have a high H-B-S effect, given their current level of development, which may prevent them to fulfill the Maastricht criteria during the required two years monitoring period in the ERM2 program. In the case of Slovenia, the H-B-S effect is evaluated to 1 to 1.5 percentage points, which in normal circumstances should not prevent a successful participation to the ERM2. Nevertheless, if the equilibrium growth speeds up upon the EU entry (due for example to a faster technology adoption, increased tradable competition, etc), the H-B-S effect may increase considerably. Also, the H-B-S effect is not a good reason to postpone the ERM2 entry since it is expected to last for decades, given the expected length of the convergence process. All the more, we have shown that the H-B-S effect may increase through time even if the growth persists at current rates, therefore only increasing the Maastricht criteria inconsistency problem. Of course, on the short-to-medium-run a restrictive macroeconomic

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[20] Eurostat (newcronos) reports for 2000 the price level in Japan to exceed the US by roughly 46%, while the average productivity of the employed in Japan is 76% of the US. As show the simulations of the model economy, these figures are not only qualitatively but also quantitatively in line with the predictions of the theory.

[21] The existence of the nominal exchange rate based equilibrium enables to stabilize the prices, in the long-run, by some type of nominal exchange rate anchorage. However, this clearly does not imply that exchange rate price stabilization is an optimal price stabilization policy.

[22] In particular, the nominal exchange rate must remain stable (i.e. should not display an increasing or decreasing trend) and the inflation rate must not exceed the average of the lowest three inflation rates in the euroarea by more than 1.5 percentage points.

[23] See, for example, the European Central Bank Agreement of the 1 September 1998, Official Journal of European Communities.

policy may decrease the inflation rate to the required levels, but that may be accompanied with high real cost. Alternatively, the country may wait for an economic downturn naturally decreasing the inflation rate. Overall, the optimal strategy to adopt during the ERM2 participation, in case of a high H-B-S effect, largely remains an open question.

The H-B-S effect may also imply an increased probability of the deflation occurrence in economic arrangements with fixed or stable nominal exchange rates. Two cases are exposed here. The first case is the convergence period after the tradable sector productivity has reached that of the industrial leader. It is shown here that this part of the convergence process is consistent with a negative H-B-S effect *vis-a-vis* the industrial leader. If the country maintains stable (or appreciating) exchange rate against a low inflation industrial leader entity (US or Europe) the occurrence of a deflation is much more probable. This may well be the case of the Japanese economy. As we have argued, the low long-run inflation, a high (the highest?) productivity in the manufacturing and a high price level are the characteristics that allow to identify a situation with a negative H-B-S effect. The negative H-B-S effect implies in the long-run a lower inflation than in the industrial leader, and may therefore substantially increase the occurrence of a deflation, given the cyclical movements in the inflation. The second case is the participation of a developed country together with the converging countries to a low inflation common currency area. The obvious example is that of Germany and the euro area. The level of development in the euro area is very diverse and is increasingly so with the accession of the Central and Eastern European countries. That leads to an important part of the euro area experiencing a positive H-B-S effect *vis-a-vis* Germany. If the monetary authority in the euro area keeps as the objective a very low inflation target, this implies an even lower equilibrium inflation for Germany and the other more developed countries. That in turn increases the probability of the deflation occurrence. But why should one worry about the deflation occurrence probability? In the presented model economy, characterized by fully flexible prices and the monetary neutrality, the deflation doesn't matter. However, if deflation *per se* goes along with real costs (for example the prices and wages are slow to adjust downwards, increased debt burdens of debt denominated in nominal terms...), these cases represent issues the monetary policy designers should be concerned of.

We end the discussion with a technical remark involving the potential measurement problem in productivity data. The H-B-S effect may be underestimated, and potentially by a fair amount, if the sectoral productivity used to compute the H-B-S effect is measured in value added per head. This study assumes that the above model is the true representation of the economy and derives the sectoral productivity so that the real growth and price dynamics are consistent with the available evidence. Conversely, researchers often take the sectoral productivity and compute the implied H-B-S effect. But there may be a problem in assessing the sectoral productivity growth. The productivity that must be taken into account in the model must be expressed in quantities and not in values, since the latter contains the relative price change. Value added per head is therefore not a correct productivity indicator, if not appropriately deflated on a sectoral basis (i.e. for instance, if the same deflator is used for both sectors to obtain real value added per head). In such a case, since the relative price change is equally embodied in both productivity measures, the productivity growth of the tradable sector is underestimated and the productivity growth of the non-tradable sector overestimated, when the relative price increases. That in turn biases downward the estimated H-B-S effect, *ceteris paribus*. Remember that a somewhat surprising result from the calibration procedure is the high difference in the sectoral technology growth. In both countries, the convergence country and the industrial leader country, the productivity grows eight times faster in the tradable than in the non-tradable sector. More work has to be done to see whether such a differential is of the right order of magnitude. Note however, that while this is true in quantities, this no more holds for values, the sectoral productivity in value added terms being much closer (see figure 2). Therefore, care must be taken in how to represent the sectoral productivity in the model.

5. CONCLUDING REMARKS

In conclusion we summarize the predictions of the theory and recall its implications for the convergence path of the Slovenian output and prices. We end by providing some guidance for further research.

We have shown that the theory implies the price convergence patterns to depend upon which sector, the tradable or the non-tradable, catches-up first with the industrial leader's productivity level. If the tradable sector productivity converges prior to the non-tradable sector productivity, the convergence country price level over-shoots the industrial leader's price level. The price level over-shooting implies a negative equilibrium H-B-S effect in the last stage of the convergence process. As a consequence, high price levels do not necessarily correspond to the high level of country's development. If, conversely, the non-tradable sector ends up converging first, a monotonous convergence in price level is predicted.

A growth process generated by a faster tradable than non-tradable sector technological progress is characterized as follows. Sectoral equality of production factor prices and imperfect substitutability between both types of goods generate a continuous increase in the relative price of the non-tradable goods versus the tradable goods price. The consumption share of the non-tradable goods decreases but their expenditure share in turn increases. Labor is reallocated to the non-tradable sector to partly offset the increasing productivity gap between the sectors. A consequence of such a growth process is an over time increasing H-B-S effect, as the high-inflation non-tradable share gains weight in consumer's expenditure, and therefore in CPI. Also, because more productive resources are being allocated to the sector characterized by a lower productivity growth, the overall real output growth may be (slightly) decreasing over very long horizons.

Quantitatively, the simulations of the model economy indicate the predominance of the tradable sector productivity as the generator of the real growth process. Nevertheless, the differences in the non-tradable sector productivity account in the long-run for potentially high price level differentials, in turn generating the dispersion in output per capita in purchasing power parity standards across developed countries. This result is partly due to the fact that there may be little difference in the non-tradable sector productivity across countries but a very large one in the tradable sector productivity, when productivity is measured in quantities and not in value added.

Two monetary policy issues are emphasized. In first lieu, The H-B-S effect may implicate a long-run real equilibrium that is inconsistent with the Maastricht criteria on exchange rate and inflation. A corollary of the real convergence process is a real appreciation in countries where the productivity in the tradable sector relative to the non-tradable sector increases faster. The accession countries, expected to experience high H-B-S effect given their current level of development, may be therefore in difficulty to fulfill the Maastricht criteria during the required two years monitoring period in the ERM2 program. While it is not clear, how the central bank and the fiscal authorities should manage their short-to-medium-run policies, we think that the H-B-S effect is not a good reason to postpone the ERM2 entry. It is indeed expected to last for decades, given the expected length of the convergence process, and may be even intensifying over time, only aggravating the Maastricht criteria inconsistency problem. In second lieu, we show that the H-B-S effect may also imply an increased probability of the deflation occurrence in some economic arrangements with fixed or stable nominal exchange rates. This gives rise to a relevant policy issue if the deflation *per se* goes along with real costs. The first case we present is the convergence period after the tradable sector productivity has reached that of the industrial leader and the country experiences a negative H-B-S effect *vis-a-vis* the latter. The second case is the participation of a developed country together with the converging countries, with positive equilibrium H-B-S effect, to a low average inflation common currency area. The Japanese economy appears to be a good example of the first case, while the German economy, or other developed countries in the euro area, may find themselves in the second case situation.

Given current trends in the sectoral productivity growth and price dynamics, the Slovenian economy tradable sector is expected to reach the industrial leader's productivity in roughly twenty-five years, while the non-tradable sector may well take significantly more time. The implied H-B-S effect lays between 1 and 1.5 percentage points and may increase by another half of a percentage point until the end of the 2020-ies, when it is expected to be maximal. After that moment, when the tradable sector is expected to catch up in productivity, the H-B-S effect should be slightly negative in order to decrease the over-shoot price level, estimated to roughly ten percent at its maximum. A one percentage point increase in the tradable sector technology level, *ceteris paribus*, rises the real GDP growth by 0.55 percentage point and both the inflation and the H-B-S effect by 0.43 percentage points. A significantly faster growth rate due the tradable sector productivity, say 6.5 percents on a yearly basis, may halve the time needed by the tradable sector to converge, but the corresponding H-B-S effect increases to roughly 3 percentage points.

A useful next step would be to bring the model economy closer to the data in order to capture more accurately the long-run movements in the economy. Instead of assuming the technological progress to be (log-)linear, we should take into account for the possibility that it can be characterized by long-run movements and display smoother convergence towards the industrial leader. Better assessment should be made of the differences in sectoral productivity. Similarly, the labor force and the relative wage movements should be more appropriately taken into account to provide further validation (or falsification) to the model parameterization.

Eventually, a quantitatively more reliable model could represent a good benchmark for the money-neutral long-run trend in output and, given the implied output gap, provide a useful guidance for the macroeconomic policy. As we have shown, even a model as simple as the one presented here is a useful tool for the analysis of the most relevant questions addressing the macroeconomic long-run. This is especially true from the macroeconomic policy viewpoint. The output gap, defined as the difference between the actual output and the output that would prevail if the prices were flexible, is often regarded as the most important source of inflation (variation). The money-neutral model of the type examined in this paper is, I believe, a good candidate to evaluate the money-neutral (i.e. the flexible price) long-run trend, since it has embodied the most relevant features characterizing the long-run economic growth, while still at a sensible level of abstraction.

In the case of Slovenia, identifying the output gap dynamics may be particularly important in perspective of the entry to the European Union. In connection with this event, the output may indeed increase significantly, but for various reasons. On the one hand, this increase may be due to an aggregate demand shock, originating from for example the low nominal interest rates necessary to maintain the exchange rate mechanism, the inability of the fiscal policy to act restrictively, some consumer behavior connected with the European Union entry, etc. Such a demand shock would require a counteractive economic policy. On the other hand, the equilibrium output may increase. That may well be due to faster technology adoption, enhanced competition, increased investment in the stock of capital or some other reason. In this case the economic policy response should be accommodative and tolerate the somewhat higher inflation generated by the H-B-S effect (in case the ERM2 criteria are not binding or after the adoption of the euro). As the two impacts require an opposite optimal policy response, identifying whether the output variation is due to a change in the trend or in the output gap, or to what combination of both, is crucial for the macroeconomic policy design.

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