Nominal and real convergence in Estonia: The Balassa-Samuelson (dis)connection

Does disaggregation provide better understanding?

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ABSTRACT

The objective of the paper is to analyse the nominal and real convergence process in Estonia drawing on the Balassa-Samuelson (B-S) framework. A 15-sectoral breakdown for GDP and a 5-digit level CPI data disaggregation with over 260 items is used for the period 1993:Q1 to 2002:Q1 to show that the productivity differential is related to the GDP-deflator relative price of non-tradable goods in the long-run. Furthermore, the role of regulated prices in the CPI basket is also investigated: we show that excluding regulated prices makes it possible to detect a robust relationship between productivity and the relative price of market services in CPI. The B-S effect could have possibly contributed to CPI by a yearly average of 2% to 3% over the sample period, with 1% to 4% at the beginning of the period and 0,5% to 1% in 2000 and 2001. The potential long-run impact of the B-S effect in Estonia is estimated to amount to 1%-2% . The analysis of the influence of the B-S effect on the inflation differential and the real appreciation of the exchange rate against Finland, Sweden, Germany and the UK shows that whereas the inflation differential attributable to the B-S effect seems to be higher in the early 1990s, it explains better the real appreciation, which has occurred in recent years.

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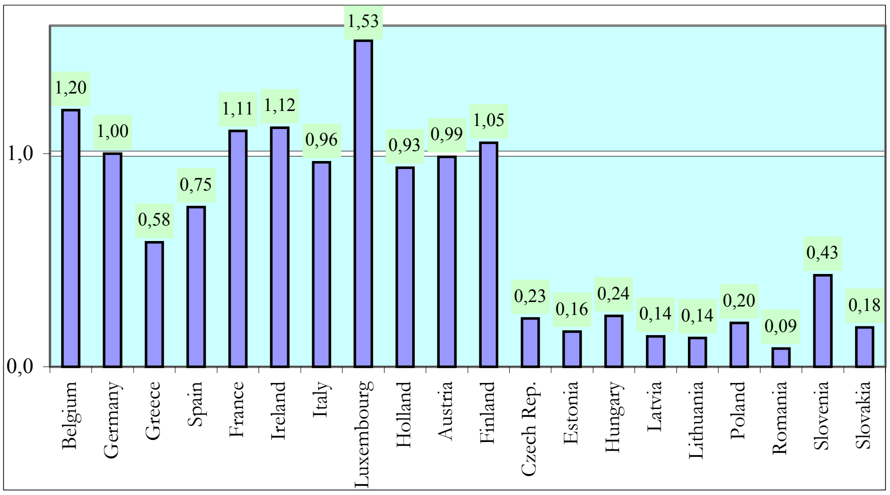
Table of Content

I. Introduction

Inflation and real exchange rate have attracted much of the interest of applied economists focusing on Central and Eastern European transition economies over the last 15 years. A popular explanation for higher inflation resulting in a steady appreciation of the real exchange rate has long been the B-S effect. The huge gap persisting in the level of productivity between the transition economies and the average of EU member States, the argument goes, allows for massive growth in productivity in the transition economies, translated into higher inflation and a steady appreciation of the real exchange rate. However, in spite of substantially higher growth in productivity, most of the transition economies still considerably lag behind the EU average after roughly a decade of transition from plan to market, as revealed in Figure 1. Therefore, according to popular belief, higher inflation and real appreciation linked to the B-S effect might prevail until the countries catch up with productivity levels in Western Europe.

Figure 1. Total average labour productivity of selected euro zone countries and the transition economies in 2000[2]



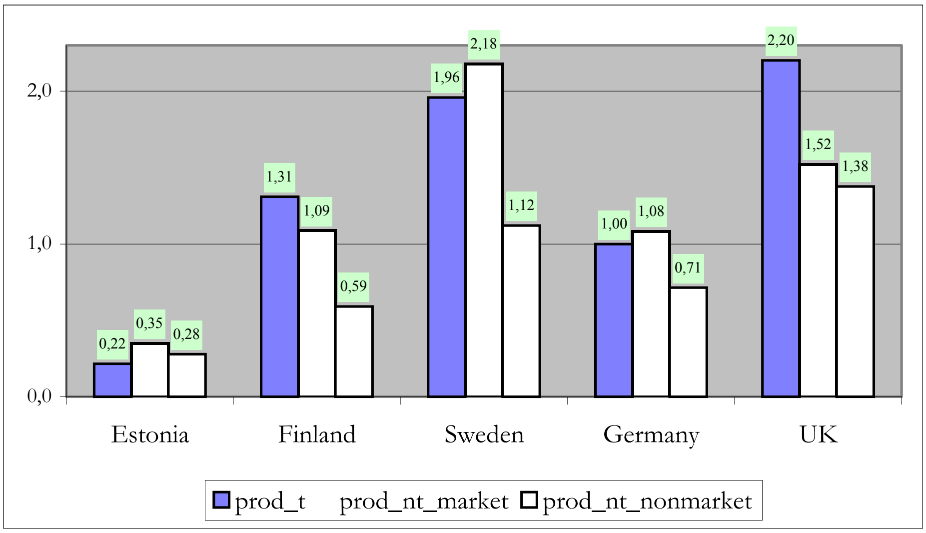
Source: Author's own calculations based on Eurostat data.

This paper focuses on investigating the real and nominal convergence process in Estonia, the most developed Baltic country. It is clear that Estonia is actually no exception to the rule since its overall productivity level is far behind that of the selected euro zone countries. A more detailed comparison with Estonia's major Western European trading partners, notably Finland and Sweden shed further light on the tremendous difference in sectoral productivity differentials. The gap between the open sectors' productivity levels, displayed in Figure 2. below seems to be considerably higher than the difference in overall productivity levels.

As a consequence, this huge room for catch-up in the productivity level of the open sector, being considered as the main driving force behind productivity convergence invites the question of whether the B-S effect has played a role in Estonia's high inflation and immense real appreciation in the past, and opens the door to speculations as to what extent future productivity growth might influence price convergence and real appreciation towards EU levels.

[2] Nominal GDP is first converted to euro at current exchange rates and then is divided by the number of employees in the whole economy. The figures are expressed in percentage of the Germany productivity level.

Figure 2. Sectoral labour productivity in Estonia compared with its main EU trading partners in 2000



Source: Author's own calculations
Note: The same methodology is applied as in Figure 1. Figures are expressed in percentage of productivity of the open sector in Germany.

The remainder of the paper is the following. Section 2 presents the theoretical model. Section 3 gives a methodological survey of the existing literature on the B-S effect related to transition countries and especially to Estonia. Sections 4 and 5 deal with data construction and provide a preliminary overview of the data used in the paper. The basic hypotheses to the B-S model presented in Section 2 are then empirically examined in Section 6, followed by Sections 7 and 8 presenting respectively the econometric approach employed and the results of the econometric estimations. Next, efforts are made in Section 9 in assessing the importance of the B-S effect on inflation and the real exchange rate. Section 10 finally provides some concluding remarks.

II. The Balassa-Samuelson framework

The Balassa-Samuelson effect[3] is originally meant to explain the level of and the changes in the real exchange rate of developing countries. In his seminal paper, Balassa (1964) argues that the purchasing power parity (PPP) as formalised by Cassel is a poor yardstick for the level of the real and nominal exchange rates since it usually leads to the conclusion that the developing country's currency vis-à-vis the developed country's is undervalued. In addition, with the economic catching-up, the undervalued currency is likely to experience a trend appreciation in the longer run. This definitely discredits PPP. In recent times, however, the B-S model has been extensively used for assessing structural inflation patterns.

To begin with, it must be noted that there are some crucial assumptions to be fulfilled for the Balassa-Samuelson effect (B-S) to be at work. First, the home economy is considered to be divided into an open and a closed sector producing respectively tradable and non-tradable goods. The second assumption is that because of trade integration, the price of tradable goods is expected to be determined on the international goods markets. Trade integration implies the absence of administrative and quantitative trade barriers so that the absolute and relative PPP is verified for the traded goods. Consequently, wages in the open sector are linked to the level of productivity. Finally, wages are assumed to be approximately the same in the open and the closed sectors or at least equalise between them. One factor promoting wages to equalise across sectors is labour mobility within the home country. If wages are higher in one sector than in the other, workers are expected to exercise pressure on wages in both sectors by moving to the higher-wage sector. The other factor providing a possible mechanism for wage equalisation is the degree of unionisation of the economy. The higher the union density, the better the wage equalisation.

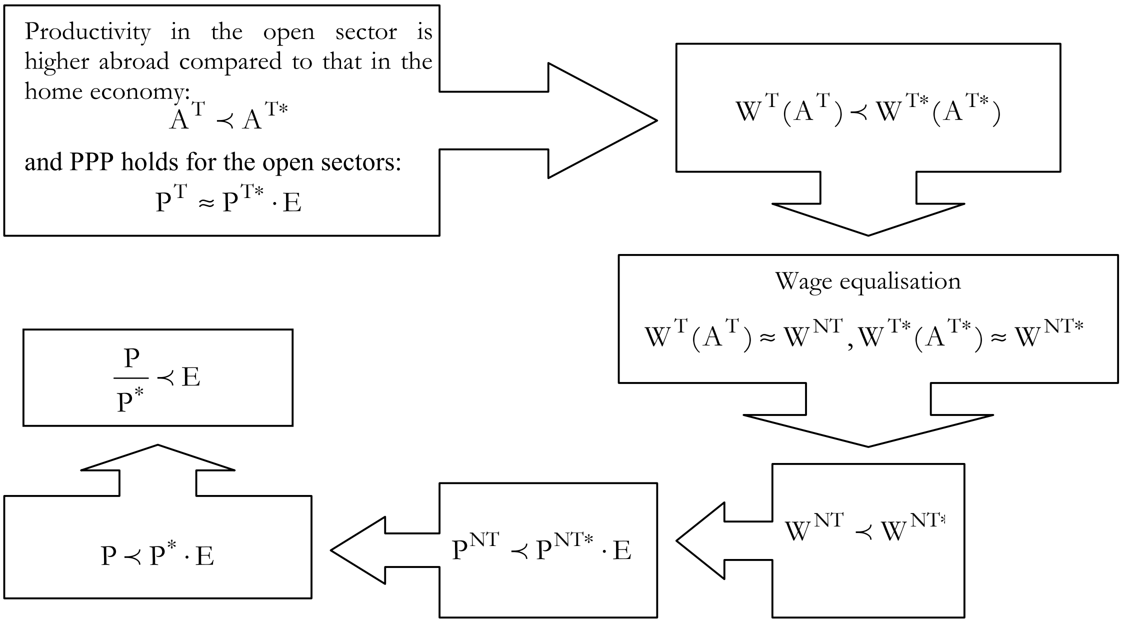
The level of productivity in the open sector is generally by far lower in the developing country compared with the developed one. As prices are exogenous and wages are a function of the level of productivity, the wage level which prevails in the developing country's open sector is also much lower than that in the developed country. Due to the wage equalisation process between the open and the closed sectors, wages in the closed sector are comparable to those in the open sector. As a result, the price level of non-traded goods turns out to be lower than that in the foreign economy, which in turn means that the general price level of a developing country is below that in a developed country. Let us now consider the definition of the real exchange rate:

$$Q = \frac{E \cdot P^*}{P} = \frac{E/P}{1/P^*} = \frac{E}{P/P^*} = E \cdot \frac{1}{E^{PPP}} = \frac{E}{E^{PPP}} \qquad (1)$$

where Q and E denote the real and the nominal exchange rates in foreign currency terms and with P and P* being respectively the domestic and foreign price levels. Recalling that the exchange rate suggested by PPP is $E^{PPP} = \frac{P}{P*}$ and that E is normally dominated by the price of domestic and foreign traded goods, it is easy to see that E^{PPP} is smaller than 1 and E. This in turn implies that Q is larger than unity and thus undervalued according to PPP.

[3] It is also common practice to call it the Ricardo-Balassa or the Harrod-Balassa-Samuelson effect.

Graph 1. The B-S effect in levels



We can now turn to the dynamic version of the B-S model and see how changes in productivity influence inflation and finally the real exchange rate. It is true to say that a successful economic catch-up process is, in the long run, driven mainly by the manufacturing industry in general and by the export sector in particular. It therefore comes as no surprise that the catching-up economy usually experiences higher productivity gains in the open than in the closed sector. Hence, higher productivity in the open sector means higher wages spilling over to the closed sector through the wage equalisation process and thus provoking a rise in the price of non-tradable goods. With PPP being respected for tradable goods, the overall CPI will increase via the increase in non-tradable prices. The relationship between the change in the productivity differential and the change in relative prices can be formally derived using constant returns to scale Cobb-Douglas production functions for the open and sheltered sectors[4]:

$$Y^T = A^T \cdot \left(L^T\right)^{\gamma} \cdot \left(K^T\right)^{1-\gamma} \tag{2}$$

$$Y^{NT} = A^{NT} \cdot \left(L^{NT}\right)^{\delta} \cdot \left(K^{NT}\right)^{1-\delta} \tag{3}$$

where A, L and K stand for total factor productivity (TFP), labour and capital in the open (T)[5] and the closed (NT) sectors. The following profit functions hold for the two sectors:

$$G^T = P^T \cdot Y^T - R \cdot K^T - W \cdot L^T \tag{4}$$

$$G^{NT} = P^{NT} \cdot Y^{NT} - R \cdot K^{NT} - W \cdot L^{NT} \tag{5}$$

G, R and W being respectively the profit, the interest rate and the wage. The respective substitution of equations (2) and (3) into equations (4) and (5) yields:

$$G^T = P^T \cdot \left(A^T \cdot \left(L^T\right)^{\gamma} \cdot \left(K^T\right)^{1-\gamma} \right) - R \cdot K^T - W \cdot L^T \tag{6}$$

[4] In this neo-classical framework, technological progress is exogenous to the economy. This seems to be a reasonable hypothesis for transition economies and especially for Estonia, since the major part of advances in technology are brought about by foreign direct investments.

[5] Capital is assumed to be mobile across sectors and the domestic and foreign economies, whereas labour is only to be mobile within the domestic economy and not across economies.

$$G^{NT} = P^{NT} \cdot \left(A^{NT} \cdot \left(L^{NT}\right)^{\delta} \cdot \left(K^{NT}\right)^{1-\delta} \right) - R \cdot K^{NT} - W \cdot L^{NT} \qquad (7)$$

Profit maximisation implies that the marginal product of capital and labour be equal to the interest rate and the wage:

$$\frac{\partial G^{T}}{\partial L^{T}} = P^{T} \cdot A^{T} \cdot \gamma \cdot \left(\frac{K^{T}}{L^{T}} \right)^{1-\gamma} = W \qquad (8)$$

$$\frac{\partial G^{NT}}{\partial L^{NT}} = P^{NT} \cdot A^{NT} \cdot \delta \cdot \left(\frac{K^{NT}}{L^{NT}} \right)^{1-\delta} = W \qquad (9)$$

$$\frac{\partial G^{T}}{\partial K^{T}} = P^{T} \cdot A^{T} \cdot (1-\gamma) \cdot \left(\frac{L^{T}}{K^{T}} \right)^{\gamma} = R \qquad (10)$$

$$\frac{\partial G^{NT}}{\partial K^{NT}} = P^{NT} \cdot A^{NT} \cdot (1-\delta) \cdot \left(\frac{L^{NT}}{K^{NT}} \right)^{\delta} = R \qquad (11)$$

Dividing by P both sides of the equation, we obtain:

$$A^{T} \cdot \gamma \cdot \left(\frac{K^{T}}{L^{T}} \right)^{1-\gamma} = \frac{W}{P^{T}} \qquad (12)$$

$$A^{NT} \cdot \delta \cdot \left(\frac{K^{NT}}{L^{NT}} \right)^{1-\delta} = \frac{W}{P^{NT}} \qquad (13)$$

$$A^{T} \cdot (1-\gamma) \cdot \left(\frac{L^{T}}{K^{T}} \right)^{\gamma} = \frac{R}{P^{T}} \qquad (14)$$

$$A^{NT} \cdot (1-\delta) \cdot \left(\frac{L^{NT}}{K^{NT}} \right)^{\delta} = \frac{R}{P^{NT}} \qquad (15)$$

Taking equations (12)-(15) in natural logarithms and normalising prices to P^{T} ($P^{T}=1$)[6] leads to:

$$w = \ln\gamma + a^{T} + (1-\gamma)\left(k^{T} - l^{T}\right) \qquad (16)$$

$$w = p^{NT} + \ln\delta + a^{NT} + (1-\delta)\left(k^{NT} - l^{NT}\right) \qquad (17)$$

$$r = \ln(1-\gamma) + a^{T} - \gamma \cdot \left(k^{T} - l^{T}\right) \qquad (18)$$

$$r = p^{NT} + \ln(1-\delta) + a^{NT} - \delta \cdot \left(k^{NT} - l^{NT}\right) \qquad (19)$$

Totally differentiating equations (16)-(19) leads to::

$$\frac{\Delta W}{W} = \frac{\Delta\gamma}{\gamma} + \frac{\Delta A^{T}}{A^{T}} + (1-\gamma)\frac{\Delta\left(\frac{K^{T}}{L^{T}}\right)}{\frac{K^{T}}{L^{T}}} \qquad (20)$$

[6] Lower-case letters stand for variables taken in natural logarithms.

$$\frac{\Delta W}{W}=\frac{\Delta P^{NT}}{P^{NT}}+\frac{\Delta\delta}{\delta}+\frac{\Delta A^{NT}}{A^{NT}}+(1-\delta)\frac{\Delta\left(\frac{K^{NT}}{L^{NT}}\right)}{\frac{K^{NT}}{L^{NT}}} \tag{21}$$

$$\frac{\Delta R}{R}=\frac{\Delta(1-\gamma)}{1-\gamma}+\frac{\Delta A^{T}}{A^{T}}-\gamma\cdot\frac{\Delta\left(\frac{K^{T}}{L^{T}}\right)}{\frac{K^{T}}{L^{T}}} \tag{22}$$

$$\frac{\Delta R}{R}=\frac{\Delta P^{NT}}{P^{NT}}+\frac{\Delta(1-\delta)}{1-\delta}+\frac{\Delta A^{NT}}{A^{NT}}-\delta\cdot\frac{\Delta\left(\frac{K^{NT}}{L^{NT}}\right)}{\frac{K^{NT}}{L^{NT}}} \tag{23}$$

Given that $\Delta R=0$ and $\Delta\gamma=\Delta\delta=\Delta(1-\gamma)=\Delta(1-\delta)=0$, thus $\frac{\Delta R}{R}=0$ and $\frac{\Delta(1-\gamma)}{1-\gamma}=\frac{\Delta\gamma}{\gamma}=\frac{\Delta(1-\delta)}{1-\delta}=\frac{\Delta\delta}{\delta}=0$ and with w, p, a and m[7] standing for $\frac{\Delta W}{W},\frac{\Delta P}{P},\frac{\Delta A}{A},\frac{\Delta\left(\frac{K}{L}\right)}{\frac{K}{L}}$, equations (20)-(23) can be simplified to:

$$w=a^{T}+(1-\gamma)\cdot m^{T} \tag{24}$$

$$w=p^{NT}+a^{NT}+(1-\delta)\cdot m^{NT} \tag{25}$$

$$a^{T}=\gamma\cdot m^{T} \tag{26}$$

$$a^{NT}=\delta\cdot m^{T}-p^{NT} \tag{27}$$

Substituting equation (26) into equation (24), as in equation (28), and inserting it into equation (26), leads to equation (29):

$$w=\gamma\cdot m^{T}+(1-\gamma)\cdot m^{T}=m^{T} \tag{28}$$

$$w=\frac{a^{T}}{\gamma} \tag{29}$$

We then substitute equation (27) into equation (25) :

$$w=p^{NT}+\delta\cdot m^{NT}-p^{NT}+(1-\delta)\cdot m^{NT}=m^{NT} \tag{30}$$

Finally, equation (30) is substituted into equation (25) and (29) is applied to (31) yielding equation (33):

$$w=p^{NT}+a^{NT}+(1-\delta)w \tag{31}$$

$$\frac{a^{T}}{\gamma}=p^{NT}+a^{NT}+(1-\delta)\frac{a^{T}}{\gamma} \tag{32}$$

$$p^{NT}=\frac{\delta}{\gamma}\cdot a^{T}-a^{NT} \tag{33}$$

[7] Lower-case letters denote hereafter growth rates expressed in natural logarithm.

Equation (33) is the so-called internal transmission mechanism of the B-S effect between the productivity differential and the relative price of non-tradable goods. Put differently, equation (33) shows the impact of productivity gains on non-tradable inflation. In practice, the equation tested is as follows:

$$\left(p^{NT}-p^{T}\right)=f\left(a^{T}-a^{NT}\right) \tag{33a}$$

Let us now consider the home and the foreign countries at the same time. If the crucial assumptions of the model hold and if (33a) can be also verified for the foreign country, the increase in the productivity differential and the change in relative prices using equation (34) should be related[8]:

$$\left(p^{NT}-p^{T}\right)-\left(p^{NT*}-p^{T*}\right)=\left(a^{T}-a^{NT}\right)-\left(a^{T*}-a^{NT*}\right) \tag{34}$$

Expressing inflation in terms of tradable and non-tradable prices as in (35) and then substituting it into equations (33a) and (34), the inflation rate and the inflation differential due to the B-S effect can be easily derived as in (36) and (37):

$$p=\alpha\cdot p^{T}+(1-\alpha)\cdot p^{NT} \tag{35}$$

$$p=p^{T}+(1-\alpha)\cdot\left(a^{T}-a^{NT}\right) \tag{36}$$

$$p-p*=\left(p^{T}-p^{T*}\right)+\left((1-\alpha)\cdot\left(a^{T}-a^{NT}\right)-\left(1-\alpha^{*}\right)\cdot\left(a^{T*}-a^{NT*}\right)\right) \tag{37}$$

Let us now consider the relationship linking the non-tradable inflation over tradable inflation (relative prices) to changes in the CPI-based real exchange rate. The substitution of (35) applied to the home and foreign economies into (1') yields (39):

$$q=e+p^{*}-p \tag{1'}$$

$$q=e+\alpha^{*}\cdot p^{T*}+\left(1-\alpha^{*}\right)\cdot p^{NT*}-\left(\alpha\cdot p^{T}+(1-\alpha)\cdot p^{NT}\right) \tag{38}$$

$$q=e+\alpha^{*}\cdot p^{T*}+\left(1-\alpha^{*}\right)\cdot p^{NT*}-\alpha\cdot p^{T}-(1-\alpha)\cdot p^{NT} \tag{38a}$$

with $\alpha^{*}\cdot p^{T*}=p^{T*}-\left(1-\alpha^{*}\right)\cdot p^{T*}$ and $-\alpha\cdot p^{T}=-p^{T}-(\alpha-1)\cdot p^{T}$

$$q=e+p^{T*}-p^{T}-\left(1-\alpha^{*}\right)\cdot p^{T*}+\left(1-\alpha^{*}\right)\cdot p^{NT*}-(1-\alpha)\cdot p^{T}-(1-\alpha)\cdot p^{NT} \tag{38b},$$

$$-\left(1-\alpha^{*}\right)\cdot p^{T*}+\left(1-\alpha^{*}\right)\cdot p^{NT*}=-\left(1-\alpha^{*}\right)\cdot\left(p^{T*}-p^{NT*}\right) \tag{38c}$$

$$-(\alpha-1)\cdot p^{T}-(1-\alpha)\cdot p^{NT}=(1-\alpha)\cdot p^{T}-(1-\alpha)\cdot p^{NT}=(1-\alpha)\cdot\left(p^{T}-p^{NT}\right) \tag{38d}$$

$$q=e+p^{T*}-p^{T}+(1-\alpha)\cdot\left(p^{NT}-p^{NT}\right)-\left(1-\alpha^{*}\right)\cdot\left(p^{NT*}-p^{NT*}\right) \tag{39}$$

To sum up, equations (34) and (39) imply that if the productivity differential of the domestic economy systematically outpaces that of the foreign country, higher domestic non-tradable inflation translated into higher overall inflation over the foreign one will provoke, all things being equal, an appreciation of the real exchange rate.

III. A methodological overview of the literature on the B-S effect

III. A. The B-S effect in CEECs

[8] This means that the neo-classical framework should apply for the foreign country as well, e.g. EU countries in this paper. However, there is more scope for endogenous technological progress in these countries implying the use of some kind of endogenous growth model.

The body of the literature on the B-S effect in Central and Eastern European transition economies has been steadily growing in recent years. The thriving number of papers tries to answer the question as to whether the B-S effect plays an important role in the transition economies and if so, to what extent should policy-makers care about it. In the mid-1990s, the general perception in the economic profession was that the B-S effect was at the root of higher inflation and the trend appreciation of the CPI-based real exchange rate. However, recent research suggests that the B-S effect might not be as strong as believed earlier.

It is clear that differences in the theoretical and empirical approaches employed in the studies makes it difficult to directly compare results. In this regard, the question that should be answered is what is tested for in the mushrooming papers? The first and the most simple way to test the B-S effect is to focus on the internal transmission mechanism, that is on the relationship linking the productivity differential to the relative price of non-tradable goods in the country under study. In this context, the B-S serves for investigating long-term inflation pattern.[9] Furthermore, considering the relative price of non-tradable goods as the internal real exchange rate is very tempting and is often used to draw general conclusions on developments in the external real exchange rate[10]. It is, however, clear that this may lead to false conclusions since the internal real exchange rate only influences the internal allocation of resources and can describe the external position of the home economy to a much lesser extent [11]. Indeed, the external real exchange rate defined as the nominal exchange rate corrected with the inflation differential vis-à-vis the foreign countries matters for external competitiveness. Hence, for the B-S effect to be a real exchange rate determination model suited for policy purposes, the home country's trading partners should also be taken into consideration. In so doing, two ways are open. First, one can directly examine the relationship between the difference of the productivity differentials and the CPI-based real exchange rate[12]. Hence, the external transmission mechanism, i.e. the pass-through from productivity differences through the difference in relative prices towards the real exchange rate is assumed to be *a priori* verified. To avoid to run the risk of a spurious relationship, though, it is desirable to test separately whether the relative price differential is connected to productivity developments and subsequently to have a look at the link between the real exchange rate and the relative price differential[13]. This simple B-S framework can be extended by including other fundamental variables when the so-called fundamental equilibrium real exchange rate is estimated[14].

The above described relationships can be investigated using either descriptive statistics, sometimes also called the accounting framework or more sophisticated econometrics. One way to handle the lack of long time series, a usual problem in transition economics, is to use panel estimations[15]. The basic assumption behind panel data analysis is the homogeneity of the elements in the panel. Put simply, the economies put in the same basket should behave similarly, at least in the longer run so that the estimated coefficient reflect a common long-term behaviour of all economies. Yet, it is often difficult to accept the homogeneity assumption, which makes

[9] See e.g. Backé et al. (2002), Kovács (2001), Simon – Kovács (1998), Rother (2000), Sinn – Reutter (2001), Égert (2002a,b,c), Égert et al (2002), Lommatzsch – Tober (2002), Mihaljek (2002), Nenovsky – Dimitrova (2002)

[10] Cf. Coricelli – Jazbec (2001) and Halpern – Wyplosz (2001)

[11] The internal real exchange rate is suited for economies mainly dominated by the production of raw material and is less useful in analysing industrialised countries.

[12] Golinelli – Orsi (2001)

[13] For recent papers, see Égert (2001, 2002a,b,c) and Égert et al. (2002)

[14] For a methodological overview on the fundamental equilibrium real exchange rates, see Égert (2002) and for empirical applications to transition economies, see Avallone – Lahrèche-Révil (1999), Égert - Lahrèche-Révil (2002), Filipozzi (2002), Frait – Komarek (1999), Begg et al. (1999), De Broeck – Slot (2001), Dobrinsky (2001), Halpern – Wyplosz (1997), Fischer (2002) and Randveer –Rell (2002)

[15] Begg et al (1999), Coricelli-Jazbec (2001), De Broeck-Slot (2001), Dobrinsky (2002), Égert et al. (2002), Halpern-Wyplosz (1997), Halpern-Wyplosz (2001) and Maurin (2002)

these estimations, from a policy point of view, hard to convert and to interpret for individual countries. Instead, panel estimation are more appropriate to explain the behaviour of the countries viewed as a single region.

A less elegant but still very useful method, and also appropriate for policy purposes, for assessing the B-S effect is the descriptive statistical analysis[16], which prevents difficulties with heterogeneity across countries and therefore allows to draw policy implications. In addition to descriptive statistics, conventional time series techniques can also be employed. On the one hand, it is true that they require quarterly[17] or monthly data[18], and that the results may lack power and robustness. However, the other side of the coin is that information obtained this way might be more valuable for individual countries compared to what one can get from panel studies.[19]

Table 1. Studies using the simple B-S framework

	Hypothesis tested	Link	Countries	Period	Variables
DESCRIPTIVE STAT					
Backé et al. (2002)	None	1	CZ, H, P, SVN	1992-2000, Y	LB, DEFL
Kovács (2001)	PPP for tradables	1, 2	H	1991-1999, Y	LB
Rother (2000)	None	1	SVN, CZ, E, SK	1993/1994-1997/1998, Y and Q	LB, DEFL
Simon – Kovács (1998)	PPP for tradables	1, 2	H	1991-1996, Y	LB, DEFL
Sinn – Reutter (2001)	None	1	E, H, P, SVN, CZ	1994/1996-1998, Y	LB
TIME SERIES					
Égert (2002a,b)	PPP for tradables	1, 2, 3	CEEC5	1991/1993–2000, M	LB, rel(CPI), RER(DEM, USD, EFF)
Égert (2002c)	Wage equalisation	1, 2, 3, 4a	CEEC5	1991 – 2001, Q	LB, rel(CPI, PPI), RER(DEM, USD, EFF)
Golinelli – Orsi (2001)	None	4a	H, P, CZ	1991:1/1993:1-2000:7, M	LB, rel (CPI/IPP), RER(EUR)
Jakab – Kovács (1999)	None	1	H	1991-1998, Q	LB, CPPI-based prices in T and NT, NEER
Lommatzsch-Tober (2002)	None		EE, CZ, H, P, SVN	1994/1995-2001, Q	LB, DEFL
Mihajlek (2002)	Wage equalisation	1	CZ, CR, H, P, SVN, SK	1993/1996-2001/2002, Q	LB, DEFL
Nenovsky – Dimitrova (2002)	Wage equalisation	1	BG	1997-2001, M	LB, rel (CPI)
PANEL					
Halpern – Wyplosz (2001)	Real wages + wage equalisation	1, 4b	CEEC5, B3, RU, RO, BG, KY	1991/1995-1998, Y	LB, GDP per capita, rel(CPI)
Égert et al. (2002)	Real wages + wage equalisation + PPP	1, 2, 3	CEEC5, B3, CR	1995-2000, Q	LB, DEFL, rel(CPI), RER(DEM)

Notes: M, Q and Y indicate the use of monthly, quarterly and yearly data. CEEC5= Czech Republic, Hungary, Poland, Slovakia and Slovenia, B3= 3 Baltic States, BG=Bulgaria, CZ=Czech Republic, CR=Croatia, EE= Estonia, H=Hungary, KY= Kirghizstan, P=Poland, RO=Romania, SK=Slovakia, SVN=Slovenia

Relationships:
1 = prod(T)-prod(NT) => relative prices
2 = (prod(T)-prod(NT)) - prod(T)*-prod(NT)* => relative prices home –relative prices abroad
3 = relative prices home –relative prices abroad => real exchange rate
4a = (prod(T)-prod(NT)) - prod(T)*-prod(NT)* => real exchange rate
4b = (prod(T)-prod(NT)) => real exchange rate

Variables used: LB=average labour productivity, DEFL=relative prices based on GDP deflators, rel(CPI)=relative prices based on CPI data, RER(DEM, USD, EFF)= real exchange rate against Germany, the US or the effective trading basket

[16] See e.g. Backé et al (2002), Kovács (2001), Kovács (2002), Rother (2000), Simon – Kovács (1998), Sinn – Reutter (1998).

[17] Cf. Égert (2002c), Jakab – Kovács (1999), Lommatzsch – Tober (2002), Mihaljek (2002).

[18] The use of high frequency monthly data can provide more powerful results econometrically. However, it is widely acknowledged that they do not provide with more economic information on long-term developments. Cf. Égert (2001), Égert (2002a, b), Golinelli – Orsi (2001), Nenovsky – Dimitrova (2002)

[19] There is always a compromise to make between econometrically robust results and economic interpretability.

Table 2. Studies using the extended B-S framework

	Countries	Period	Variables
TIME SERIES			
Égert-Lahrèche (2002)	CEEC5	1992/1993-2001, Q	REER, LB, Private cons., rel(CPI), CA, TOT, OPEN
Avallone- Lahrèche (1999)	H	1985-1996, Q	GDP per capita, TOT, Private and public cons over GDP
Filipozzi (2000)	E	1993-1999, Q	Prod, CA/GDP, INV, NEER
Frait-Komarek (1999)	CZ	1992-1999, Q	GDP, TOT, real interest rate, savings
Randveer –Rell (2002)	E	1994-2001, Q	LB, TOT
Taylor-Sarno (2001)	CEEC5, B3, BG, RO	1993/1994-1997/1998, M	Real interest rate, trend
PANEL			
Arratibel et al (2002)	CEEC5, B3, BG, RO	1997-2000	LB, prices for traded and non-traded goods, inflation equation
Begg et al. (1999)	85 countries including CEEC5, B3, BG, RU, RO	1975, 1980, 1985, 1990, 1995	GDP/capita, OPEN, Public cons., NFA, NFA in banking, private credits
Coricelli-Jazbec (2001)	CEEC5, B3, BG, RO, 7 FSU	1990/1995-1998, Y	Prod, private cons. on non-tradables, public cons., number of employees in industry and in services, structural Reforms
De Broeck – Slot (2001)	CEEC5, B3, BG, RO, FSU, M, OECD	1991-1998, Y	Prod, OPEN, public deficit, TOT, brent, monetary aggregates
Dobrinsky (2001)	CEEC5, B3, BG, RO	1993-1999, Y	TFP, GDP/capita, public cons., M1
Fischer (2002)	CEEC5, B3, BG, RO	1993/1994-1999, Y/Q	LB, private and public consumption/GDP, real interest rate, real raw material prices
Halpern-Wyplosz (1997)		1975, 1980, 1985, 1990	

Notes: RU=Russia, TOT=terms of trade, OPEN=openness ratio, CA=current account, NFA=net foreign assets. For other abbreviations, see notes in Table 1.

III. B. The B-S effect in Estonia: The lack of empirical studies

Estonia is often included in a larger set of transition economies for which then panel econometric estimations are employed. This is the case of Begg et al. (1999), De Broeck and Slot (2001) and Dobrinsky (2001) where the impact of the productivity differential on the real exchange rate is investigated in the extended version of the B-S model by directly regressing the real exchange rate on the productivity differential. Coricelli and Jazbec (2001), also employing panel data, analyse the factors that influence the relative price of non-tradables in the home country. By means of the panel estimates, they proceed to decompose the rise in relative prices, measured by the implicit sectoral GDP deflators and conclude that in the case of Estonia, less than half of the increase in the relative price of non-tradable goods can be attributed to the productivity differential, as demand side factors also turn out to play an important role. Halpern-Wyplosz (2001), prior to performing panel estimations, investigate whether one of the basic assumption to the B-S model, the wage equalisation process across sectors holds and conclude that relative wages are quite stable in Estonia. In a panel context, Égert et al. (2002) also have a closer look at two of the hypothesis: real wages seem to be in line with productivity developments in the open sector, and the wage equalisation, similar to the findings of Halpern-Wyplosz (2001), turns out to be roughly fulfilled. Furthermore, they argue that between 1995 and 2000, the contribution of the B-S effect to inflation amounts to about 1,2% on average and the corresponding inflation differential against Germany ranges from 0,3% to 0,5%. This is something in a big contrast with Sinn-Reutter (2001) who argue, based on descriptive statistics, that the inflation resulting from the B-S effect was on average 4,06% between 1994 and 1998. Rother (2000) examines the slightly different period from 1993 to 1997. The yearly decomposition of the B-S effect suggests that whereas the B-S effect contributed from 1 to 3% to domestic inflation between 1993 and 1995, it negatively affected inflation during 1996 and 1997.

The number of papers using time series econometrics in an attempt to examine the B-S effect in Estonia is very limited. One of them, Lommatzsch-Tober (2002) stick to the simple B-S framework and aim at assessing the relationship between the productivity differential and the relative price of non-tradable goods computed in terms of implicit sectoral deflators. According to the estimation carried out using the Engle-Granger cointegration technique for the period 1994:Q1 to 2001:Q3, there is a long-term cointegrating vector connecting the two variables with a significant coefficient of 1,02 for productivity. In contrast with Lommatzsch and Tober, the goal of Filipozzi (2000) and Randveer and Rell (2002) is not to investigate the long-term inflation but rather to compare the development of the effective real exchange rate with the estimated equilibrium real exchange rate. The estimations performed for the respective periods of 1993:Q2-1999:Q2 and of 1994:Q1-2000:Q3 yield, in different specifications including a different set of macro-variables, a coefficient of 0,2 to 0,4 for the difference between the domestic and the effective foreign productivity differentials and the effective real exchange rate.

IV. Data definitions

We proceeded to construct productivity, relative price and real exchange rate series for Estonia and for its most important trading partners for the period of 1993:Q1 to 2002:Q1. All series are transformed in natural logarithms and are seasonally adjusted if the X-12 ARIMA technique detects the presence of seasonality.

The productivity series

First, the productivity differential series are calculated for Estonia. Since sectoral TFP estimates are not available, average labour productivity is employed as a proxy by dividing gross real output by the number of employees. One of the most difficult and important questions in the empirical investigation is how to determine the open and the closed sector. As shown in Table 3., there is no beaten path for transition economies. The vast majority of papers use a A6 of ESA 95-like disaggregation level, which offers data for agriculture including forestry and fishing, industry including mining and energy, construction, services considered mainly as private such as trade, transportation and telecommunication and public services such as public administration, health and education. At this disaggregation level, industry is considered as the sector producing tradable goods. Sometimes agriculture and construction are also included. Nevertheless, more often agriculture is excluded from both sides as it can heavily depend on subsidies and government interventions. Furthermore, construction is usually treated as a non-tradable sector. The uncertainty surrounding these two sectors indicates that they might be borderline cases producing tradable goods with a higher non-tradable component. As to the closed sector, it normally contains the remaining sectors, i.e. services. However, according to the model described earlier, profit maximisation is assumed in both sectors. This would imply the inclusion of only market services or market-based non-tradable sectors[20]. The only paper dealing with Estonia, which follows this approach is that of Lommatzsch-Tober (2002), whereas the other studies consider the remaining categories as the closed sector. Randveer-Rell (2002) use very detailed sectoral data and consider, in addition to agriculture and manufacturing, also the hotel and transportation sectors as producing tradable goods, while the rest of the economy, including mining and construction is treated as non-tradables.

[20] Another practical reason for excluding non-market sectors is the uncertainty that surrounds prices (as there are no market prices) at which output is measured there.

Table 3. Classification of sectors into open and closed sectors in transition economies.

	Open sector	Closed sector
Studies including Estonia		
Coricelli-Jazbec (2001)	Industry + construction	Rest, agriculture excluded
De Broeck – Slot (2001)	Industry + construction	Rest, agriculture excluded
Égert et al. (2002)	Industry + Agriculture	Rest
	Industry	Rest, agriculture excluded
Filipozzi (2000)		
Fischer (2002)	Industry	
Halpern-Wyplosz (2001)	Manufacturing/Industry	Services, agriculture and construction excluded
Lommatzsch-Tober (2002)	Industry	Construction, trade, finance
Randveer-Rell (2002)	Agri, Manuf, Hotels, Transport	Rest (mining)
Rother	Manufacturing	Rest, agriculture excluded
Sinn-Reutter (2001)	Manufacturing+agriculture	Construction, Energy, Services
Studies excluding Estonia		
Backé et al. (2002)	Manufacturing	Rest
Dobrinsky (2001)	Whole economy	
Égert (2001,2002a,b,c)	Industry	Rest
Golinelli-Orsi (2001)	Industry	Rest
Kovács (2001), Simon-Kovács (1998)	Manufacturing	Services, agriculture and public services are excluded
Nenovsky-Dimitrova (2002)	Industry + construction	All services, agriculture excluded

In this study, we employ very disaggregated data broken down into 15 sectors, which are classified into tradable, market non-tradable and total non-tradable categories including market and non-market non-tradables. One selection criterion for the tradable sector is that it has to be opened to competition (through privatisation). The other one is that trade arbitrage, the main mechanism ensuring PPP to hold in the sector as assumed in the model, should be possible. Two clear candidates are agriculture and manufacturing. It must be noted that agriculture, contrary to other candidate and EU countries, was purified by a "survival race" triggered by complete privatisation and the total disengagement of the State. The tradability of this sector is clearly proven by figures shown in Table 4., according to which the average of exported agricultural products over total agricultural production is 24,6% between 1993 and 2001.

Table 4. The share of exports in agricultural production

1993	1994	1995	1996	1997	1998	1999	2000	2001	AVERAGE
10,41%	14,39%	19,30%	16,55%	25,47%	30,17%	31,83%	35,98%	37,35%	24,60%

Note: General exports of live animals, animals product, vegetable products, animal and vegetable oils and their cleavage, wood and article of woods over nominal GDP of agriculture, fishing and forestry. Source: Author's calculations based on data obtained from the Statistical Office of Estonia (www.stat.ee)

The market non-tradable sector consists of wholesale and retail trade, hotels and restaurants, financial intermediation, real estate, renting and business activities. Finally, the energy sector (electricity, gas and water supply), mining, public administration and defence, education, health and social work and other community, social and personal service activities constitute the non-market non-tradable sector. The reason why mining is considered as non-market non-tradable sector is that first, it is largely dominated by oil-shale production (nearly 100%), a product entirely used by the domestic energy industry and second, because of the presence of a single, still publicly owned company. The same reasoning applies for the energy sector. Even though the electricity industry largely covers domestic consumption, the surplus can be transferred only to Russia and Latvia as there is no connection yet to the Western and Nordic electricity network. Like in mining, it is a monopolistic market with few market participants whose partial privatisation has been aborted after September 11, 2001.

Classification has proved to be difficult for two sectors. While transportation, storage and telecommunication clearly belong to the closed sector, the dominance of market forces is less clear cut. On the one hand, the railway system was sold only in 2001, the harbours are still publicly owned, and even if private companies are present in urban public transportation, it is heavily regulated by local municipalities. Similarly, although 49% of Eesti Telecom has been sold in 1991, it remained the only player in the market. On the other hand, storage is completely privatised and is a competing market, and the emergence of mobile operators had had a direct impact on the fixed-line market. As the position of this sector is rather ambiguous, we experimented by considering it first as a market and then as a non-market closed sector. Another sector difficult to classify is construction. As private companies dominate the sector, the question to be answered is whether it belongs to the open or to the closed sector. From the viewpoint of tradability of the end product, it should be a non-tradable sector. However, given developments in productivity and prices, it might also be treated as a tradable sector. As shown later on, productivity growth has been pretty high over the period under study, while prices have been rather flat and real wages have grown in line with productivity gains. One explanation may lie in the high share of imported tradable goods used in the sector and the relatively high capital intensity. So, we first choose to include construction into the closed sector, then to treat it as a traded goods sector and finally not to consider it at all.

Because the classification into open and closed sector bore a number of difficult judgements, we calculated a whole set of measures of the productivity differential and the relative price increases. We first built the differential between productivity in the open and the market closed sectors and then between the open and the closed sector as a whole to figure out the difference the use of the latter may bring about. Tables 5-6 summarise the 9 productivity measures calculated.

Table 5. Productivity series used in the paper for Estonia

	OPEN SECTOR		CLOSED SECTOR
PROD_T1	A+B+D	**PROD_NT_MARKET1**	**F**+G+H+J+K
PROD_T2	A+B+D+**F**	**PROD_NT_MARKET2**	**F**+G+H+J+K+**I**
		PROD_NT_MARKET3	G+H+J+K
		PROD_NT_MARKET4	G+H+J+K+**I**
		PROD_NT_TOTAL1	(**F**+G+H+J+K)+I+(C+E+L+M+N+O)
		PROD_NT_TOTAL2	(G+H+J+K)+I+(C+E+L+M+N+O)

Note: A= agriculture, hunting, forestry, B= fishing, C= mining and quarrying, D= manufacturing, E= electricity, gas and water supply, F= construction, G= wholesale and retail trade, H= hotels and restaurants, I= transport, storage, telecommunication, J= financial intermediation, K= real estate, renting and business activities, L= public administration and defence, compulsory social security, M= education, N= health and social work, O= other community, social and personal services activities

Table 6. Productivity differential series for Estonia

	OPEN SECTOR	CLOSED SECTOR
DIFF_PROD1	PROD_T1	PROD_NT_MARKET1
DIFF_PROD2	PROD_T1	PROD_NT_MARKET2
DIFF_PROD3	PROD_T1	PROD_NT_TOTAL1
DIFF_PROD4	PROD_T1	PROD_NT_MARKET3
DIFF_PROD5	PROD_T1	PROD_NT_MARKET4
DIFF_PROD6	PROD_T1	PROD_NT_TOTAL2
DIFF_PROD7	PROD_T2	PROD_NT_MARKET3
DIFF_PROD8	PROD_T2	PROD_NT_MARKET4
DIFF_PROD9	PROD_T2	PROD_NT_TOTAL2

In a next step, we calculate the difference of the productivity differential in Estonia and in a benchmark foreign economy so as to see the influence of productivity growth on inflation differentials and the real exchange rates. In so doing, we proceed to construct an effective productivity measure including 4 major trading partners, namely Finland, Sweden, Germany and the UK. The reason why we do not consider other FSU countries, e.g. Latvia, Lithuania and Russia is that we are basically interested in the catch-up process towards Western European levels of development. As can be seen in Table 7, the four EU economies adds up to 50% of total Estonian exports and imports. The weights employed when the effective measure is calculated correspond to the average share of the four countries in their totalled exports and imports to and from Estonia between 1993 to 2001. The respective figures are shown in Table 8. in the column "average".

Table 7. The share of the four benchmark economies in total exports and imports (%)

	1993	1994	1995	1996	1997	1998	1999	2000	2001
Finland	25,5	24,6	27,9	24,9	20,3	21,0	21,3	25,2	21,4
Germany	9,8	8,6	8,6	8,8	8,3	8,7	8,5	8,3	8,5
Sweden	9,5	9,8	9,5	9,5	10,8	12,1	13,3	12,4	9,8
UK	1,5	2,4	2,7	3,4	3,3	3,5	3,3	2,9	3,0
TOTAL	46,3	45,4	48,6	46,6	42,7	45,4	46,3	48,8	42,7

Source: Author's own calculations based on SOE data

Table 8. The share of the four benchmark economies in relative exports and imports (%)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	AVERAGE
Finland	55,0	54,2	57,4	53,4	47,5	46,4	45,9	51,6	50,2	**51,3**
Germany	21,2	18,9	17,6	19,0	19,4	19,2	18,4	17,0	19,8	**18,9**
Sweden	20,6	21,5	19,5	20,4	25,4	26,8	28,6	25,4	23,0	**23,5**
UK	3,2	5,3	5,5	7,2	7,7	7,7	7,0	6,0	7,0	**6,3**
Total	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	**100,0**

Source: Author's own calculations based on SOE data

The classification of sectors into open and closed sectors roughly follows the approach adopted in the case of Estonia. So, based on 15-sector data, we determine the average labour productivity for Germany, Finland and Sweden by dividing real output by total hours worked. We note that in countries with a high share of part-time workers, it is theoretically more appropriate to use hours worked instead of the number of employees[21]. The open sector includes mining and manufacturing, on the one hand. On the other hand, whilst construction, energy, wholesale and

[21] In Sweden and in Germany, the share of part-time workers is respectively as high as approximately 24% and 15% (European Commission(2001)). The corresponding figure for Finland is considerably lower, about 10% . In Estonia, the share of part-time workers in total employment is as low as about 7%. Contrary to what could be expected, the difference between the two series when using the number of employees and total hours worked turns out to be very small for all three countries.

retail trade, hotels and restaurants, transport, storage and telecommunication, financial intermediation and finally real estate, renting and other business activities form the market closed sector, agriculture, public administration, education, health and social work and other community, social and personal services make up the non-market closed sector. Contrary to Estonia, agriculture is treated as a non-market non-tradable sector because of the distorting CAP in the EU. Another difference to Estonia is the energy market in general and the electricity market in particular. Because of the early liberalisation of these markets, we consider them as market-based sectors[22]. As to the UK, we only dispose of data on 5 sectors, that is agriculture, industry, construction, trade including hotels and restaurant , transport and communication, financial services and other service activities. Therefore, as energy makes part of industry, it cannot be separated and put into non-tradables. Fortunately enough, the importance of the energy sector is negligible, so it won't have a large impact on the productivity differential. Furthermore, only the number of employees is at our disposal in a sectoral breakdown. But, once again, the small weight attributed to the UK in the effective basket makes life easy and will not substantially influence the effective measure which is dominated by Finland (with a weight of 50%). Based on results to be presented later on, the following differences between the Estonian and the foreign productivity differentials are used in the investigation:

Table 9. Productivity differentials for the foreign benchmark

	OPEN SECTOR	CLOSED SECTOR
DIFF_PROD1	C+D	E+F+G+H+I+J+K
DIFF_PROD2	C+D	REST excluding agriculture
DIFF_PROD3	C+D	REST including agriculture

Note: see Table 5.

Table 10. The difference in productivity differentials

	ESTONIE	BENCHMARK
D_DIFF_PROD1	DIFF_PROD5	DIFF_PROD1
D_DIFF_PROD2	DIFF_PROD6	DIFF_PROD2
D_DIFF_PROD3	DIFF_PROD6	DIFF_PROD3

The relative price series

The calculation of the relative price of non-tradables relies on both deflator and CPI price measures. As a first step, the implicit deflators corresponding to the above described productivity series are determined based on nominal and real sectoral GDP. The respective relative prices are calculated subtracting the logarithms of the deflator series of the open sector from those of the closed sector. The same has been done to obtain the relative price of non-tradable goods for the effective foreign benchmark. Finally, the difference between the Estonian and the foreign relative prices is calculated as shown in Table 13. However, it must be noted that the overall GDP deflator and the calculated deflators for the open and the closed sectors do not coincide with the consumer price index. As the CPI inflation is at the heart of economic policy in general and of monetary policy in particular, the relative price of non-tradable goods derived from the CPI is more appropriate to be used instead. We therefore separated the CPI into different goods and service categories. As we have at our disposal monthly time series of the about 260 items included in the Estonian CPI, we could construct series for food, non-food goods, market services, regulated services, household energy, fuel and finally alcohol and tobacco[23]. Subsequently, we chose to compute two series approximating the development of non-tradable

[22] Though, it is clear that they are not completely freed. In fact, because of its very low weight in GDP, whether or not the energy sector is classified as market or non-market sector will not change too much.

[23] For the precise definition of each category, see appendix. Alcohol and tobacco and fuel are not considered in the analysis as they are very often subject to tax changes and to fluctuations in world oil prices.

prices. One contains only non-food goods whilst the other also includes food products. It has to be mentioned that the two series behave very similarly as the non-food goods and food series run very closely to each other. The only difference is the higher non-seasonal short-term disturbances in the food series. Next, three series for non-tradable prices are considered. Beside the market service prices, a series including both market and regulated services and a third one containing, in addition, household energy are computed. Based on these data series, we determine 6 relative prices series for Estonia, which are summarised in Table 11.

Table 11. CPI-based relative prices for Estonia

	NON-TRADABLES	TRADABLES
REL1	MARKET SERVICES	NON-FOOD GOODS
REL2	TOTAL SERVICES	NON-FOOD GOODS
REL3	TOTAL SERVICES + ENERGY	NON-FOOD GOODS
REL4	MARKET SERVICES	FOOD + NON-FOOD GOODS
REL5	TOTAL SERVICES	FOOD + NON-FOOD GOODS
REL6	TOTAL SERVICES + ENERGY	FOOD + NON-FOOD GOODS

For the sake of comparability, the same relative prices have to be used for the foreign countries. For Sweden, we calculate the same series as for Estonia using a 2-digit level disaggregation for CPI prices corresponding to the COICOP. For Finland and Germany, we use 1-digit COICOP data. Finally, we use very disaggregated CPI data (with over 75 categories) for the UK obtained from the Bank of England.

Table 12. CPI-based relative prices for the foreign countries

	NON-TRADABLES	TRADABLES
REL1	MARKET SERVICES	NON-FOOD GOODS
REL2	MARKET SERVICES	FOOD + NON-FOOD GOODS
REL3	TOTAL SERVICES	NON-FOOD GOODS
REL4	TOTAL SERVICES	FOOD + NON-FOOD GOODS

Table 13 The difference in the CPI-based relative prices in Estonia and in the foreign countries

	ESTONIA	BENCHMARK
D_REL1	REL1	REL1
D_REL2	REL4	REL2
D_REL3	REL2	REL3
D_REL4	REL5	REL4

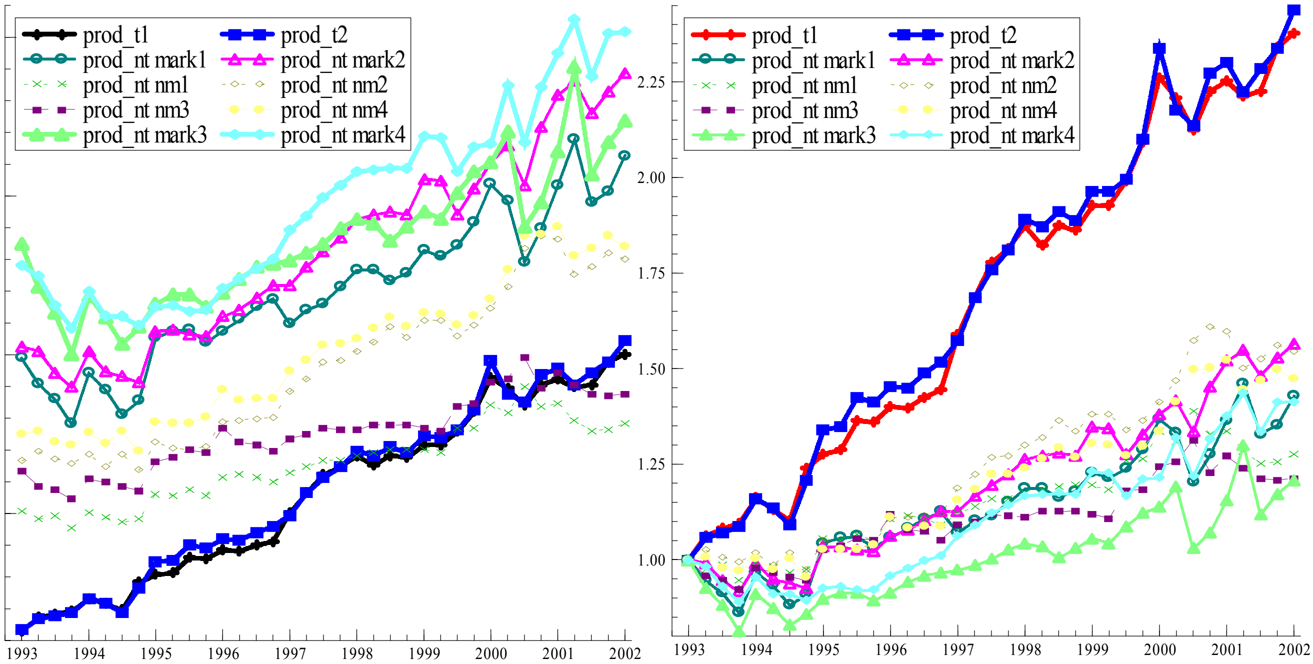
The real exchange rate series

The nominal exchange rate series are based on average monthly data based on which several real exchange rate series are computed. First, the ones based on the official CPI and industrial PPI indexes. Then, the real exchange rate based on goods prices including food and without food are calculated. Finally, a synthetic CPI index based on consumer goods and market services is determined and used for measuring the real exchange rate.

V. A preliminary data analysis

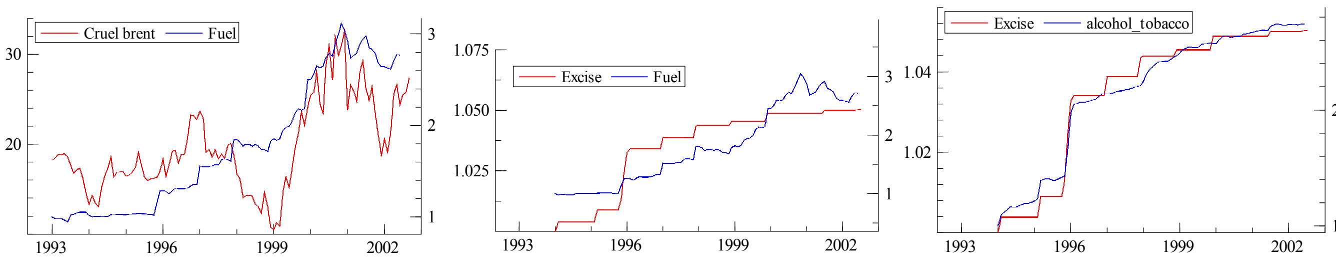
Figure 1. presents the labour productivity in absolute values and as normalised to the first period for the open sectors, the market-based and non-market non-tradable goods sectors as described in the data section. It can be seen that the level of productivity in the open sector is considerably lower than that in the closed sector, irrespective of whether it is market or non-market. At the same time, productivity in market non-tradables is still well over that in non-market non-tradables. Furthermore, the data also show that while the rate of growth in the open sector well outpaces that of the closed sector, the non-market segment of the closed sector clearly lags behind of market non-tradables in terms of productivity growth. Hence, the difference in open and closed sector productivities is clearly positive.

Figure 1. Labour productivity in Estonia



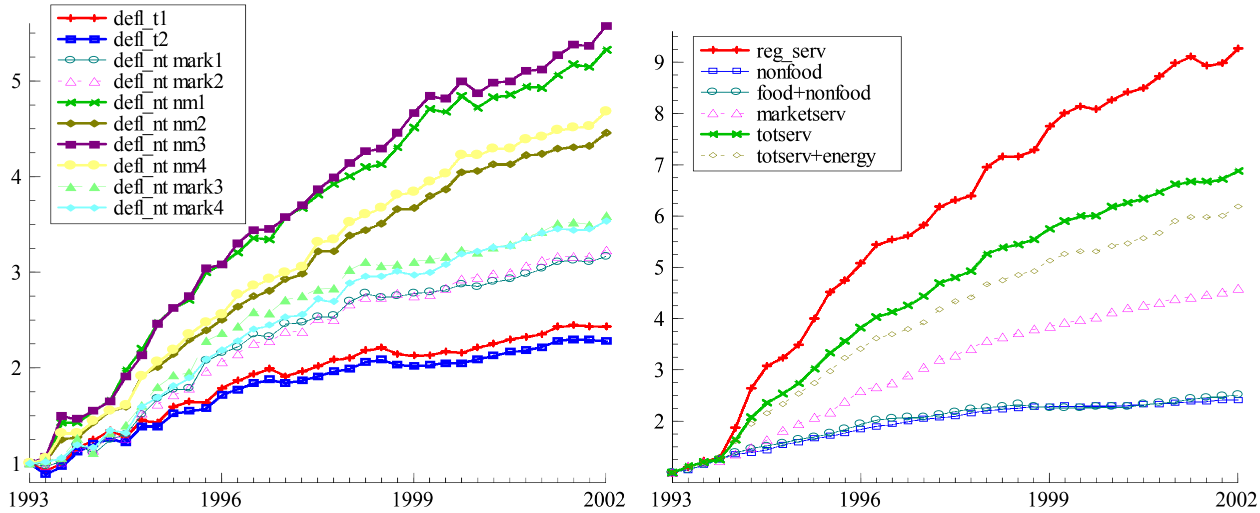
When constructing the relative price series, the alcohol&tobacco and the fuel items were completely ignored from the CPI because they are all heavily influenced by changes in the excise tax and the fuel price is subject to changes in the oil price on the international markets. Figures 2. below well demonstrates this effect.

Figure 2. Alcohol&tobacco and fuel prices



As to the relative price series, they also show substantial increases over the period under investigation. Both using sectoral deflators and disaggregated CPI data, the price of non-tradables turns out to increase much faster compared with tradable prices. In addition, the non-market component of non-tradable prices outpaces market non-tradable prices. This is especially the case for the CPI-based measures, as regulated prices grow 2,5 times faster than market service prices.

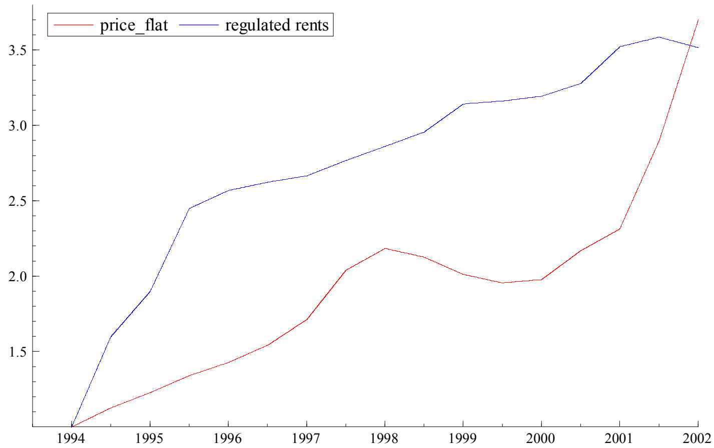
Figure 3. GDP deflators and the CPI



Regulated prices have three major components: public transportation, post and telecommunication and finally rent for publicly owned housing and housing related communal services[24]. The most important reason for the huge increase in regulated prices roots in the fact that regulated prices were unchanged at the beginning of the transition period when other prices were free to adjust. So, the large increase in regulated prices mirrors the late catch-up with other prices, mainly those of services. As soon as the adjustment process has finished, they are expected to behave similarly and therefore can be considered as normal market services in the long-run. Nevertheless, there are two problems with this. First, it is not well-known, where is their target value to adjust to. But, prices of regulated services still do not allow cost recovery, which implies further increases beyond what the B-S effect would imply on normal market services. Second, housing prices in general and rents included in the CPI in particular cannot be directly linked to the B-S effect. Non-market rents have undergone a big adjustment process. Even so, they are expected to still lag behind market rents. As can be observed in every transition economies, housing prices started adjusting relatively late in the second half of the 1990s[25] and bubble-like price developments were to be observed in the real estate markets. This seems to be also the case in Estonia as shown in Figure 4. below. It can also be seen that while the major hike in rents occurred in 1994-1995, flat prices started rising sharply recently, indicating future increases in market rent, and later on in rents for State-owned housing.

[24] In addition, housing energy turns out to be regulated as well as it exhibits one stepwise increase at the beginning of every year. Housing energy is treated separately.
[25] See e.g. Valkovszky (1999) for Hungary.

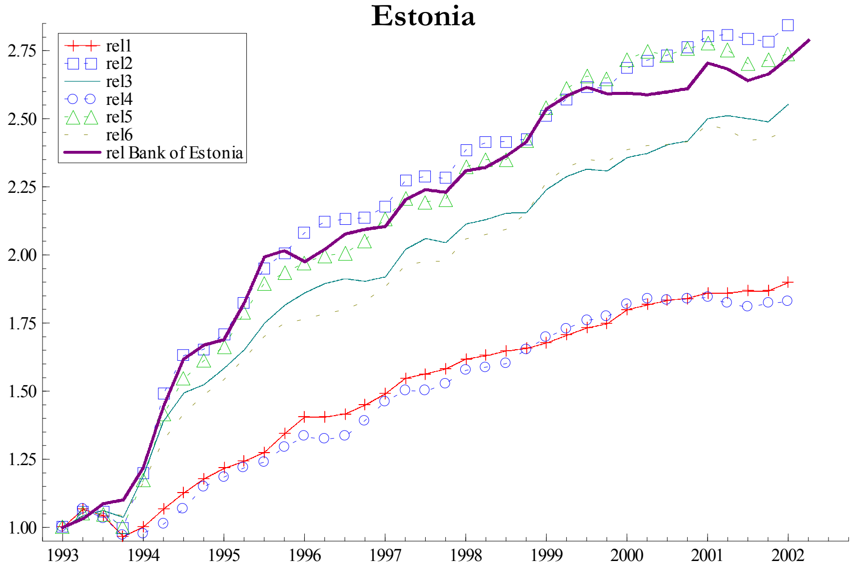
Figure 4. Regulated rent prices and the price of flats



Source: Bank of Estonia
Note: The price of flat refers to flats in Tallinn and Tartu, in satisfactory condition: inhabitable, partly out of repair, no changes in subdivision plat done, no improvements to the building made, area 54m².

So, as shown in Figure 5. below, the relative price excluding regulated services is substantially lower than the one including them. Comparing these series to the relative price of non-tradable goods using the official non-tradable and tradable series published by the Bank of Estonia, the latter is very similar to the ones with regulated items and excluding household energy.

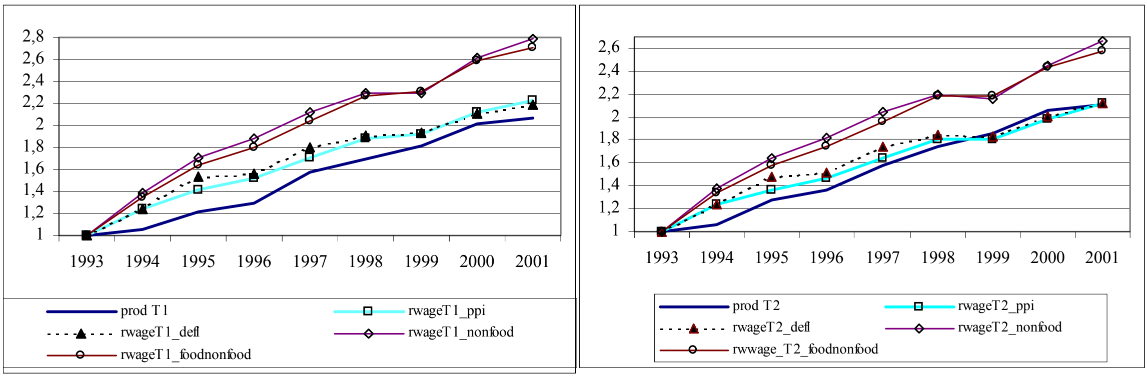
Figure 5. Relative price measures compared to the official relative price of the Bank of Estonia



VI. Are the basic assumptions of the model fulfilled?

There are several assumptions to be verified prior to the econometric analysis. The theoretical model explicitly assumes perfect capital mobility between Estonia and the outside world, and labour mobility within the Estonian economy. The first one is obviously fulfilled with the early implementation of the currency board system: not only all capital movements are liberalised, but also there are important *de facto* capital movements to and from Estonia[26]. As to the labour mobility assumption, it is hard to empirically verify. As it is needed for the wage equalisation to hold, we have a closer look at the wage equalisation process. We begin by examining whether the transmission from sectoral productivity growth to the increase in the price of non-tradable goods is secured. As in equation (12) of the model, the real wage should be linked to the productivity in the open sector. Since we are investigating the model in dynamics, it is most important to check whether changes in the real wage deflated by tradable prices are related to productivity developments. Four different tradable price indexes are employed to calculate changes in the real wage in the open sector defined as T1 and T2[27]: the corresponding sectoral deflator, the PPI, and two CPI sub-indexes, namely non-food price inflation and total goods inflation including food. As can be seen in Figure 6., both productivity measures (PROD_T1 and PROD_T2) move very closely in line with the deflator and the PPI deflated real wage series. Nevertheless, using goods prices from CPI leads to a different conclusion: even though the short-term dynamics seem to correspond, the real wage measures grow faster and move steadily away from productivity, with a 30% positive gap over the whole period (3,33% a year). Indeed, this is not a serious concern because productivity in the open sector should be in line with the real wage when prices in the same sector and not from the CPI are employed.[28]

Figure 6. Productivity and real wages in the open sector



The second step is now to see to what extent nominal wages do equalise between the open and the closed sectors[29]. Nominal wages in the open sector seem to be lower than those in both the market-based closed sector including transport and communication and the closed sector as a whole (see Figure 7.) - independently whether or not construction is considered. The absolute wage equalisation may be slightly better achieved between the open sector and the market-based

[26] *De facto* current account convertibility was achieved in 1992. Full current account convertibility in line with article VIII of IMF and quasi-total capital account convertibility is completed by 1994. Today, the only restriction remaining on capital movements is related to land purchases.

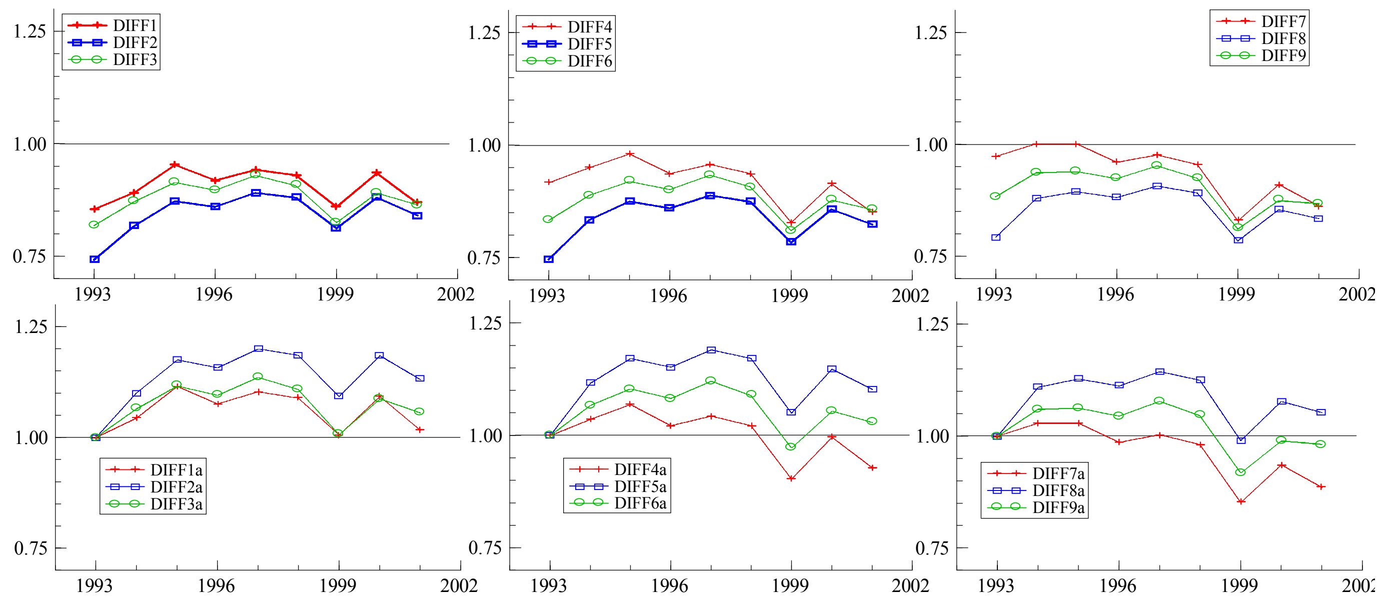
[27] The sectoral nominal wages are weighted using sectoral employment data.

[28] This means actually that the tradable component of CPI has risen more slowly than the PPI. This can happen because the two indexes contain different goods. The PPI consists of domestically produced goods, whereas a large part of goods in CPI is imported goods. It is difficult to say precisely this share as CPI statistics do not consider the origin of the goods. As imported goods in household consumption is of importance and because the CPI should broadly reflect household consumption patterns, the share of imported goods should be of a comparable magnitude. Furthermore, there is also a mismatch between the characteristics of the goods included in the two price indexes: PPI contains more industrial goods while the good component of CPI includes consumer goods and durable consumer goods. Bearing all this in mind, developments in export and import prices can explain this phenomenon: export prices have risen compared to import prices, which in turn means that the PPI including a great deal of exported goods has experienced larger increases than the goods component of the CPI containing a considerable amount of imported goods.

[29] The open and closed sectors are defined as for the productivity and the deflator and the equalisation is considered for the differences developed for productivity, that is DIFF1 to DIFF9 where data for the open sector is divided by that for the closed sector.

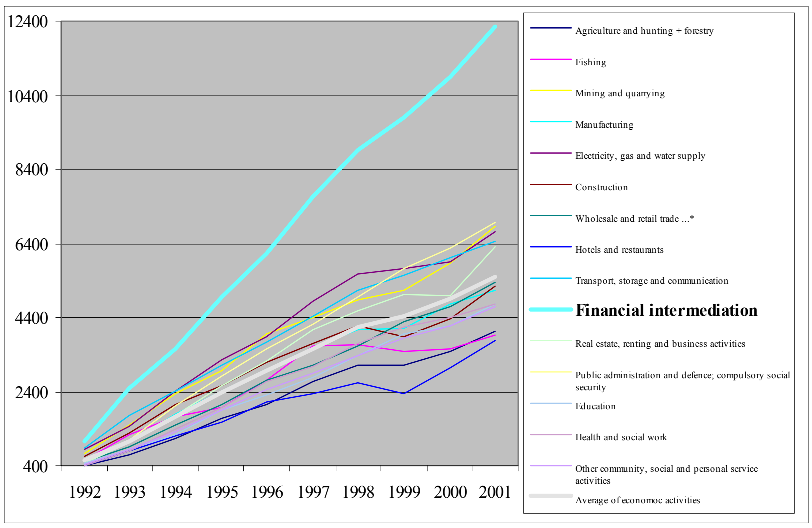
closed sector including transport and communication as the ratio is closer to unity. However, looking at relative figures shows, seemingly paradoxically, that the wage ratio may follow a downward trend whereas in the two former cases, the ratio turns out to be rather stable.

Figure 7. The wage equalisation process in absolute and relative terms, 1993-2001



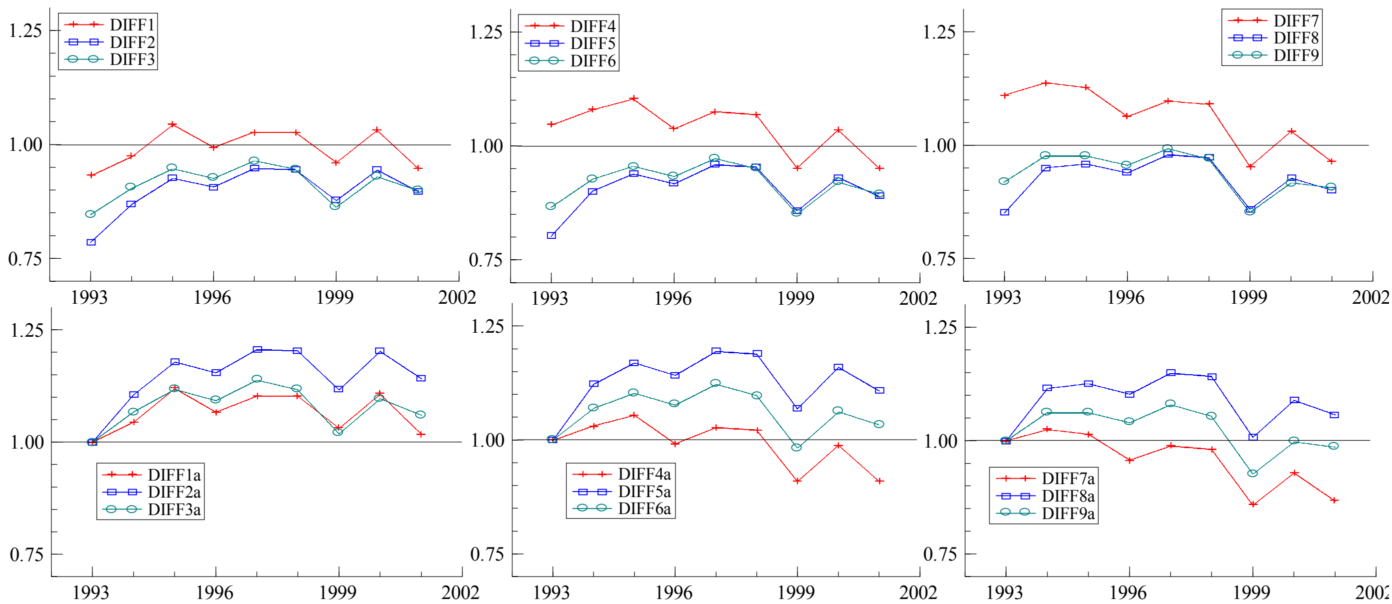
The analysis of the individual sectors reveals that this is mainly due to huge wage increases in financial intermediation. While wages in other sectors move in line over the period considered, wages in financial intermediation, already initially higher, grow by far the fastest.

Figure 8. Average nominal wages in 15 sectors of the Estonian economy, 1993-2001 (EEK)



By eliminating wages in financial intermediation from the closed sector, the ratio turns out to be very close to unity. In addition, if transport and telecommunication are taken as a market-based non-traded goods sector, the ratio proves to be more stable than in the case when they are excluded. So, it is not false to state that wages seem to be ready to transmit the effect of productivity growth onto non-tradable prices. However, given the institutional setting in Estonia, it remains somewhat unclear how wage equalisation comes about. First, labour mobility across sectors is rather unidirectional in Estonia. If the open sector is the leader in wage setting, and if wages grow there faster, mobility towards the open sector should be observed. In practice, the contrary happened in Estonia. Over the last 10 years, the number of employees has dramatically decreased in the open sector while it slightly increased in the market-based non-traded goods sector[30]. Second, given that union density in Estonia is one of the lowest among transition economies[31] and because unions are present mainly in mining and the public sector, trade unions cannot promote wages to equalise across the whole economy.

Figure 9. The wage equalisation process in absolute and relative terms, excluding financial services, 1993-2001



VII. The econometric approach

As the series are constructed with 1993:Q1 being the basis=100, they are expected to be non-stationary in levels[32]. The first thing to do in the econometric analysis is therefore to check the order of integration of each single series used in the investigation. The testing strategy proposed by Dickey and Pantula (1987) is combined with the strategy suggested in Hurlin (2001). Dickey and Pantula argue that testing the null of I(1) against I(0) might lead to the rejection of the null hypothesis even though the series are truly I(2) or I(3) processes. For this reason, it is more secure to start by testing higher order of integration and, as the null is rejected, continue to test lower order of integration. In line with this technique, we start testing I(3) against I(2). If the alternative hypothesis is accepted, we then perform the test for the null of I(2) against I(1), and finally the null of I(1) is checked against the alternative of I(0). Given this, the testing strategy as in Hurlin (2001) is followed using conventional Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests. Let us consider the null of I(1) against the alternative of I(0)[33]. In a first step, the tests are carried out using the model including a linear trend and a constant. If the null is rejected, the significance of the trend can be checked for using the standard t-Student distribution. When the trend turns out to be significant, the series is stationary around a linear trend (trend stationary). Otherwise, in case the trend is not found to be significant, we have to test the model with a constant. On the contrary, if the null of the presence of a unit root is accepted, the unit root and the trend have to be jointly tested for using critical values given in DF(1981) and PP(1988). If the null of no unit root and no significant trend is rejected, the series

[30] The difference is apparently absorbed by the decreased activity rate.
[31] See Paas et al. (2002), pp. 55.
[32] As noted in Nelson and Plosser (1982), 95% of the macroeconomic series contain a unit root in levels.
[33] This strategy is applied to test I(3) against I(2), and I(2) against I(1).

is I(1) with a linear trend. In other word, it has a trend in first differences. If the null is accepted, we tested the wrong model, hence the model containing only a drift should be tested. For the model with a drift the same procedure applies. The only difference is that the significance of the constant has to be checked. If the constant finally does not turn out to be significant, the model without constant and trend is employed.[34]

When the series are found to be I(1) in the end, the appropriate econometric tool to use for analysing potential relationships among the variables under investigation is the co-integration technique. In this paper, the VAR-based Johansen co-integration is used. The optimal lag length based on a set of information criteria is chosen and likelihood ratio tests are performed to determine whether the I(0) and I(1) components of the model contain a constant or a trend. Subsequently, the number of co-integration vectors is checked for employing the Johansen trace statistics. When the tests are able to reject the null of no cointegration, the stability of the rank and the estimated coefficients is verified using diagnostic tests proposed in Hansen-Johansen (1999). For the sake of robust results, there is need for a properly specified VAR model in which co-integration is tested for. Therefore, a number of diagnostic tests have to be carried out. It is important to ensure that absolute values of the roots of the autoregressive polynomial of the VAR be below unity. Otherwise, the AR processes would not be stationary. Then, we have to make sure that the chosen lag length *ex post* ensures the assumption of the absence of serial correlation in and normality for the residuals of the VAR. For this purpose, Jarque-Bera and Mardia multivariate normality tests and the graphical analysis of correlograms are employed. Finally, weak exogeneity and exclusion tests are performed.[35]

VIII. Results of the cointegration analysis

The results of the combined strategy of testing for unit roots are shown in Tables 1-3 of Appendix 4. and suggest that the series are non-stationary in level and stationary in first differences. Notable exceptions are some of the CPI-based relative prices, namely REL2, REL3, REL5 and REL6 since it turns out to be difficult to determine their order of integration. Whereas in the case of all other series the tests clearly indicate their I(1) nature, results for the 4 mentioned series are strikingly contradictory. The ADF test suggests they are TS processes, whilst according to the PP test statistics, they are stationary with a drift or difference stationary with a linear trend (that is explosive in levels). The tests were performed using lags up to 5, and the image has not proven clearer. For this reason, we do not consider these variables for the cointegration analysis[36]. Using the I(1) series, testing for cointegration is done as follows. First, the relationship between the domestic productivity differential and the domestic relative prices is investigated (Cf. equation (33a)). If the relative price series are found to bear a long-term relationship with the productivity differential series conditioned on the rough fulfilment of the basic assumptions, it seems a reasonable attempt to verify the extent to which productivity driven inflation brings about the real exchange rate to appreciate. In doing so, the difference of the home and the foreign productivity differentials and that of the domestic and foreign relative prices are analysed (see equation (34)). If the difference in productivity differentials turn out to be connected to the difference in relative prices, the relationship between the former and the CPI-deflated real exchange rate is examined (Cf. equation (39)).

[34] The whole testing procedure is shown in appendix.
[35] See appendix for the testing strategy.
[36] Actually, tentatively performing some cointegration tests with the necessary diagnostic tests clearly confirm this by very bad specifications.

VIII. A. How strong is the relationship between the productivity differential and relative prices in Estonia?

As the first step of the cointegration analysis, the internal transmission mechanism is investigated using relative prices based on sectoral GDP deflators. A first glance at results shown in Table 14. indicate that the corresponding productivity and relative price measures but one are connected with each other. Indeed, the tests were unable to reject the null of no cointegration for PROD3 and DEFL3. For the other series, a cointegration vector is detected with a statistically significant coefficient having the expected sign. That is to say, an increase in the productivity differential goes in tandem with an increase in the relative price series. Nevertheless, there are notable differences in the coefficients depending on whether the sector "transport, storage and telecommunication" is considered as market-determined closed sector or not. When it is excluded from market non-tradables, the coefficient is systematically lower, amounting to about 0,6%, irrespective of how the construction sector is classified. The estimated coefficient of the cointegration vector are normalised to the relative price series. By contrast, if the sector in question is treated as a market non-tradable sector, the estimated coefficients rise slightly over 1. This is also the case when the whole non-tradable sector is taken[37]. This far we have only analysed whether or not cointegration is found. However, having a closer look at the diagnostic tests tells us that only a fraction of these cointegration relationships can be regarded as well specified and stable. Even though no major problems are encountered in terms of serial correlation and normality, a number of estimated cointegration relationships turn out to be unstable over time with not-too-robust coefficients. In addition, a score of VAR models are found to have roots higher than 1, which of course invalidates the cointegration relationship[38]. Therefore, we are left with three correctly specified long-term cointegration relationships, notably No. 5, 6 and 8. However, as the coefficients determined for these relationships are very similar, we conclude that the productivity differential seems to go together with quasi proportionate increases in the deflator-based relative prices.

[37] We are mainly interested in the open and the market non-tradable sectors, but for the sake of comparability series including the whole closed sector are also used.

[38] We note that the exclusion tests do not exclude any of the variables included into the cointegration space. The weak exogeneity tests show that the productivity differentials are systematically weakly exogenous. This means that only relative prices adjust to equilibrium in the short run.

Table 14. Cointegration tests for the internal transmission mechanism (DEFL, PROD)

Relationship	Model	Lags	H0	trace	1	Beta1	Const	Normality J-B	Mardia	Roots	Stability Param.	Rank
PROD1, DEFL1	M1	4	R=0	15,48*	1*	-0,560		3,896	19,568	NO	OK	NO
			R=1	3,52		-15,135		(0,420)	(0,002)			
PROD2, DEFL2	M2	1	R=0	24,02*	1*	-1,141	0,204	2,368	7,118	OK	OK	???
			R=1	6,43		-10,097	5,513	(0,668)	(0,212)			
PROD3, DEFL3	M2	1	R=0	17,04				2,614	7,766	OK	OK	NO
			R=1	4,74				(0,624)	(0,170)			
PROD4, DEFL4	M1	4	R=0	17,02**	1*	-0,644		8,462	8,267	NO	???	???
			R=1	2,54		-24,769		(0,076)	(0,142)			
PROD5, DEFL5	M2	1	R=0	26,74**	1*	-1,197	0,259	5,484	6,304	OK	OK	OK
			R=1	7,47		-10,981	5,756	(0,241)	(0,278)			
PROD6, DEFL6	M2	2	R=0	22,40*	1*	-1,227	0,115	3,180	4,457	OK	OK	OK
			R=1	5,82		-17,529	4,107	(6,528)	(0,486)			
PROD7, DEFL7	M1	5	R=0	14,13*	1*	-0,681		7,109	8,554	NO	NO	NO
			R=1	1,05		42,561		(0,130)	(0,128)			
PROD8, DEFL8	M2	1	R=0	25,90**	1*	-1,236	0,244	7,656	8,226	OK	OK	OK
			R=1	8,09		-10,387	4,784	(0,105)	(0,145)			
PROD9, DEFL9	M1	3	R=0	28,76**	1*	-1,107		2,217	3,659	NO	OK	OK
			R=1	1,78		92,250		(0,696)	(0,600)			

Notes: M1, M2 and M3 refer to the models tested for with different deterministic components. M1: no trend and no constant neither in the I(0) nor in the I(1) components. M2: neither trend nor constant in the I(0) component and constant in the I(1) component. M3: trend in the I(0) component. M4 and M5 including a linear and a quadratic trend in the cointegration relationship are not considered at all since there are no theoretical consideration for trends in the long-term relationship. * and ** indicate that the null is rejected at the 5% and the 1% significance levels. The estimated cointegrating vector is normalised to the relative prices. The shown coefficients is thus that of the productivity series. Normality is accepted if p-values in parenthesis are higher than 0,05. OK under the column "roots" indicates that the roots of the model are below one. OK also indicates that the tests accept the stability of the rank and the coefficients of the estimated cointegration vector.

Moving one step ahead, we examine whether changes in the productivity differential are related to changes in the CPI-based relative prices. As a matter of fact, productivity differentials and the relative price of non-tradable goods including regulated services and household energy cannot be cointegrated, because of the statistical nature of the relative price series presented earlier. This is also partly demonstrated in Figure 2. of Appendix 2. showing that the relative price of total non-tradables increases at a much higher pace than the productivity differential. On the other hand though, the visual inspection of the data suggests that the "core" relative prices, that is the relative price of market non-tradable goods might be in line with the growth of the productivity differential. This speculation seems to come true according the results, which can be seen in Table 15. below[39]. Despite the fact that the diagnostic statistics indicate some problems, we can find a score of correctly specified cointegration relationships. All the cointegrating vectors are significant and correctly signed. We note, that the estimated coefficients are, in all cases, higher compared with those for the deflator-based relative prices. But, they are still rather close to unity as they range from 0,9 to 1,6 indicating a close relationship between productivity and the "core" relative prices.

[39] Only results of the estimations employing the REL4 series are show because estimations using REL1 yields very similar results and because the diagnostic tests for the latter are slightly worse.

Table 15. Cointegration tests for the internal transmission mechanism (REL4, PROD)

Relationship	Model	lags	H0	Trace	1	Beta1	const	Normality J-B	Mardia	Roots	Stability Param.	Rank
PROD1, REL4	M1	3	r=0	18,61**	1*	-1,284		4,536	4,651	NO	OK	OK
			r=1	0,25		-24,692		(0,338)	(0,460)			
PROD2, REL4	M1	4	r=0	30,98**	1*	-1,468		3,957	2,963	OK	OK	OK
			r=1	0,10		-50,621		(0,412)	(0,706)			
PROD3, REL4	M2	4	r=0	42,18**	1*	-1,347	0,005	6,383	4,118	OK	OK	OK
			r=1	7,30		-19,249	0,192	(0,172)	(0,532)			
PROD4, REL4	M1	3	r=0	22,18**	1*	-0,985		3,752	5,196	NO	OK	OK
			r=1	0,01		-28,941		(0,441)	(0,392)			
PROD5, REL4	M1	4	r=0	28,37**	1*	-1,227		7,208	2,417	OK	NO	OK
			r=1	0,67		-45,444		(0,125)	(0,789)			
PROD6, REL4	M1	3	r=0	34,18**	1*	-1,649		3,502	2,210	OK	OK	OK
			r=1	2,97		-27,949		(0,478)	(0,819)			
PROD7, REL4	M1	4	r=0	24,41**	1*	-0,932		5,024	2,669	OK	NO	OK
			r=1	0,04		46,621		(0,285)	(0,751)			
PROD8, REL4	M1	3	r=0	18,33**	1*	-1,234		3,810	2,463	OK	OK	OK
			r=1	0,14		-23,283		(0,432)	(0,782)			
PROD9, REL4	M1	3	r=0	20,68**	1*	-1,214		4,075	2,647	OK	OK	OK
			r=1	0,00		31,947		(0,396)	(0,754)			

Notes: As for Table 14.

VIII.B. The difference in productivity differentials, in relative prices and the real exchange rate

When investigating the external relationship, let us assume that the B-S effect is also at work between relative prices and the productivity differential in the foreign benchmark[40]. Again, we start by testing the difference in sectoral deflators between the home and the foreign countries and the difference in the productivity differentials. The conclusion that can be drawn based on results presented in Table 16 hereafter is that it is possible to find long-term cointegrating vectors linking the investigated variables. More specifically, we can identify one sound, properly specified relationship, notably for the case when only market services are used for both the domestic and the foreign benchmark countries. This confirms the finding that the public sectors of the countries show differing developments, mainly as regards prices. The significant coefficient of 1,1 leaves no doubt about that this relationship, in accordance with the theoretical models, is a quasi equiproportional one.

Continuing by examining the same relationship using the CPI-based relative price series yields different results. According to the well identified cointegrating vectors, the impact of the productivity differential on the relative price of non-tradable goods compared to that of the non-food tradable goods is over 1,7%, while the according coefficient when using food and non-food prices for tradables is 2,5%. This difference in coefficients might be led back to the fact that food prices grew much slower in the benchmark countries, especially in Finland than non-food prices. Moreover, the coefficients considerable higher than unity and at the same time higher than that obtained for the deflator-based relative price differential have two explanations. The first one is

[40] This hypothesis is not formally tested here, but the raw data analysis tells us that the productivity differentials in the four benchmark countries move broadly in line with the deflator-based relative price series. When CPI-based relative prices are looked at, the conclusion is somewhat darker.

that prices as measured in CPI and as obtained from deflators differ at least as much as for Estonia. Second, the B-S effect seems to have a lower impact on prices in Finland and Sweden than in Estonia, as the same productivity increase results in a smaller relative price increase abroad than in the home country. The reason for this should be searched in the basic hypotheses of the model, and especially in the real wage – productivity relationship in the open sector.

Finally, coming to the real exchange rate, the ADF and PP integration tests indicate that the series used contain a linear trend in first differences (See Table 5 of Appendix 4). Consequently, when the CPI-based real exchange rate is regressed on the CPI-based relative price[41], we could not find a properly specified cointegrating relationship. Even so, the estimated coefficient is as high as 2,2. Combining the coefficient of the relative price – productivity differential and that of the relative price and the real exchange rate vectors, a 1% change in the difference of the productivity differential causes an appreciation in the real exchange rate of at least approximately 3,3%. (1,5*2,2 and a change of 5,5% with 2,5*2,2). These figures are rather high when compared with those suggested by the model. We can find two explanation why the real exchange rate appreciates more than proportionally to productivity. First, different weights for different items in the CPI might be at the root of it. Second, the PPI-based real exchange rate has also sharply appreciated at the beginning of the period under study, moving very closely with the CPI-based real exchange rate. Consequently, not only higher non-tradable inflation caused the real appreciation but also tradable prices growing faster in Estonia than abroad.

Table 16. Cointegration tests for the external transmission mechanism

(RER_CPI, DIFFDEFL, DIFFREL, DIFFPROD)

Relationship	Model	lags	H0	Trace	1	Beta1	Const	Normality J-B	Mardia	Roots	Stability Param.	Rank
PROD1, DEFL1	M2	3	r=0	27,47**	1*	-1,103	0,115	3,580	4,072	OK	OK	OK
			r=1	5,99		-13,556	8,846	(0,466)	(0,539)			
PROD2, DEFL2	M1	1	r=0	14,79*	1*	-1,335		2,343	2,113	NO	OK	OK
			r=1	0,24		-24,722		(0,673)	(0,833)			
PROD3, DEFL3	M1	1	r=0	14,58*	1*	-1,242		2,254	2,070	NO	OK	NO
			r=1	0,34		-25,845		(0,689)	(0,839)			
PROD1, REL2	M1	3	r=0	17,50**	1*	-1,765		1,926	5,381	OK	OK	OK
			r=1	0,04		-15,429		(0,749)	(0,371)			
PROD1, REL4	M1	2	r=0	12,77*	1*	-2,638		13,444	17,679	NO	OK	OK
			r=1	0,19		-20,936		(0,009)	(0,003)			
PROD2, REL2	M1	3	r=0	17,81**	1*	-1,968		2,616	4,838	NO	OK	OK
			r=1	0,00		-17,729		(0,624)	(0,436)			
PROD2, REL4	M1	2	r=0	14,35*	1*	-2,497		5,661	2,486	OK	OK	OK
			r=1	0,69		-24,243		(0,226)	(0,780)			
PROD3, REL2	M1	3	r=0	17,71**	1*	-1,767		2,438	5,216	OK	OK	OK
			r=1	0,00		-19,000		(0,656)	(0,391)			
PROD3, REL4	M1	2	r=0	14,53*	1*	-2,832		2,317	3,559	NO	NO	OK
			r=1	0,77		23,600		(0,599)	(0,604)			
REL2, RER2	M1	2	r=0	22,56**	1*	1,548		4,135	4,421	OK	OK	OK
			r=1	6,00		0,062		(0,388)	(0,491)			
REL2, RER_CPI	M1	2	r=0	25,21**	1*	2,172		4,358	14,143	NO	OK	OK
			r=1	0,01		37,448		(0,360)	(0,015)			

Notes: As for Table 14.

[41] The same exercise is not performed between the CPI-deflated real exchange rate and the GDP deflator-based relative price series as it would not make too much sense.

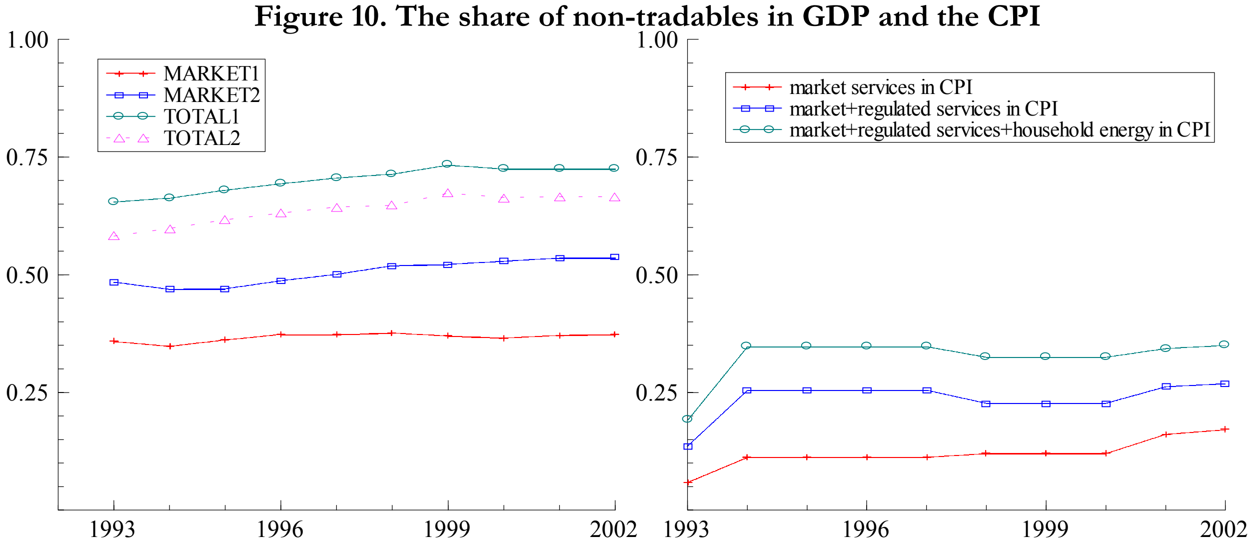
IX. Descriptive statistics: A routine exercise

IX. A. Structural inflation in Estonia

Up to now, we have tried to determine whether changes in the relative price of non-tradable goods are linked to productivity advances in the traded goods sector. However, the impact of the B-S effect on Estonian inflation depends also on the size of the productivity differential and the share of non-traded goods in GDP and CPI (cf. equation 36). We therefore proceeded to compute the average yearly increase of the productivity differential for the period under consideration. Two measures of productivity growth are used: average annual change in the original productivity series [42] and the long-term trend obtained using the Hodrick-Prescott (HP) technique. As we observe a step-like increase in all productivity differentials at the beginning of the period under study, in addition to the whole period we also calculated averages for the sub-periods of 1995-2002 and 1996-2002. Actually, as can been seen in Figure 11. below, the average productivity growth for the whole period ranges from 6% to 11%, which is considerably higher than in the sub-periods when it amounted to 2% - 6%. The figures also show that the differences in productivity growth between different periods are less marked when the long-run trend approximated using the HP technique is employed for the calculation.

As the impact of the B-S effect passes through the increase in the price of non-tradable goods, we need to know the respective share non-tradables represent in GDP and in the consumer price basket. Using the share in GDP for the two market-based non-tradable sectors and the two non-tradable sectors definition[43] including all non-tradable sectors shows that the share of non-tradables in Estonian GDP varies from 35% up to 70%, depending on the definition of the closed sector. According to the theoretical model, only the market-based closed sectors should be taken into account, i.e. when prices are directly linked to wage costs. However, there are good reasons to think that the regulated or public non-tradable sectors will similarly behave in the long-run because of some spill-over effects from market-driven non-tradable sectors towards the rest of the closed sector of the economy. As to the CPI, market-based non-tradable items account on average for a mere 12% during the period from 1993 to 2002. Including also regulated services yields an average weight of 23,7% in CPI. An even broader definition of non-tradables, i.e. taking household energy into consideration, the respective figure rises to 32,5%. In order to get an impression on the differences shares of non-tradable goods in the implicit GDP deflator and in CPI exhibit, their developments are plotted in the figures below.

Figure 10. The share of non-tradables in GDP and the CPI



[42] Averages are calculated for all 9 productivity measures as in the data section.
[43] NT_MARKET1, NT_MARKET2, NT_TOTAL1, NT_TOTAL2

Hence, we expect that the B-S effect has a higher impact on the deflator than on the consumer price index.

Figure 11. Average productivity growth

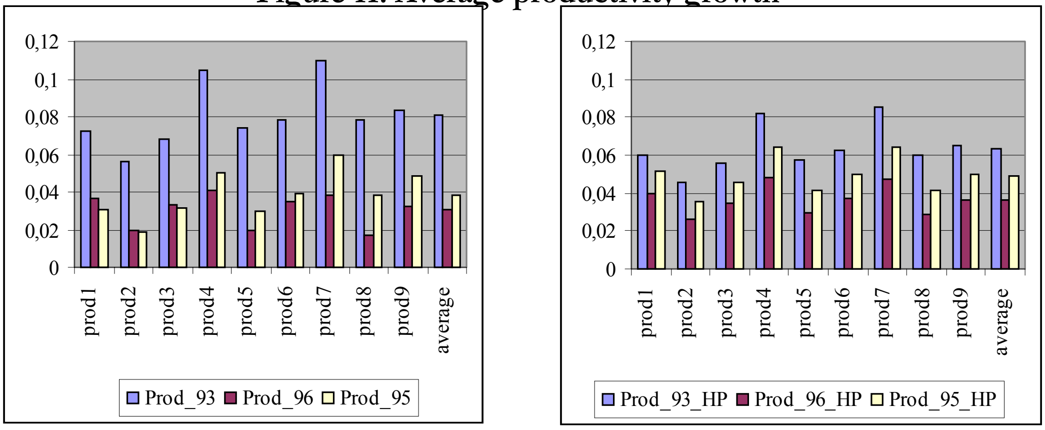


Figure 12. Measures for CPI

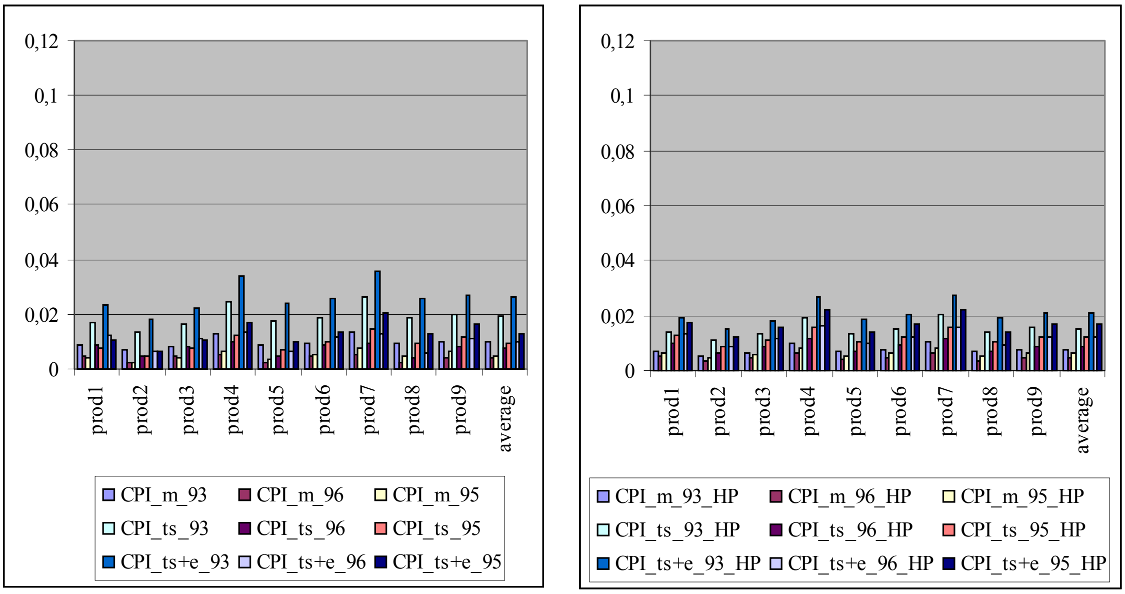
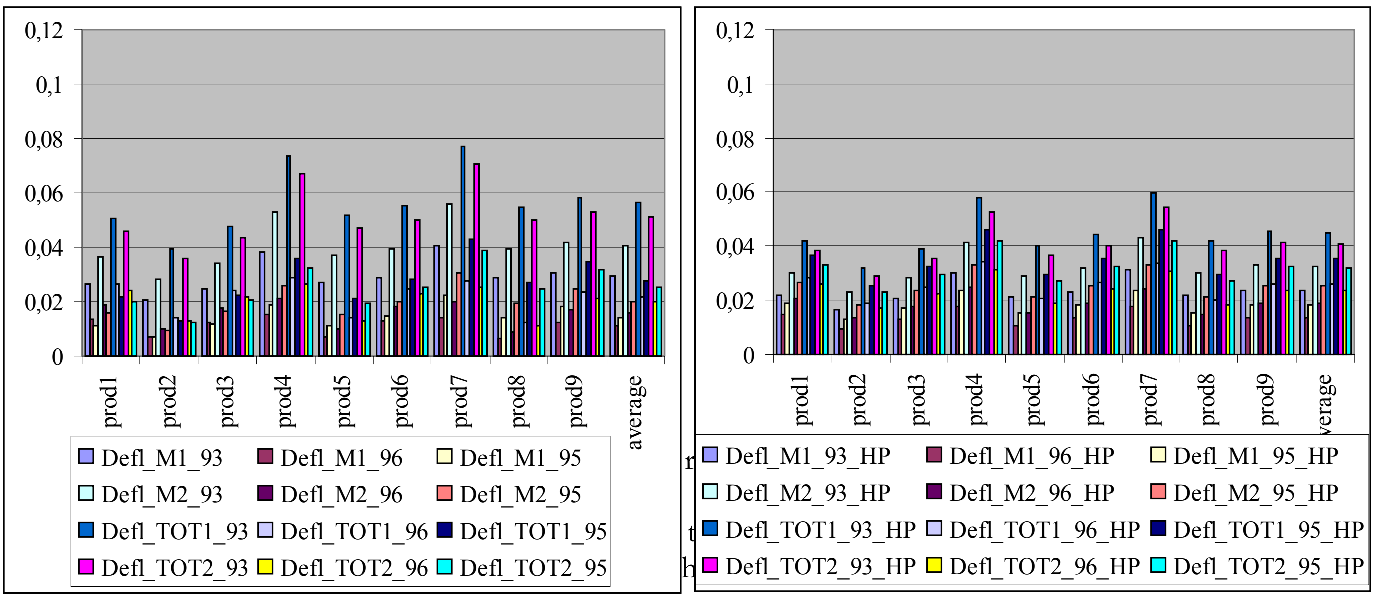
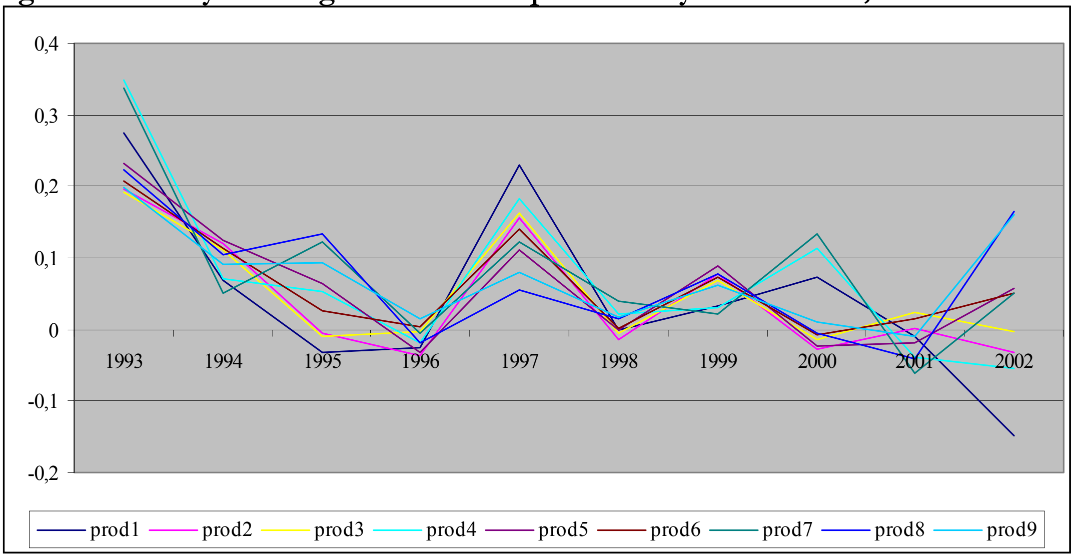


Figure 13. Measures for GDP deflator



per annum. However, because productivity increases and hence the B-S effect was stronger in the beginning of the period under study, it is worth having a look on the annual productivity and B-S inflation figures. Therefore, for each year of the investigated period, growth rates of the productivity differential are calculated using both the original series and the trend obtained using the HP technique. Figures presenting the results obtained for the original series indicate that there were two major hike in productivity growth, namely in 1993 and in 1997. In these years, the productivity differential grew by 20-30% and over 10%, respectively. Consequently, this also would mean that the B-S effect should have been higher during these periods compared to the rest of the period, both in terms of the GDP deflator and the CPI.

Figure 14. Yearly rate of growth of the 9 productivity differentials, 1993-2002



However, as the B-S effect is considered as a long-term phenomenon and given the relatively short period under observation, it seems to be more appropriate to analyse the long-term component of the series.

Figure 15. Year-on-year growth rate in productivity using trend estimates, 1993-2002

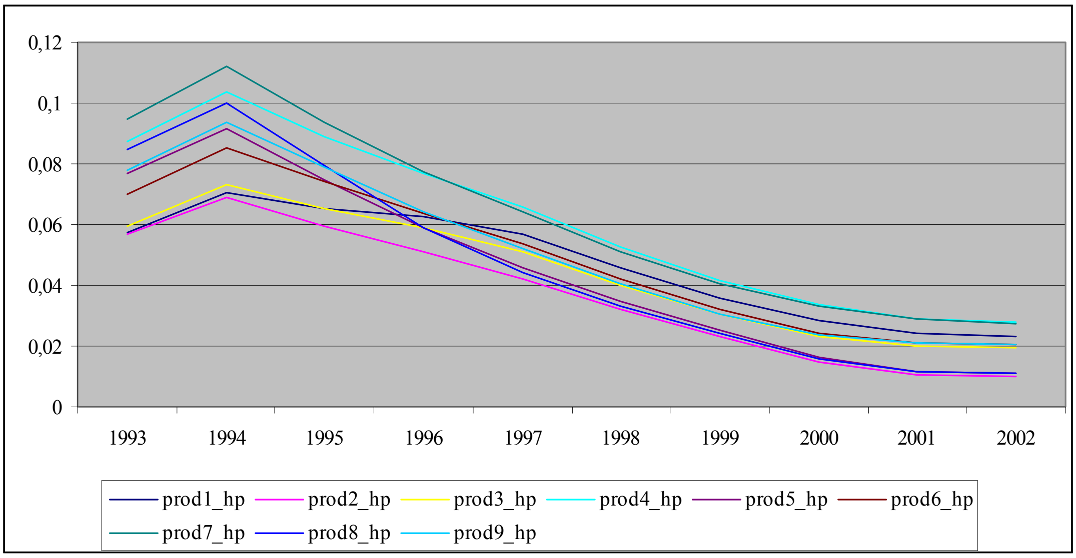
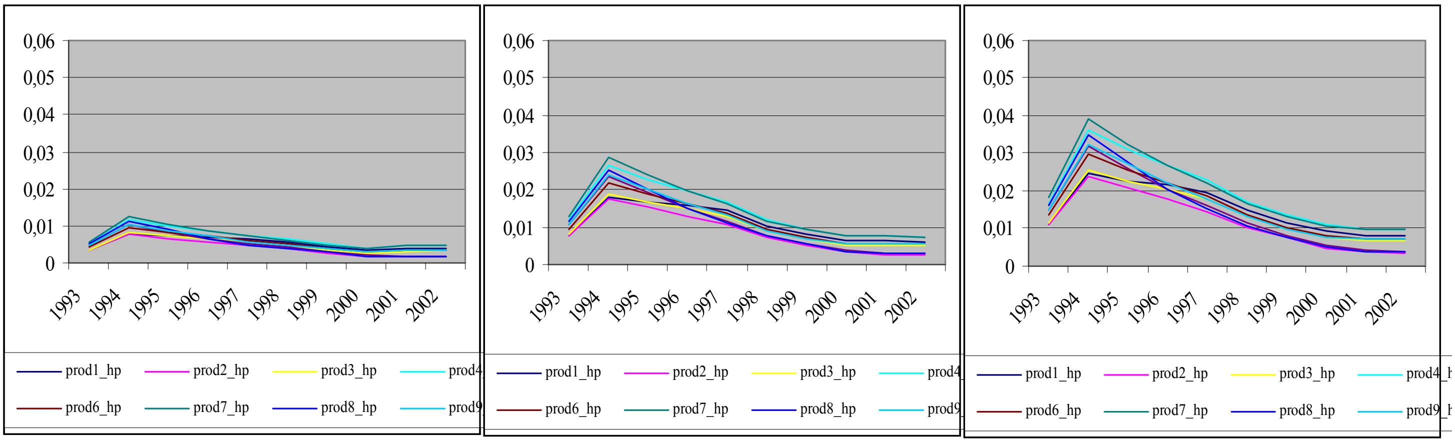


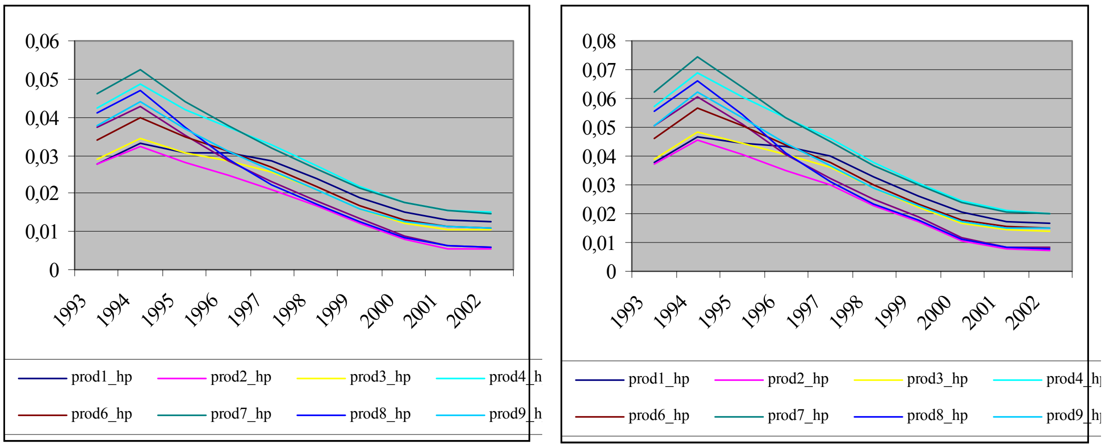
Figure 16. reveals that, irrespective of the different classifications of the sectors into tradable and non-tradable, the trend in the rate of growth of the productivity differential has been on a

decreasing path since 1994 and seems to be stabilised at the end of the period in the band of 1% to 3%. The corresponding figures for the consumer price inflation and the GDP deflator are shown below.

Figures 16. Productivity growth and the consumer price index, 1993-2002[44]



Figures 17. Productivity growth and the GDP deflator, 1993-2002[45]



From the analysis we conclude that the productivity driven inflation in Estonia has been rather low during the investigated period. Using the strict model, i.e. weights for market services in CPI, we find that while inflation due to the B-S effect peaked in 1994 with about 1%, the structural inflation steadily decreased to 0,3 to 0,5% in 2000 and 2001. Taking a broader definition of non-tradables, the resulting contribution to overall inflation is higher as it ranges between 3% and 4% in 1994 and somewhere between 0,5% to 1% at the end of the period.

Looking forward, the impact of productivity driven price increases on the CPI could increase again. As we have shown earlier, the share of non-tradables in GDP is at least twice as high as in the consumer price basket. In developed EU countries such as Germany and France the structure of the CPI is much closer to that of the than in Estonia. So, as the structure of the Estonian GDP is very similar to that in the aforementioned countries, we can expect the share of services

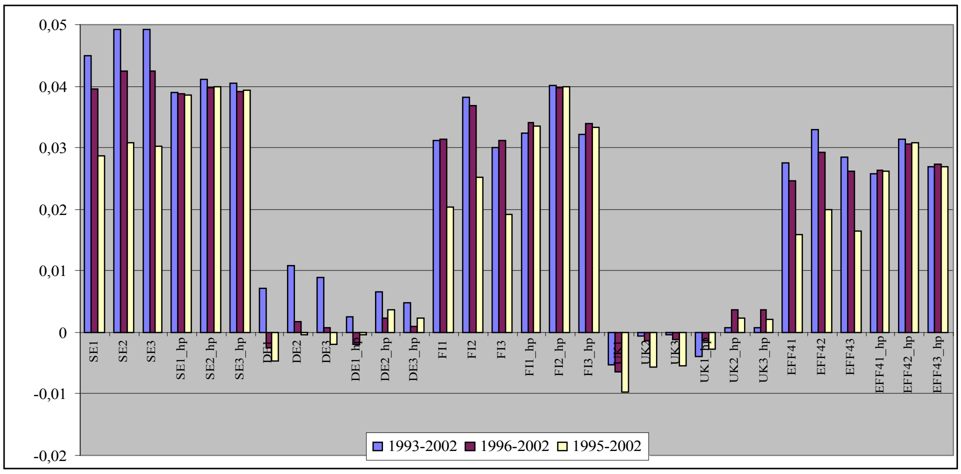
[44] Weights for market services, for total services and finally for total services plus household energy are used respectively in Figures 16a, b and c.
[45] Weights for NT_MARKET2 and NT_TOTAL1 are used, respectively.

in CPI to rise with the catch-up process.[46] If the share of non-tradables in GDP is seen as a target value for the CPI, Figure 17 can provide a general idea on the potential long-term inflation in Estonia. Accordingly, all things being equal, it can be placed in a band of 0,5% to 2%.

IX. B. The structural inflation differential vis-à-vis the benchmark countries

We have shown that the productivity differential is strongly related to the relative price of non-tradables in Estonia when using GDP deflators or market service prices from the CPI. However, with the share of non-tradables being rather low in CPI, the overall inflation due to the B-S effect seems to be situated between 0,5% and 2,5%. The question this provokes is that of the size of the inflation differential driven by productivity gains compared with its main trading partners. Similarly to the case of Estonia, we determine the average inflation rate for the benchmark countries. The average annual productivity figures depicted in Figure 18. below reveal that the average growth in the productivity differential has been rather high in Sweden and Finland, whereas productivity advances in Germany and the UK are low. As Finland and Sweden make up to 70% of the effective basket, it also exhibits substantial increases, up to 3% p.a. Applying the share of services in CPI leads to the estimated size of the B-S effect in those countries. We are basically interested in the inflation differential vis-à-vis the four countries taken together and against Germany. The effective benchmark is important for Estonia, and Germany is often considered as a good proxy for the euro zone.

Figure 18. Average productivity growth in the foreign countries, 1993-2002



According to the cointegration analysis, the difference in the productivity differentials is connected to the difference in GDP deflator-based relative prices with a coefficient close to one. Nevertheless, the estimated coefficient between the difference in productivity differentials and the CPI price-based relative price of non-tradable goods, i.e. market services turns out to be close to 2. Given that the corresponding coefficient for the Estonian economy is found to be close to 1, this means that a change in the productivity differential in the foreign countries is to be well below 1, i.e. approximately 0,5. In turn, this implies that let's say a 1% change in productivity with a share of services as high as 50% in CPI will bring about 0,25% overall inflation instead of 0,5%. To find out exactly how are productivity and CPI-based relative prices linked, formal econometric tests were carried out. Results shown in Table 17. indicate that the tests were unable to reject to null of no cointegration or the estimated coefficients are badly signed and not

[46] Economic growth and increasing wealth means that a larger variety of goods can be consumed reflected in an increased share of services in the CPI basket.

significant for the relationships including the 3 productivity measures and REL2 and REL4[47]. We then went on examining the linkage between productivity and REL1 and REL3[48] and could establish long-run relationships reported in the same table. The coefficients we are interested in are, as expected, below unity, namely around 0,6. Although the diagnostic tests are disastrous, this might give us some indications as to the coefficient between productivity and REL2 and REL4. However, they represent an upper-bound estimation as REL1 and REL3 definitely grow faster than REL2 and REL4. The answer for why productivity increases are not fully reflected in the relative price of CPI market and total services is provided by wage settings in Sweden and Finland. First, real wages lag behind productivity growth in the open sector and second, nominal wages rise slower in the closed sector compared with the open sector.

Table 17. Cointegration tests for the internal transmission mechanism, effective foreign benchmark

Relationship	Model	lags	H0	Trace	1	Beta1	const	Normality J-B	Mardia	Roots	Stability Param.	Rank
PROD1, REL2	M2	1	R=0	27,00**	1	0,045	-0,147	8,574	7,800	NO	OK	OK
			R=1	5,05		0,194	-4,323	(0,073)	(0,168)			
PROD1, REL4	M3	2	R=0	9,55				3,469	2,192	OK		
			R=1	1,99				(0,484)	(0,822)			
PROD2, REL2	M2	1	R=0	28,36**	1	0,0001	-0,139	7,548	5,383	OK	OK	OK
			R=1	5,04		0,000	-4,483	(0,110)	(0,371)			
PROD2, REL4	M3	2	R=0	11,23				3,383	1,927	NO		
			R=1	2,59				(0,496)	(0,859)			
PROD3, REL2	M2	1	R=0	27,30**	1	0,0004	-0,138	8,119	5,900	OK	OK	OK
			R=1	5,02		0,000	-4,313	(0,087)	(0,316)			
PROD3, REL4	M1	3	R=0	34,18**				3,502	2,210	OK		
			R=1	2,97				(0,478)	(0,819)			
PROD1, REL1	M3	2	R=0	24,14**	1*	-0,621		2,936	6,493	NO	NO	OK
			R=1	0,84		-16,784		(0,569)	(0,261)			
PROD1, REL3	M3	3	R=0	15,16				7,556	5,849	NO		
			R=1	1,23				(0,109)	(0,321)			
PROD2, REL1	M3	2	R=0	25,80**	1*	-0,525		3,227	2,305	NO	OK	NO
			R=1	0,37		-18,103		(0,521)	(0,806)			
PROD2, REL3	M3	2	R=0	18,56*	1*	-0,792		5,505	0,477	NO	OK	NO
			R=1	0,71		-15,231		(0,339)	(0,993)			
PROD3, REL1	M3	2	R=0	23,80**	1*	-0,599		2,756	4,101	NO	OK	NO
			r=1	0,78		-16,189		(0,599)	(0,535)			
PROD3, REL3	M3	3	R=0	16,08*	1*	-0,865		6,412	5,980	NO	OK	NO
			r=1	1,42		-14,340		(0,170)	(0,308)			

Notes: As for Table 14.

When estimating the foreign structural inflation, we face severe uncertainties. Firstly, as shown by the cointegration analysis, changes in productivity might not be linked to relative price developments. Second, the coefficients we estimated are not robust. So, we first consider the B-S

[47] With food and non-food goods being tradable. The reason for using these relative price measures is that they turned out be working better for Estonia than REL1 and REL3. However, in the case of Estonia, there are no big differences in the tradable goods whether or not food is excluded. However, , this is definitely not the case for the foreign benchmark countries.

[48] Where food items are excluded from the tradable category.

inflation equal to zero in the foreign countries, considering it as a lower bound estimate. Next, the inflation rate brought about by the B-S effect if calculated multiplying productivity growth rates by the share of both market and total services in CPI and the estimated coefficient linking productivity and relative prices. These upper bound are then compared with the estimates obtained for Estonia (Cf. Figure 18).

Figure 18. The average impact of productivity growth on CPI inflation differentials, 1993-2001

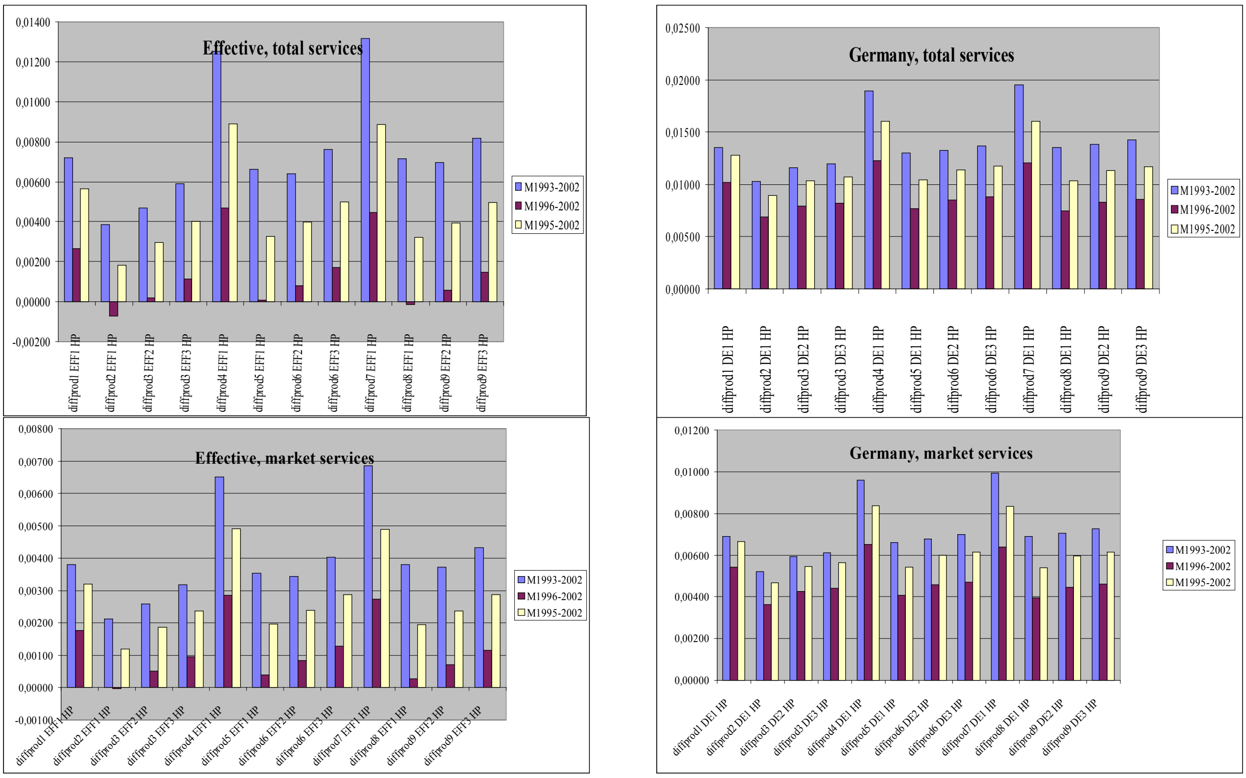
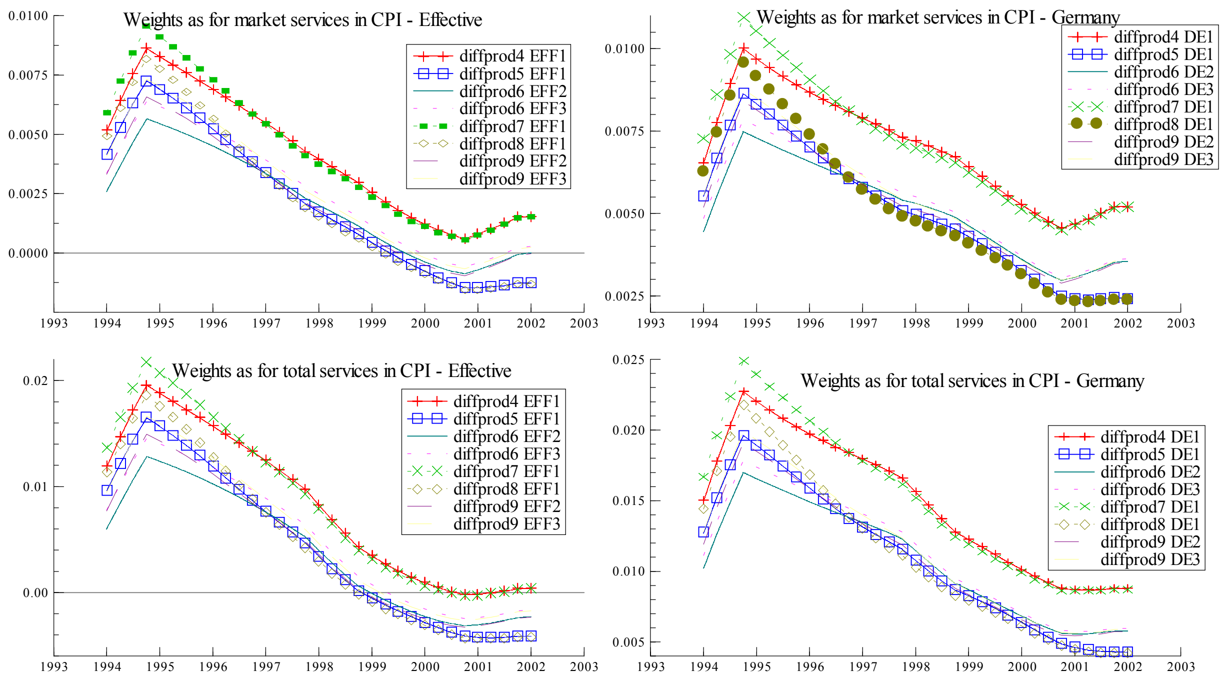
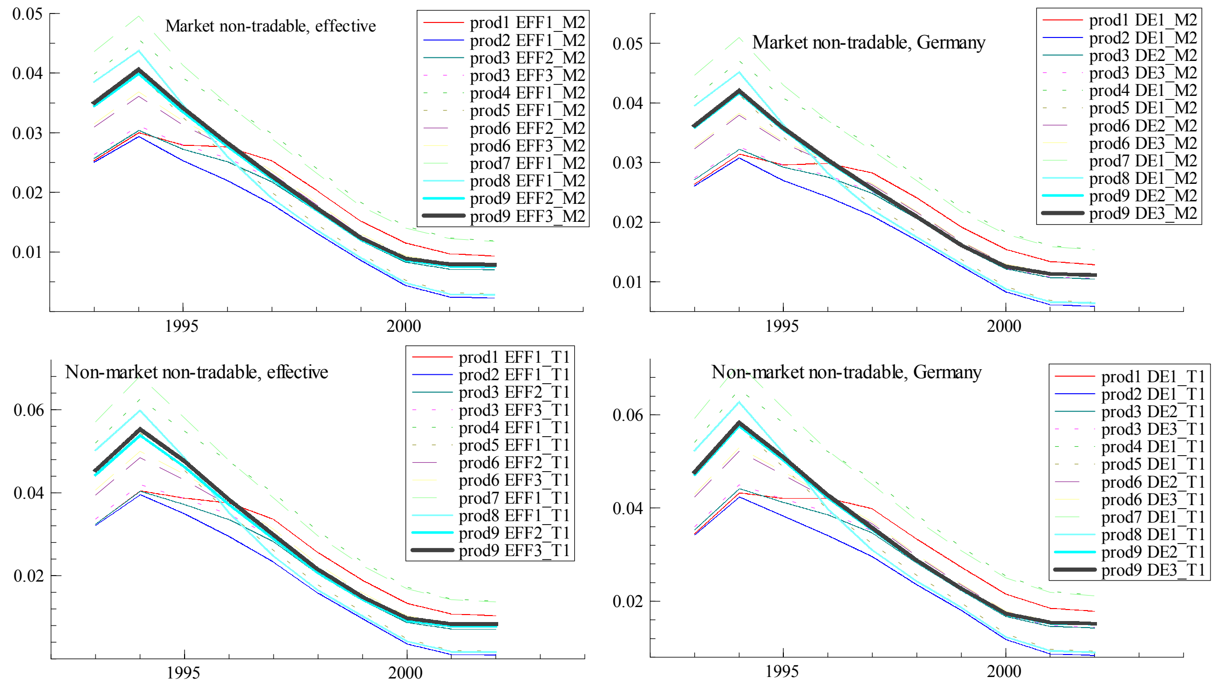


Figure 19. The impact of productivity growth on CPI inflation differentials, 1994:Q1-2002:Q1



As can be seen in Figure 19, the actual influence of the B-S effect on the inflation differential varies from 0,3% to 0,8% for the effective benchmark, and from 0,6% to 1,5% for Germany if we consider the whole period under study. It is clear that the inflation differential is higher in the early years of the period and then steadily declines to 0% for the effective benchmark and to 0,25% to 0,5% for Germany at the very end of the period. However, assuming once again the convergence of non-tradable share's in CPI towards that in GDP, all things being equal, the inflation differential brought about by the B-S effect should range, in the long run, from 0,5% to 1,5% for the effective benchmark and from 1% to 2% for Germany.

Figure 20. The potential impact of productivity growth on CPI inflation differentials, 1994:Q1-2002:Q1

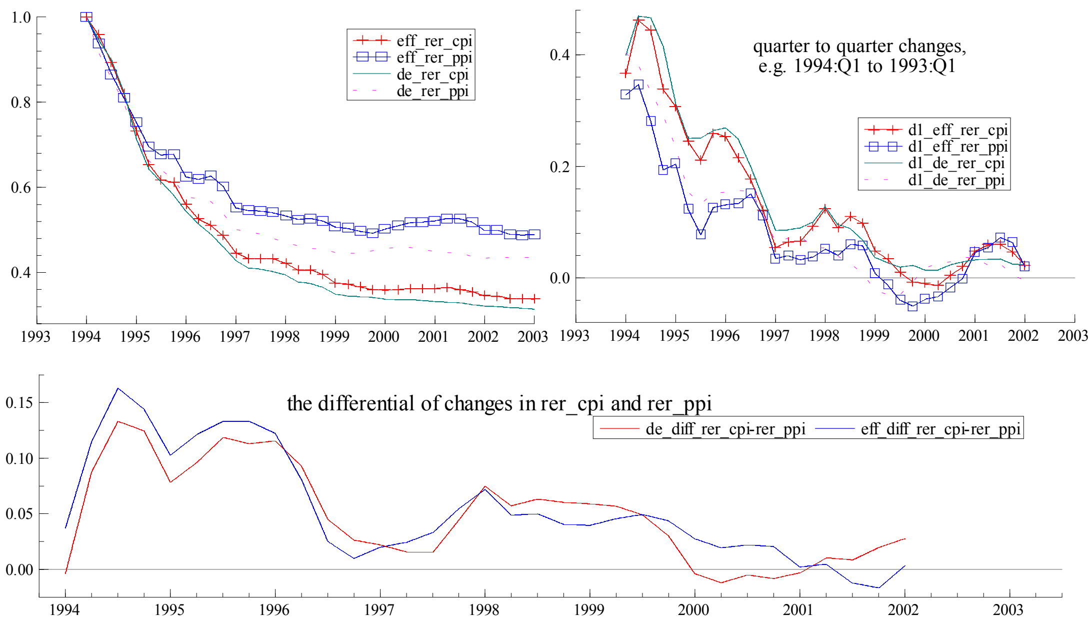


IX. C. The appreciation of the real exchange rate

Determining the inflation differential between Estonia and its trading partners enables us to assess whether the extent of the appreciation of the real exchange rate is in line with what the B-S effect would imply. First, it is worth having a quick look at the CPI and PPI-based real exchange rates vis-à-vis the basket of foreign countries and Germany. According to the model, the B-S effect, since it operates through the prices of non-tradable goods, can explain the excess appreciation of the CPI-based real exchange rate over the appreciation of the PPI-deflated real exchange rate. Therefore, for the B-S model to fully explain the real appreciation of the currency, the purchasing power parity should hold for the PPI-deflated real exchange rate. In other words, the real exchange rate deflated by non-tradable goods should be stationary. As plotted in Figure 21 below, the CPI and the PPI-based real exchange rates moved in tandem at the beginning of the period under investigation. Hence, this real appreciation could not have been caused by the B-S effect. However, the visual inspection confirms that after this period, the appreciation of the PPI-based real exchange rate slowed down compared with that of the consumer price-based real exchange rate, and finally it stabilised from 1997/1998 onwards, both in effective terms and against the German mark. Consequently, there is more scope for the B-S effect in the second half of the period under investigation. As noted earlier, both the CPI-based and the PPI-based real exchange rates contain a linear trend in first differences. It could mean either that the series are explosive or that they collapse very quickly to a certain value. In the case of Estonia, the meaning of this is that the exchange rate series converge towards a long-term value. Actually, this is in line with the B-S effect and PPP if the PPI-deflated real exchange rates converges faster than the CPI-based series so that the gap can be explained by the B-S effect. In fact, this is probably the case. In Figure 21. the gap between the CPI and the PPI-based real exchange rate is depicted. The B-S effect, i.e. the inflation differential related to higher productivity growth should actually explain this difference, which, as shown in Figure 21, is rather substantial at the beginning with over 15%, and decreasing to 0% at the end.

However, it must not be forgotten that the official CPI with the aid of which the real exchange rate is calculated has a number of drawbacks making this mission impossible. First, there is the regulated price component of the CPI, which, in the case of Estonia largely outpaces other CPI-components and thus brings about an excessive real appreciation. Two artificial CPI indexes are constructed, both for Estonia and for its trade partners. The first one consists of market service prices and the combined series of food and non-food goods, with the share of market services in the original CPI being attributed for services and the rest (1-(share of market services)) for the traded goods (RER2). The second differs only in the weights, as the share of total services in the original CPI is attributed to the market service series[49], the rest being considered as the weight for the tradable goods. This method allows us to control for regulated prices, fuel, alcohol and tobacco, which are simply not taken into account (RER4). However, the problem of differing weights across countries still persists. The weights in the newly constructed CPI are therefore normalised to weights used in the Estonian consumer price index and so making the CPI-based real exchange rate fully comparable with the inflation differential provoked by the B-S effect.

Figure 21. The CPI and PPI-deflated real exchange rates, cumulated and Y-o-Y changes



The gaps between the real exchange rate constructed using service and good price series and the PPI, and the combined food and non-food goods price-deflated real exchange rate are depicted below with the corresponding changes of the difference in the productivity differentials. We can

[49] Assuming that regulated prices should behave similarly to market services in the longer run.

observe that whilst the huge initial gap is not explained by the productivity driven inflation differential, the difference between the two real exchange rate series are relatively well explained afterwards. We note however that this is especially the case for the German mark.

Figure 22. The CPI-PPI gap and the productivity driven inflation differential

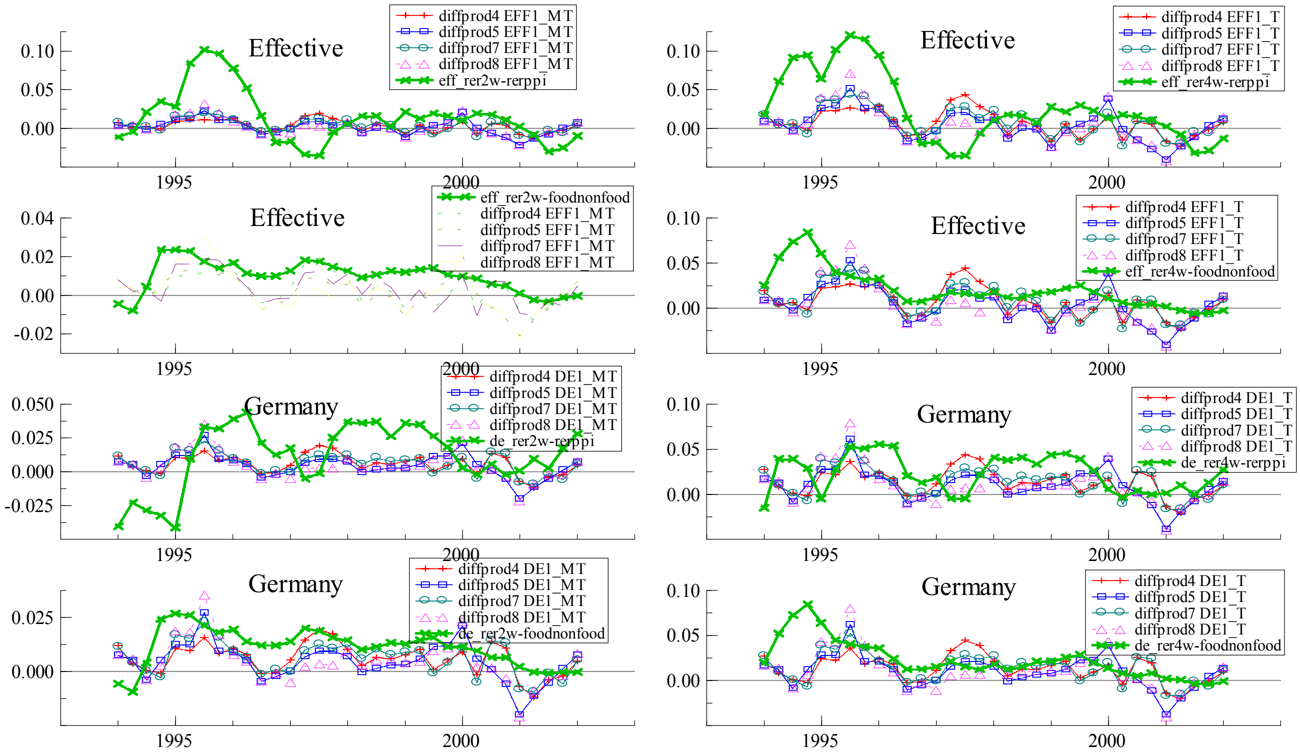
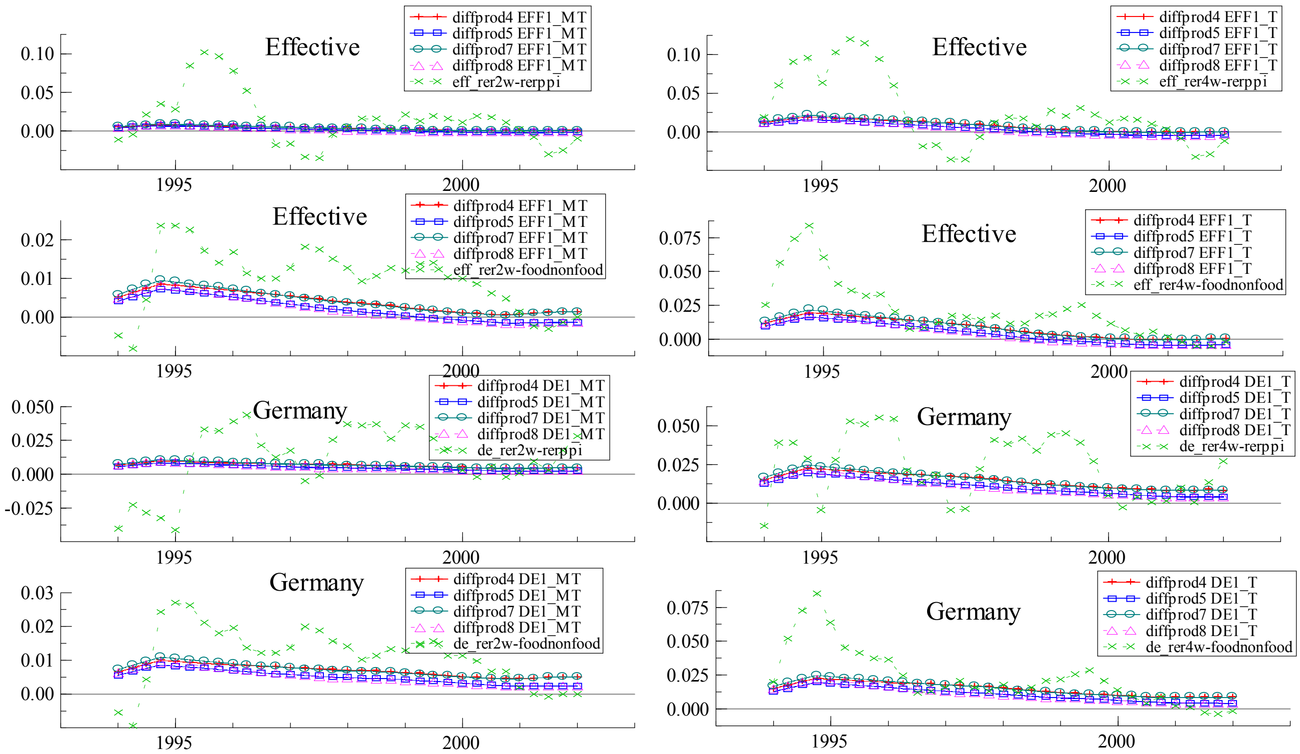


Figure 23. The CPI-PPI gap and the productivity driven inflation differential, HP filter



X. Concluding remarks

In this paper, we examined the B-S effect and its influence of the nominal and real convergence in Estonia. Based on very disaggregated sectoral GDP and CPI data, the main findings of our investigation are as follows:

First, all major assumptions of the B-S model are found to be fulfilled. So, we found, not surprisingly, that the productivity differential is linked to the GDP deflator-based relative price of non-tradable goods.

Second, the notable difference between the GDP deflator and the CPI has to be emphasised. The two series differ not only in their structure, which will have serious consequences later on, but also in the developments of their components. One of the most important difference is the share of non-tradable goods: the GDP deflator contains at least twice as much non-tradable goods as the consumer price index. On the other hand, the CPI is largely dominated by regulated prices that increases twice as fast as normal services. As a consequence, the cointegration analysis could not establish long-term relationship between the productivity differential and the CPI-based relative price of non-tradable including regulated prices. However, controlling for regulated prices, i.e. excluding these items allows us to detect a nearly one-to-one relationship between productivity and the relative price of market services.

Third, the analysis also revealed the fact that the classification as regards the open and the closed sector may influence results: the cointegration analysis suggests that construction and the transport, storage and telecommunication sectors do not belong to the open or the non-market closed sector, but are rather market-driven non-tradable sectors.

Fourth, the quantitative analysis indicates that in spite of huge productivity advances in Estonia, the impact of the B-S effect has been rather limited on overall inflation between 1993 and 2002. The main reason for this is the very low share of market and total services in the CPI basket. We established that the average contribution of the B-S effect to overall inflation has been 0,5% to 2%. Although the productivity driven inflation peaked in 1994 with 4-5%, it has dropped to 0,3% to 1% in 2001. Nevertheless, the B-S effect might be amplified in the future due to an increased share of services in CPI. Considering the share of non-tradable sectors in GDP as a long-term target value for the structure of CPI, we estimated the long-term potential inflation of the Estonian Economy to 1%-2%.

Fifth, we could also establish quasi equiproportional relationships between the difference of the productivity differential in Estonia and its main Western trading partners, notably Finland, Sweden, Germany and the UK and the difference in the implicit GDP deflator-based relative price of non-tradable goods. However, the CPI-based relative price differential shows that productivity advances in the foreign countries' open sector are less than proportionally translated into service price increases, because of the wage setting system. Even so, productivity increases are big enough in Finland and Sweden to bring down the B-S related inflation differential from 1-2% in 1994 to close to zero in 2001. Even though the inflation differential steadily decreases vis-à-vis Germany, it amounts to 0,2-1% in 2001. This implies that even if the long-term potential differential is higher with 0,2-2%, fulfilling the Maastricht criterion on price stability will not be hindered because of the B-S effect. The actual and the potential inflation differentials are also indicating the size of the real appreciation of the Estonian kroon, which can be justified by the B-S effect.

Sixth, turning to the past, we argue that even though the B-S effect was higher in the early years of the period under investigation, it could hardly explain the huge real appreciation. Controlling for regulated prices and differing weights in Estonian and foreign consumer price indexes, we show that the lower real appreciation in the second half of the period is better explained by productivity driven inflation differentials, e.g. the B-S effect. In fact, the traded good price-based real exchange rate seems to stop appreciating and consequently ensures more room for the B-S effect.

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Appendix 1. Data sources

Estonia
Nominal sectoral GDP: Bank of Estonia
Real sectoral GDP: Bank of Estonia
Number of employees: Bank of Estonia
Average nominal wages: Statistical Office of Estonia, www.stat.ee
CPI: Statistical Office of Estonia
PPI: Statistical Office of Estonia
EEK/EURO: Bank of Estonia
EEK/DEM: Bank of Estonia
EEK/FIM: series converted using FIM/DEM obtained from Pacific Exchange Rates
EEK/SEK: series converted using SEK/DEM obtained from Pacific Exchange Rates
EEK/GBP: series converted using GBP/DEM obtained from Pacific Exchange Rates

Finland
Nominal sectoral GDP: Statistical Office of Finland
Real sectoral GDP: Statistical Office of Finland
Number of employees: Statistical Office of Finland
Total compensation: Statistical Office of Finland
CPI: Statistical Office of Finland
PPI: Statistical Office of Finland

Germany
Nominal sectoral GDP: Eurostat
Real sectoral GDP: Eurostat
Number of employees: Eurostat
Total compensation: Eurostat
CPI: Eurostat and Bundesbank
PPI: Eurostat and Bundesbank

Sweden
Nominal sectoral GDP: Statistical Office of Sweden
Real sectoral GDP: Statistical Office of Sweden
Number of employees: Statistical Office of Sweden
Total compensation: Statistical Office of Sweden
CPI: Statistical Office of Sweden
PPI: Statistical Office of Sweden

United Kingdom
Nominal sectoral GDP: Eurostat
Real sectoral GDP: Eurostat
Number of employees: Eurostat
Total compensation: Eurostat
CPI: Bank of England
PPI: Bank of England

Appendix 2. Data

Figure 1. Estonia, productivity differentials and GDP deflator-based relative prices

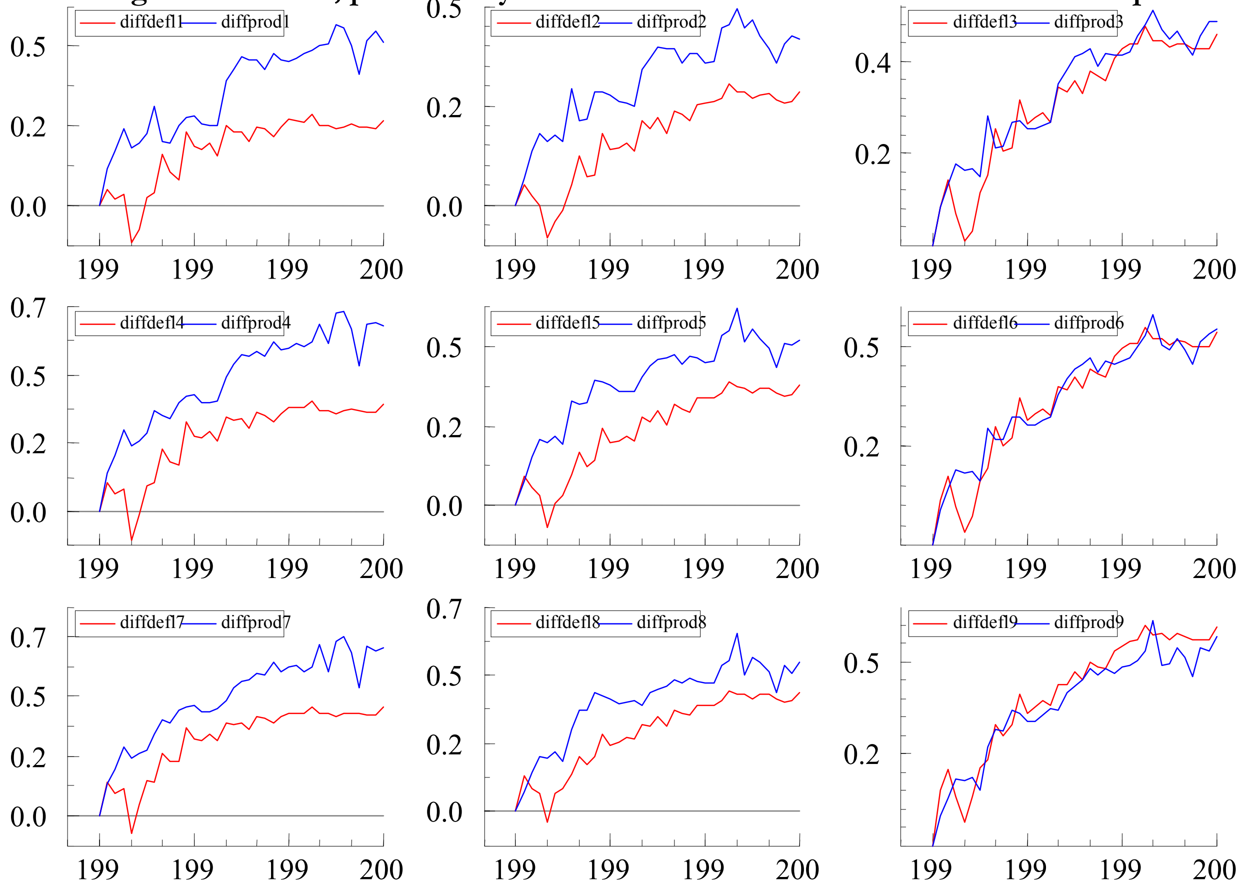


Figure 2. Estonia, productivity differentials and CPI price-based relative prices

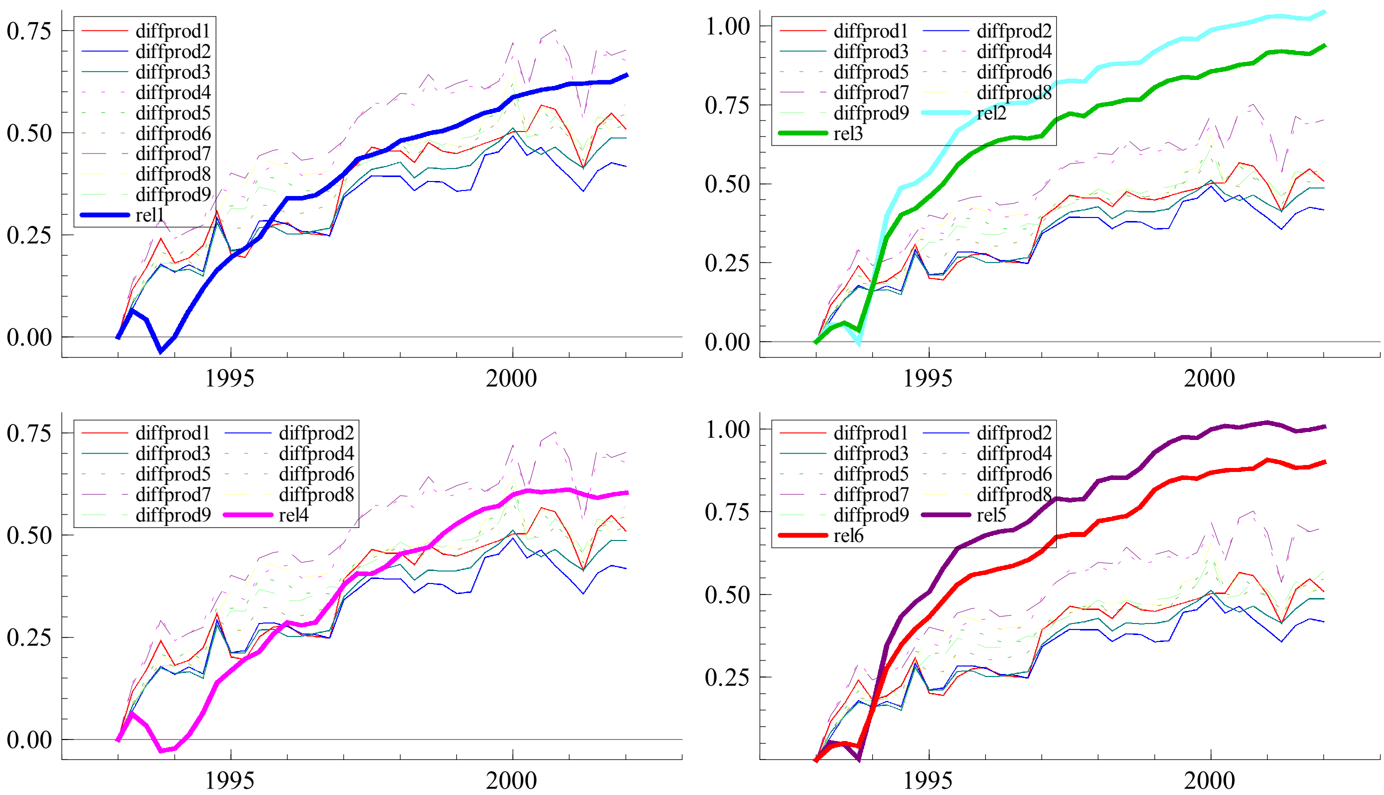


Figure 3. Foreign benchmark (4 countries), internal transmission mechanism

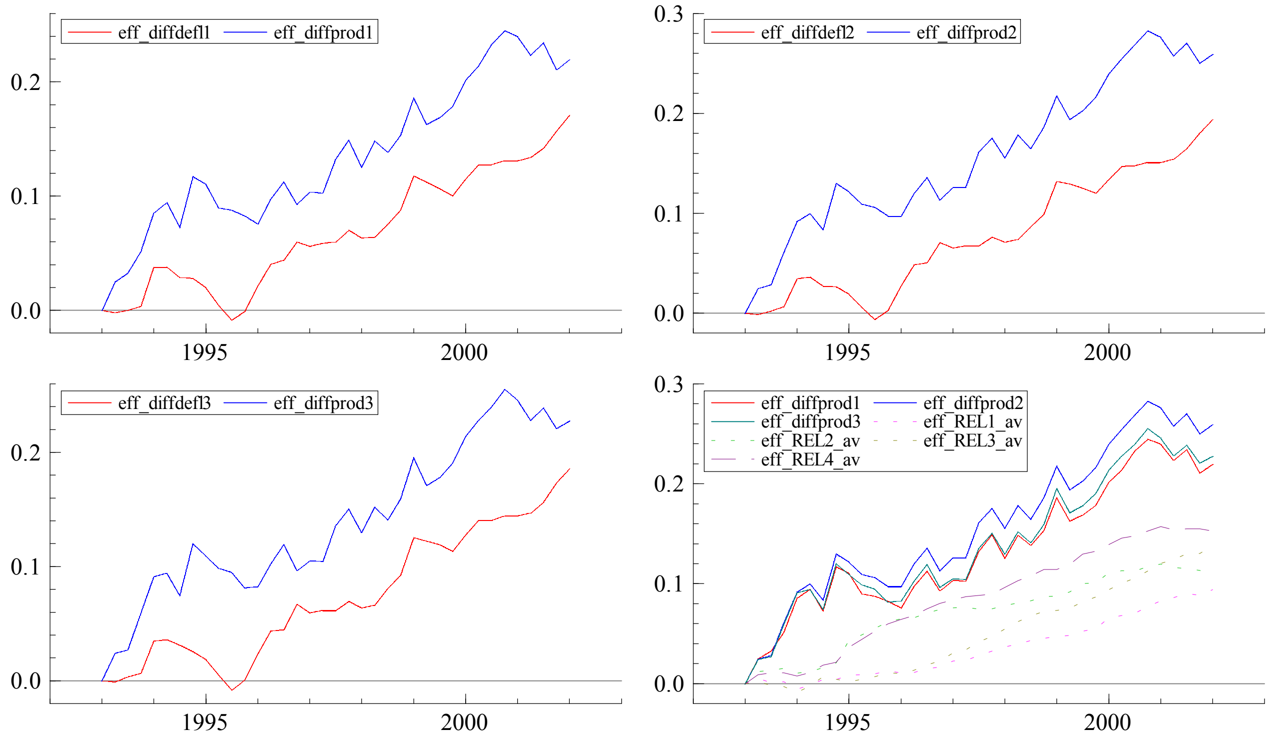
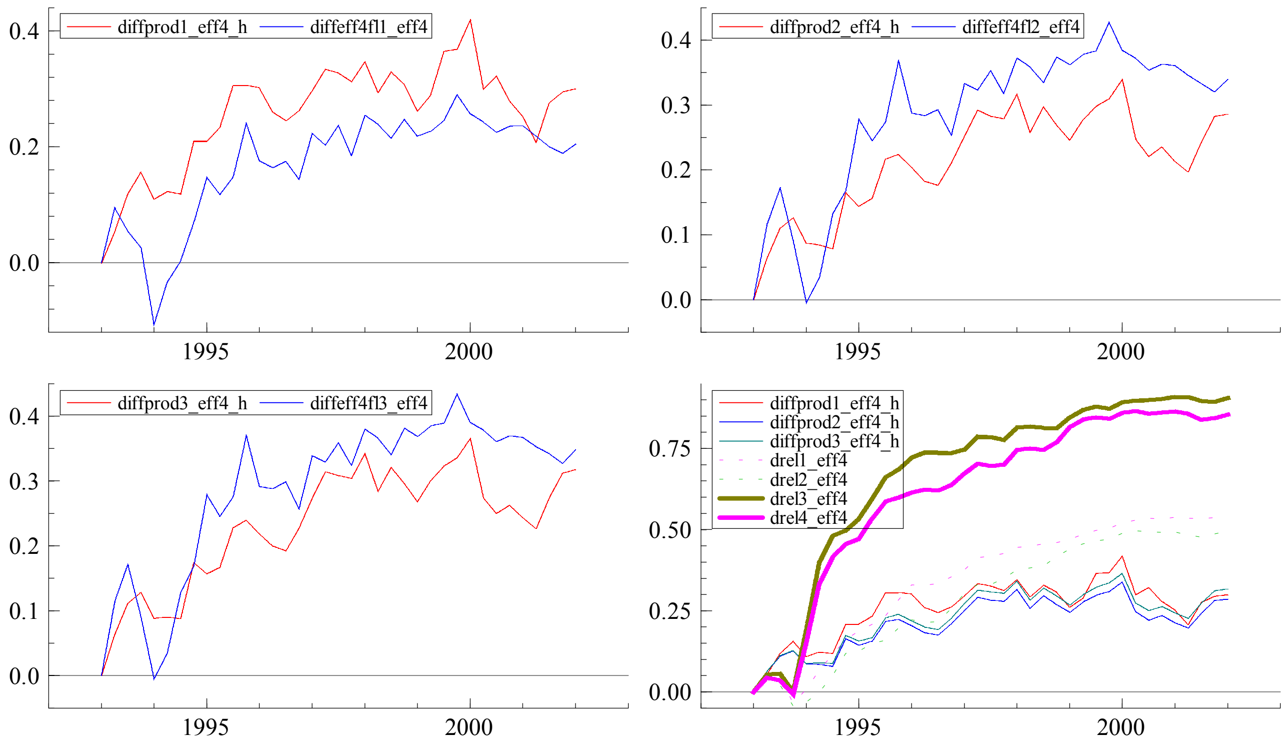


Figure 4. Differences between Estonia and the foreign benchmark



Appendix 3. Testing strategies

Figure 1. **Testing strategy for unit roots**

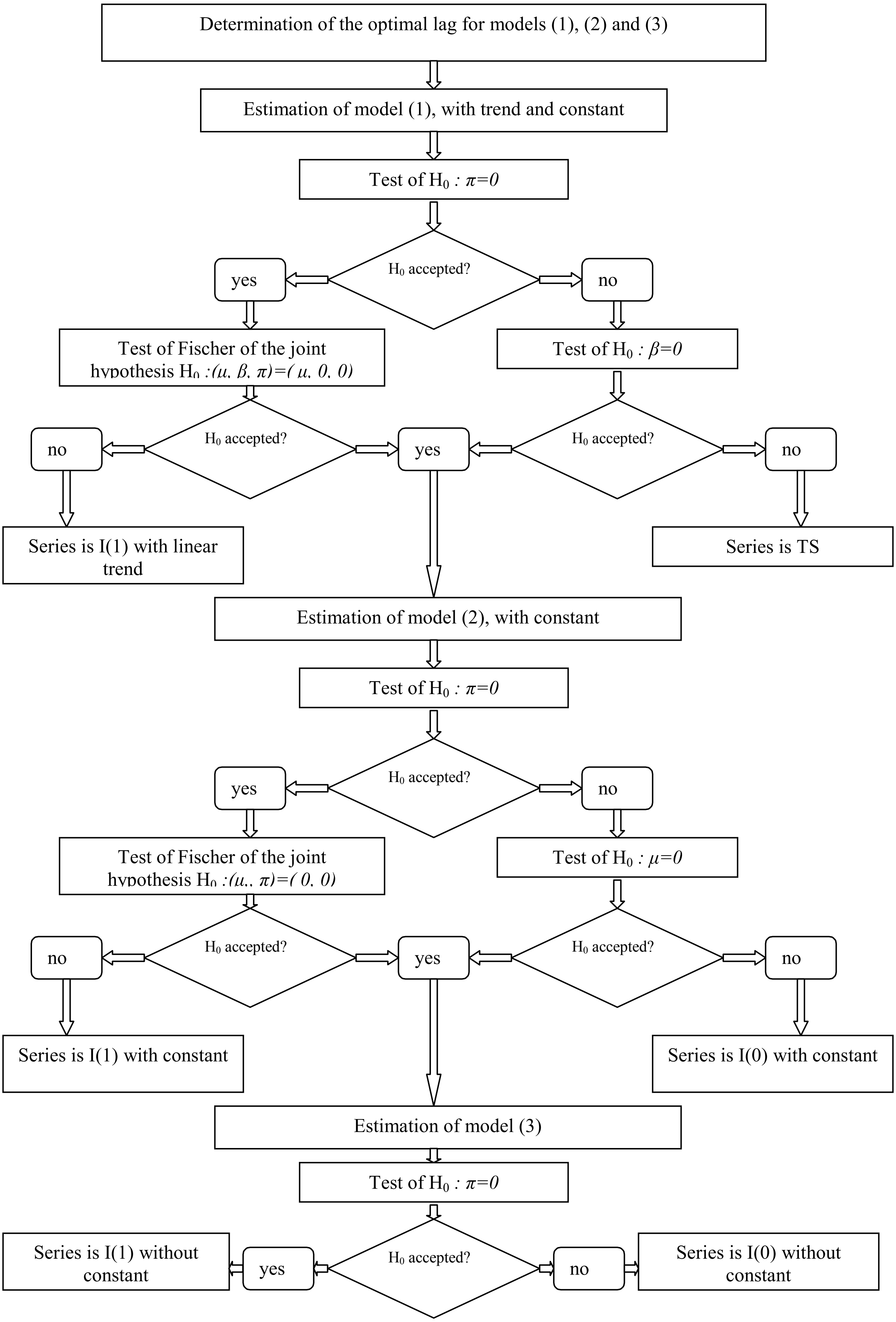
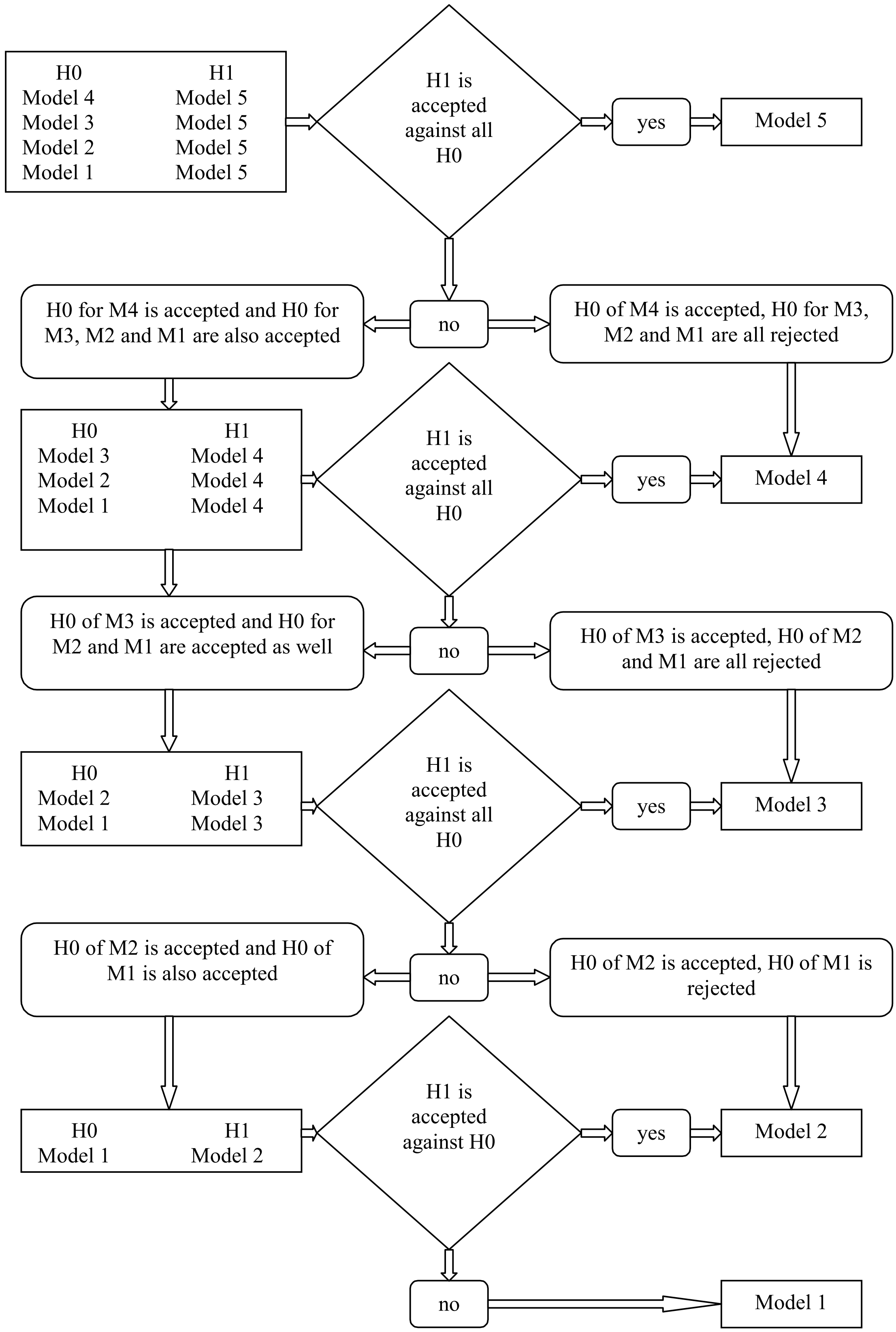
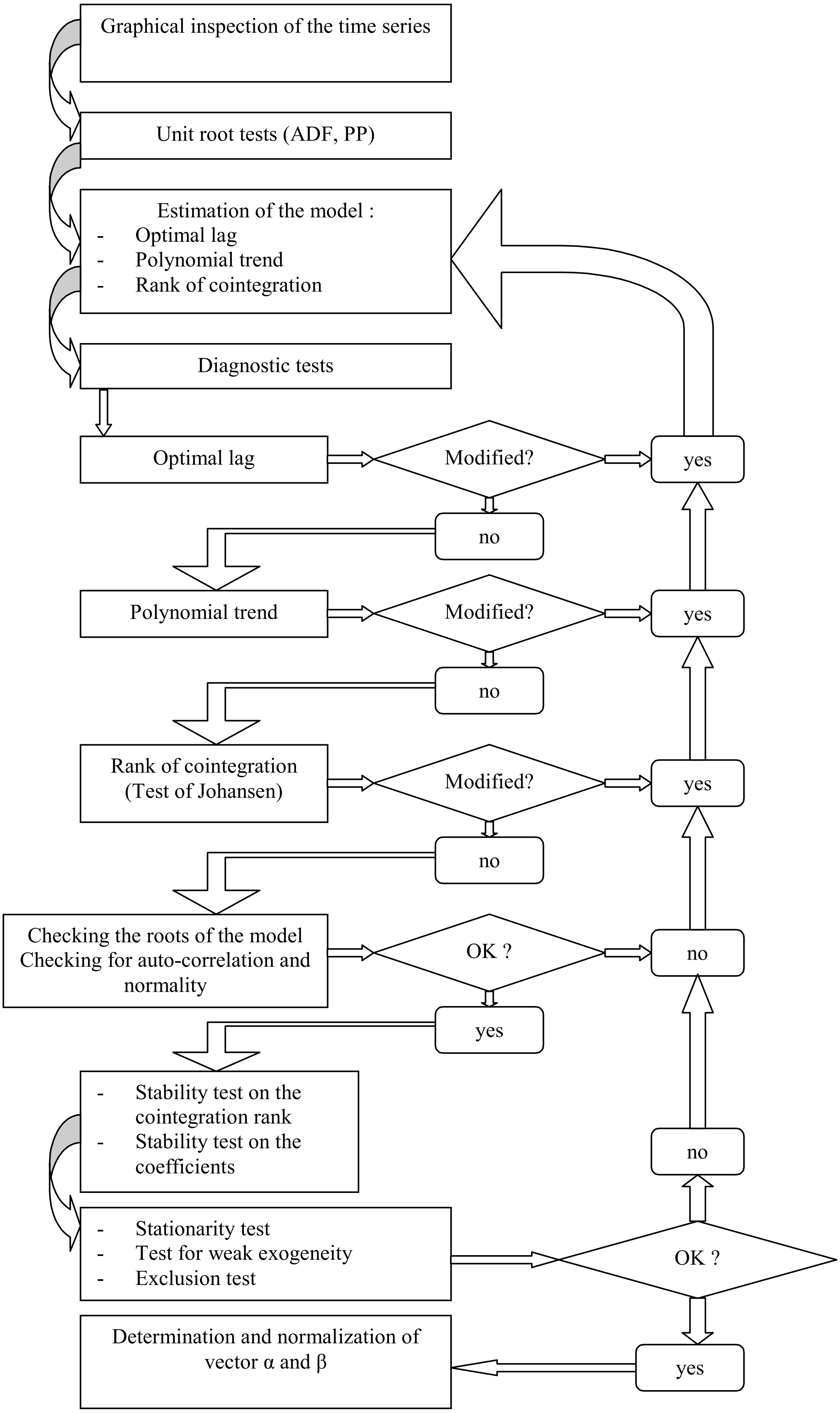


Figure 3. Likelihood ratio tests



Figures 3. Cointegration analysis



Appendix 4. Unit root tests

Table 1. Unit root tests for the productivity series, Estonia

	ADF							PP						
	M3			M2			M1	M3			M2			M1
	H0	F2	Trend	H0	F1	Drift	H0	H0	F2	Trend	H0	F1	drift	H0
D2 PROD1 (3)	-8.46**		-0.82	-8.32**		0.29	-7.77**	-20.32**		0.12	-20.36**		-0.04	-20.01**
D1 PROD1 (3)	-5.27**		-2.11*					-13.20**		-1.07	-11.82**		1.24	-10.47**
PROD1 (3)	-1.30	1.87		-1.89	3.03		0.47	-3.54	6.36		-1.99	2.48		0.05
D2 PROD2 (3)	-4.65**		0.00	-4.70**		0.02	-4.42**	-16.02**		0.32	-15.70**		-0.24	-15.31**
D1 PROD2 (3)	-3.47*		-0.75	-3.38*		1.07	-2.94**	-7.59**		-1.16	-7.20**		1.26	-6.65**
PROD2 (3)	-1.25	1.45		-1.50	2.70		1.18	-3.98*		2.59*				
D2 PROD3 (3)	-4.88**		-0.03	-4.96**		0.19	-4.98**	-16.44**		0.34	-16.08**		-0.21	-15.71**
D1 PROD3 (3)	-3.60*		-0.47	-3.61*		1.62	-2.82**	-7.93**		-0.93	-7.67**		1.59	-6.78**
PROD3 (3)	1.25	1.08		-1.08	3.87		1.89	-4.07*		3.03*				
D2 PROD4 (3)	-5.80**		-0.02	-5.93**		0.03	-5.66**	-15.01**		0.22	-14.78**		-0.26	-14.37**
D1 PROD4 (3)	-5.95**		-0.67	-6.01**		2.25*		-7.82**		-1.01	-7.50**		1.43	-6.69**
PROD4 (3)	-2.23	2.88		-1.33	3.34		1.61	-4.98**		3.51**				
D2 PROD5 (4)	-4.35**		-0.04	-4.37**		-0.06	-4.02**	-17.45**		0.39	-17.06**		-0.28	-16.59**
D1 PROD5 (4)	-4.08*		-1.91	-3.21*		1.52	-2.39*	-8.14**		-1.52	-7.32**		1.55	-6.58**
PROD5 (4)	-1.81	2.78		-2.02	3.14		0.84	-3.97*		2.41*				
D2 PROD6 (3)	-5.48**		-0.12	-5.77**		0.26	-5.30**	-15.72**		0.37	-15.40**		-0.19	-15.06**
D1 PROD6 (3)	-4.57**		-1.74	-3.88**		2.39*		-8.12**		-1.06	-7.63**		1.74	-6.50**
PROD6 (3)	-1.61	1.82		-1.38	3.30		1.44	-4.16*		3.07*				
D2 PROD7 (3)	-5.48**		0.14	-5.55**		-0.02	-5.31**	-18.36**		0.25	-17.99**		-0.24	-17.50**
D1 PROD7 (3)	-6.48**		-1.23	-6.43**		2.55*		-9.36**		-1.22	-8.71**		1.68	-7.54**
PROD7 (3)	-2.54	4.20		-1.88	4.74		1.65	-5.36*		3.72**				
D2 PROD8 (3)	-5.13**		0.23	-5.14**		0.06	-4.85**	-16.33**		0.37	-15.95**		-0.14	-15.62**
D1 PROD8 (3)	-4.66**		-1.45	-4.30**		2.21*		-8.46**		-1.19	-7.89**		1.90	-6.69**
PROD8 (3)	-1.48	2.18		-1.85	5.69*			-4.08*		2.94*				
D2 PROD9 (3)	-5.13**		0.23	-5.14**		0.06	-4.85**	-16.33**		0.37	-15.95**		-0.14	-15.62**
D1 PROD9 (3)	-4.66**		-1.45	-4.30**		2.21*		-8.46**		-1.19	-7.89**		1.90	-6.69**
PROD9 (3)	-1.48	2.18		-1.85	5.69*		1.65	-4.08*		2.94*				

Notes: D2 and D1 refer to the series in second and first differences. The number in parenthesis after the name of the series is the lag length employed that is determined using the Schwartz information criterion. ADF and PP refer to the Augmented Dickey-Fuller and the Phillips-Perron unit root tests. M3, M2 and M1 stand for the model including trend and constant, the model containing a constant and finally the model without trend and constant. H0 is the null hypothesis for the presence of a unit root, e.g. $H_0\!:\!\phi=0$. F2 and F1 denote the joint hypotheses of a unit root and a trend, and a unit root and a constant, e.g. $H_0^{F2}: (\phi, t, c) = (0,0,c)$ and $H_0^{F1}: (\phi, c) = (0,0)$. Critical values are those provided in Dickey – Fuller (1979) and Phillips – Perron (1988). * and ** denote the rejection of the null respectively at the 5% and 1% levels.

Table 2. Unit root tests for the deflator series-based relative price series, Estonia

	ADF							PP						
	M3			M2			M1	M3			M2			M1
	H0	F2	Trend	H0	F1	drift	H0	H0	F2	Trend	H0	F1	drift	H0
D2 DEFL1 (1)	-8.80**		-0.00	-8.80**		0.02	-8.53**	-12.44**		-0.01	-12.45**		0.06	-12.25**
D1 DEFL1 (1)	-5.86**		-0.70	5.75**		1.17	-5.35**	-8.14**		-0.41	-8.11**		0.93	-7.83**
DEFL1 (1)	-2.11	2.34		-1.44	1.51		0.11	-2.77	3.98		-1.81	2.14		0.11
D2 DEFL2 (1)	-7.65**		-0.21	-7.64**		0.19	-7.41**	-12.23**		0.03	-12.24**		0.09	-12.05**
D1 DEFL2 (1)	-5.17**		-0.51	-5.12**		1.44	-4.59**	-11.15**		-0.72	-10.64**		1.32	-9.37**
DEFL2 (1)	-2.22	2.50		-1.02	1.42		0.55	-2.66	3.65		-1.37	1.94		0.44
D2 DEFL3 (1)	-7.95**		-0.09	-7.98**		0.12	-7.75**	-10.46**		0.50	-10.42**		-0.19	-10.29**
D1 DEFL3 (1)	-6.09**		-0.77	-6.02**		1.88	-5.23**	-7.18**		-0.79	-7.10**		1.67	-6.48**
DEFL3 (1)	-2.14	2.69		-1.52	2.73		0.91	-2.74	4.43		-2.02	4.07		0.34
D2 DEFL4 (1)	-8.51**		0.04	-8.51**		0.00	-8.25**	-13.14**		0.05	-13.15**		0.03	-12.95**
D1 DEFL4 (1)	-5.78**		-0.86	-5.64**		1.37	-5.14**	-8.65**		-0.55	-8.61**		1.15	-8.21**
DEFL4 (1)	-1.86	1.91		-1.41	1.74		0.45	-2.76	4.15		-2.00	2.85		0.29
D2 DEFL5 (1)	-7.42**		-0.20	-7.41**		0.19	-7.19**	-12.99**		0.10	-13.02**		-0.06	-12.83**
D1 DEFL5 (1)	-5.09**		-0.61	5.02**		1.61	-4.40**	-8.22**		-0.36	-8.23**		1.52	-7.68**
DEFL5 (1)	-1.93	1.94		-1.01	1.77		0.86	-2.67	3.85		-1.59	2.74		0.71
D2 DEFL6 (1)	-8.02**		-0.07	-8.06**		0.12	-7.84**	-9.95**		0.54	-9.91**		-0.21	-9.76**
D1 DEFL6 (1)	-6.40**		-0.92	-6.29**		1.88	-5.38**	-7.12**		-0.81	-7.06**		1.70	-6.42**
DEFL6 (1)	-2.12	2.66		-1.52	2.81		1.00	-2.86	5.09		-2.24	4.86		0.94
D2 DEFL7 (1)	-8.23**		0.07	-8.23**		-0.02	-7.98**	-13.85**		0.12	-13.88**		-0.00	-13.68**
D1 DEFL7 (1)	-5.76**		-0.98	-5.58**		1.54	4.99**	-9.28**		-0.69	-9.27**		1.38	-8.68**
DEFL7 (1)	-1.67	1.68		-1.43	2.09		0.73	-2.88	4.72		-2.23	3.71		0.53
D2 DEFL8 (1)	-7.24**		-0.21	-7.24**		0.22	-7.03**	-14.03**		0.19	-14.09**		0.02	-13.89**
D1 DEFL8 (1)	-5.11**		-0.74	-5.01**		1.84	-4.26	-9.14**		-0.53	-9.15**		1.86	-8.37**
DEFL8 (1)	-1.62	1.48		-1.06	2.46		1.35	-2.89	4.41		-1.91	3.93		0.95
D2 DEFL9 (1)	-8.21**		-0.04	-8.27**		0.12	-8.45**	-9.12**		0.56	-9.09**		-0.21	-8.95**
D1 DEFL9 (1)	-6.99**		1.24	-6.76**		2.74*		-7.19**		-0.82	-7.15**		1.83	-6.45**
DEFL9 (1)	-2.05	2.47		-1.48	2.98		1.18	-3.19	6.45		-2.58	6.32*		

Notes: As for Table 1.

Table 3. Unit root tests for the CPI-based relative price series, Estonia

	ADF							PP						
	M3			M2			M1	M3			M2			M1
	H0	F2	Trend	H0	F1	Drift	H0	H0	F2	Trend	H0	F1	Drift	H0
D2 REL4 (2)	-5.24**		-0.84	-5.11**		-0.05	-4.87**	-7.08**		-0.77	-6.97**		0.27	-6.86**
D1 REL4 (2)	-5.55**		-3.64*					-4.39**		-0.49	-4.37**		1.92	-3.66**
REL4 (2)	-0.04	3.02		-2.41	10.14**			-0.92	1.23		-1.45	7.28*		
D2 REL5 (3)	-7.37**		1.52	-6.97**		1.91	-5.83**	-6.48**		-0.34	-6.45**		0.06	-6.33**
D1 REL5 (3)	-2.94	5.10		-2.57	4.67		-2.73*	-4.01*		-1.82	-3.46*		-3.35**	
REL5 (3)	-8.03**	2.78*						-1.23	6.04		-3.47*		4.83**	
D2 REL6 (3)	-6.07**		1.28	-5.91**		-1.59	-5.06**	-6.76**		-0.25	-6.74**		0.00	-6.61**
D1 REL6 (3)	-2.81	4.27		-2.14	3.10		-2.14*	-3.91*		-2.07*				
REL6 (3)	-6.21**		2.59*					-1.21	7.38*					

Notes: As for Table 1.

Table 4. Unit root tests for the differences in productivity differentials, relative prices and for the real exchange rate against the foreign benchmark

	ADF							PP						
	M3			M2			M1	M3			M2			M1
	H0	F2	Trend	H0	F1	drift	H0	H0	F2	Trend	H0	F1	Drift	H0
D2 DIFFPROD1 (1)	-6.20**		0.57	-6.14**		-0.19	-5.95**	-12.14**		0.49	-12.04**		-0.25	-11.85**
D1 DIFFPROD1 (1)	-4.48**		-0.93	-4.35**		0.72	-4.14**	-6.98**		-1.37	-6.65**		1.02	-6.37**
DIFFPROD1 (1)	-2.57	4.52		-2.93	4.99		0.20	-2.82	5.42		-3.21	6.08*		0.11
D2 DIFFPROD2 (1)	-7.36**		0.63	-7.30**		-0.09	7.07**	-10.04**		0.49	-9.97**		-0.19	-9.80**
D1 DIFFPROD2 (1)	-5.23**		-0.69	-5.18**		1.03	-4.84**	-6.37**		-0.77	-6.28**		1.04	-6.00**
DIFFPROD2 (1)	-2.48	3.46		-2.23	3.14		0.31	-2.87	4.92		-2.78	4.90		0.32
D2 DIFFPROD3 (1)	-7.27**		0.62	-7.22**		-0.09	-6.99**	-9.92**		0.49	-9.85**		-0.19	-9.69**
D1 DIFFPROD3 (1)	-5.19**		-0.75	-5.13**		1.16	-4.74**	-6.28**		-0.81	-6.18**		1.16	-5.86**
DIFFPROD3 (1)	-2.41	3.32		-2.15	3.12		0.43	-2.78	4.71		-2.68	4.89		0.44
D2 DIFFDEFL1 (1)	-6.92**		-0.25	-6.92**		0.11	-6.71**	-12.70**		0.05	-12.72**		-0.01	-12.53**
D1 DIFFDEFL1 (1)	-4.64**		-0.65	-4.56**		0.59	-4.36**	-7.71**		-0.49	-7.69**		0.53	-7.54**
DIFFDEFL1 (1)	-1.84	1.84		-1.50	1.28		-0.18	-2.46	3.42		-2.16	2.64		-0.27
D2 DIFFDEFL2 (1)	-7.56**		-0.14	-7.60**		0.06	-7.39**	-9.87**		0.46	-9.85**		-0.24	-9.69**
D1 DIFFDEFL2 (1)	-5.82**		-0.92	5.70**		0.87	-5.40**	-6.79**		-0.88	-6.70**		0.82	-6.49**
DIFFDEFL2 (1)	-2.02	2.52		-1.93	2.25		0.14	-2.66	4.58		-2.70	4.41		0.12
D2 DIFFDEFL3 (1)	-7.55**		-0.14	-7.59**		0.06	-7.38**	-9.89**		0.46	-9.86**		-0.23	-9.71**
D1 DIFFDEFL3 (1)	-5.78**		-0.92	-5.66**		0.91	-5.35**	-6.78**		-0.89	-6.68**		0.84	-6.47**
DIFFDEFL3 (1)	-1.90	2.45		-1.90	2.23		0.17	-2.62	4.47		-2.67	4.35		0.15
D2 DIFFREL1 (1)	-10.59**		-1.51	-10.15**		0.55	-9.81**	-7.12**		-0.36	-7.11**		-0.15	-7.01**
D1 DIFFREL1 (1)	-6.36**		-2.48*					-5.02**		-0.96	-4.88**		-2.14	-4.05**
DIFFREL1 (1)	-1.10	1.12		-1.30	3.39		1.25	-1.02	2.01		-1.96	8.21**		
D2 DIFFREL2 (1)	-8.11**		-1.24	-7.84**		0.46	-7.57**	-6.95**		-0.59	-6.93**		0.27	-6.82**
D1 DIFFREL2 (1)	-5.76**		-1.78	-5.23**		3.13**		-4.54**		-0.35	-4.53**		1.86	-3.86**
DIFFREL2 (1)	-1.99	2.06		-0.80	2.21		1.09	-1.18	1.20		-1.25	5.63*		
D2 DIFFREL3 (1)	-8.35**		-0.71	-8.25**		0.12	-8.00**	-6.24**		-0.17	-6.23**		0.02	-6.14**
D1 DIFFREL3 (1)	-6.23**		-3.33*					-4.52**		-1.84	-3.92**		1.55	-3.39**
DIFFREL3 (1)	-2.15	4.40		-2.86	5.67*			-1.75	5.39		2.35	10.35**		
D2 DIFFREL4 (1)	-8.22**		-0.76	-8.11**		0.08	-7.86**	-5.97**		-0.28	-5.96**		0.07	-5.88**
D1 DIFFREL4 (1)	-6.45**		-3.52**					-4.31**		-1.75	-3.76**		1.57	-3.21**
DIFFREL4 (1)	-2.05	3.69		-2.63	5.03		0.59	-1.52	4.64		-2.04*	9.98**		
D2 RERCPI2 (2)	-4.26**		-1.10	-4.37**		1.06	-3.95**	-9.01**		-0.66	-8.81**		0.83	-8.41**
D1 RERCPI2 (2)	-2.33	3.24		-2.12	2.86		2.22*	-3.54	6.26		-2.03	2.18		-1.77
RERCPI2 (2)	-3.24	7.20*						-3.41	28.86**					
D2 RERCPI4 (2)	-5.80**		-1.52	-5.44**		1.41	-4.82**	-7.53**		-0.47	-7.46**		0.67	-7.18**
D1 RERCPI4 (2)	-2.26	2.74		-1.70	1.79		-1.75	-3.25	5.27		-1.87	1.86		-1.67
RERCPI4 (2)	-4.04*		0.01	-4.69**		-4.48**		-3.35	28.78**					
D2 RERPPI (2)	-6.64**		-1.15	-6.43**		1.41	-5.76**	-8.15**		-0.13	-8.13**		0.44	-7.85**
D1 RERPPI (2)	-2.78	3.98		-1.68	1.81		-6.27**	-4.67**		-3.33*				
RERPPI (2)	-4.27*		0.20	-6.33**		6.27**		-2.56	28.13**					

Table 5. Unit root tests for the productivity differential and the relative prices, foreign benchmark

	ADF							PP						
	M3			**M2**			**M1**	**M3**			**M2**			**M1**
	H0	**F2**	**Trend**	**H0**	**F1**	**drift**	**H0**	**H0**	**F2**	**Trend**	**H0**	**F1**	**Drift**	**H0**
D2 PROD1 (1)	-9.32**		0.09	-9.32**		-0.37	-9.01**	-11.98**		-0.01	-11.98**		-0.18	-11.78**
D1 PROD1 (1)	-5.26**		-0.74	-5.16**		2.13	-4.22**	-7.47**		-0.73	-7.37**		2.09	-6.51**
PROD1 (1)	-2.68	3.94		-1.47	3.54		1.26	-3.23	5.69		-1.77	4.33		1.19
D2 PROD2 (1)	-8.54**		0.21	-8.54**		-0.39	8.25**	-11.78**		-0.08	-11.78**		-0.14	-11.59**
D1 PROD2 (1)	-5.08**		-0.98	-4.90**		2.32	-3.81**	-7.34**		-0.89	-7.19**		2.38	-6.14**
PROD2 (1)	-2.81	4.48		-1.56	4.42		1.45	-3.27	5.69		-1.80	5.34*		
D2 PROD3 (1)	-8.68**		0.23	-8.67**		-0.38	-8.37**	-11.52**		-0.07	-11.52**		-0.13	-11.33**
D1 PROD3 (1)	-5.19**		-0.84	-5.05**		2.13	-4.10**	-7.26**		-0.75	-7.16**		2.08	-6.32**
PROD3 (1)	-2.68	3.95		-1.49	3.54		1.23	-3.14	5.40		-1.76	4.34		1.19
D2 DEFL1 (1)	-5.57**		0.21	5.56**		0.20	-5.38**	-7.81**		0.15	-7.81**		0.21	-7.68**
D1 DEFL1 (1)	-4.31*		0.63	-4.23**		2.04	-3.33**	-4.69**		0.60	-4.62**		1.89	-3.93**
DEFL1 (1)	-3.11	5.08		-0.22	1.92		-1.29	-2.45	3.39		0.08	2.69		1.81
D2 DEFL2 (1)	-5.39**		0.21	-5.38**		0.19	-5.21**	-8.07**		0.16	-8.06**		0.19	-7.93**
D1 DEFL2 (1)	-4.07*		-0.72	3.97**		2.12	-2.98**	-4.67**		0.67	-4.58**		2.09	-3.73**
DEFL2 (1)	-2.94	4.64		-0.03	2.33		1.53	-2.36	3.26		0.28	3.64		2.18*
D2 DEFL3 (1)	-5.20**		0.21	-5.19**		0.19	-5.02**	-8.91**		0.18	-8.90**		0.18	-8.76**
D1 DEFL3 (1)	-3.81*		0.74	-3.70*		1.93	-2.85**	-4.93**		0.71	-4.83**		2.08	-3.99**
DEFL3 (1)	-2.68	3.94		0.00	2.31		1.55	-2.26	3.04		0.27	3.37		2.10*
D2 REL1 (1)	-7.12**		-0.59	-7.06**		0.32	-6.83**	-13.41**		-0.40	-13.30**		0.28	-13.09**
D1 REL1 (1)	-4.34*		2.04	-3.55*		2.78*		-7.77**		-3.07*				
REL1 (1)	-3.03	11.08 **						-1.99	6.09		2.03	17.76**		
D2 REL2 (1)	-6.38**		-0.69	-6.31**		-0.38	-6.09**	-10.30**		-0.44	-10.25**		-0.40	-10.07**
D1 REL2 (1)	-3.11	4.96		-2.74	3.85		-2.24*	-4.99**		-1.26	-4.69**		2.04	-3.89**
REL2 (1)	-0.92	1.32		-1.50	3.50		1.08	-1.01	2.46		-2.16	8.85**		
D2 REL3 (1)	-6.63**		-0.51	-6.59**		0.55	-6.33**	-8.82**		-0.38	-8.78**		0.47	-8.60**
D1 REL3 (1)	-4.60**		2.30*	-3.61*		3.04*		-5.04**		-2.69*				
REL3 (1)	-3.39	10.77 **						-2.82	11.44 **					
D2 REL4 (3)	-4.47**		-1.31	-3.98**		-0.24	-3.71**	-10.52**		-0.64	-10.12**		-0.33	-9.93**
D1 REL4 (3)	-4.59**		-3.00*					-4.54**		-0.98	-4.40**		2.80*	
REL4 (3)	-1.94	3.57		-1.92	3.25		-0.12	-0.98	1.31		-1.40*	16.09**		

Appendix 5. Diagnostic tests for the cointegration analysis

Table 1. Estonia, internal, deflators versus productivity

	Weak exogeneity	Exclusion	Roots			LR test	
	χ^2 (p-value)	χ^2 (p-value)	Number	Root	Absolute value	χ^2 (DGF, p-value)	
Prod1 – Defl1	8,33(0,004)	7,40 (0,007)	1	(1.02053, -0.00000)	1.02053	M1	17,92 (4, 0,001)
	0,01 (0,944)	8,37 (0,003)	2	(0.74313, 0.34276)	0.81837		11,25 (3, 0,010)
			3	(0.74313, -0.34276)	0.81837		8,66 (2, 0,013)
			4	(-0.47307, -0.64452)	0.79950		3,592 (1, 0,058)
			5	(-0.47307, 0.64452)	0.79950		
			6	(0.22180, -0.74680)	0.77904		
Prod2- Defl2	1,12 (0,290)	10,34(0,001)	1	(0.90744, 0.00000)	0.90744	M2	3.99 (3, 0,262)
	7,54 (0,006)	10,44 (0,001)	2	(0.41668, 0.00000)	0.41668		2,88 (2, 0,237)
							2,79 (1, 0,094)
Prod3 – Defl3			1	(0.93904, 0.00000)	0.93904	M2	3.64 (3, 0,303)
			2	(0.51981, -0.00000)	0.51981		3,04 (2, 0,219)
			3	(-0.11200, 0.17802)	0.21032		2,49 (1, 0,114)
			4	(-0.11200, -0.17802)	0.21032		
Prod4 – Defl4	11,64(0,000)	9,41 (0,002)	1	(1.02029, 0.00000)	1.02029	M1	24,54 (4, 0,000)
	1,32 (0,250)	10,90 (0,000)	2	(-0.46684, -0.58827)	0.75100		16,63 (3, 0,001)
			3	(-0.46684, 0.58827)	0.75100		6,93 (2, 0,031)
			4	(0.63063, -0.27692)	0.68875		5,88 (1, 0,015)
			5	(0.63063, 0.27692)	0.68875		
			6	(0.15868, -0.62704)	0.64681		
			7	(0.15868, 0.62704)	0.64681		
			8	(-0.58764, -0.00000)	0.58764		
Prod5 – Defl5	0,16 (0,652)	18,59(0,000)	1	(0.90516, 0.00000)	0.90516	M2	4.89 (3, 0,180)
	10,00(0,002)	17,76 (0,002)	2	(0.41811, 0.00000)	0.41811		3,14 (2, 0,208)
							3,06 (1, 0,078)
Prod6 – Defl6	1,35 (0,246)	14,74(0,000)	1	(0.93872, -0.00000)	0.93872	M2	4.52 (3, 0,211)
	7,35 (0,007)	14,79 (0,000)	2	(0.27225, 0.00000)	0.27225		3,66 (2, 0,160)
			3	(-0.03242, -0.19488)	0.19755		3,29 (1, 0,070)
			4	(-0.03242, 0.19488)	0.19755		
Prod7 – Defl7	10,53 (0,001)	12,15(0,000)	1	(1.01697, 0.00000)	1.01697	M1	23,52 (4, 0,000)
	0,02 (0,887)	11,94(0,000)	2	(-0.89345, 0.00000)	0.89345		16,34 (3, 0,001)
			3	(-0.11951, -0.85515)	0.86347		14,42(2, 0,001)
			4	(-0.11951, 0.85515)	0.86347		13,28 (1, 0,000)
			5	(-0.53483, 0.60536)	0.80778		
			6	(-0.53483, -0.60536)	0.80778		
			7	(0.72650, -0.00000)	0.72650		
			8	(0.59088, 0.00000)	0.59088		
			9	(0.38643, 0.41161)	0.56458		
			10	(0.38643, -0.41161)	0.56458		
Prod8- Defl8	1,92 (0,989)	16,23(0,000)	1	(0.90185, 0.00000)	0.90185	M2	6.27 (3, 0,099)
	9,14 (0,003)	16,84(0,000)	2	(0.40234, 0.00000)	0.40234		4,05 (2, 0,132)
							3,28 (1, 0,070)
Prod9 – Defl9	10,53 (0,001)	12,15(0,000)	1	(1.02285, 0.00000)	1.02285	M1	11,80 (4, 0,019)
	0,02 (0,887)	11,94(0,000)	2	(0.21439, 0.71790)	0.74923		8,43 (3, 0,038)
			3	(0.21439, -0.71790)	0.74923		8,42 (2, 0,015)
			4	(-0.48813, 0.42900)	0.64985		1,66 (1, 0,197)
			5	(-0.48813, -0.42900)	0.64985		
			6	(0.63403, 0.00000)	0.63403		

Notes: The first statistics for weak exogeneity and long-run exclusion stand for the deflator variable, while figures underneath below refer to statistics related to the variable productivity.

Table 2. Estonia, internal transmission from CPI relative prices to productivity

	Weak exogeneity	Exclusion	Roots			LR test
	χ^2 (p-value)	χ^2 (p-value)	Number	Root	Absolute value	χ^2 (DGF, p-value)
Prod1 – Rel4	16,55 (0,000)	13,31(0,000)	1	(1.01488, 0.00000)	1.01488	M1 11,80 (4, 0,019)
	0,08 (0,775)	16,26(0,000)	2	(0.87685, 0.00000)	0.87685	4,48 (3, 0,213)
			3	(0.42075, 0.57224)	0.71027	4,06 (2, 0,132)
			4	(0.42075, -0.57224)	0.71027	0,89 (1, 0,345)
			5	(-0.15108, 0.46707)	0.49089	
			6	(-0.15108, -0.46707)	0.49089	
Prod2- Rel4	22,83(0,000)	27,96(0,000)	1	(0.97261, -0.01345)	0.97270	M1 11,41 (4, 0,022)
	0,05 (0,818)	30,18 (0,000)	2	(0.97261, 0.01345)	0.97270	0,88 (3, 0,829)
			3	(0.08323, -0.68616)	0.69119	0,58 (2, 0,748)
			4	(0.08323, 0.68616)	0.69119	0,10 (1, 0,750)
			5	(0.44313, -0.50281)	0.67021	
			6	(0.44313, 0.50281)	0.67021	
			7	(-0.51810, 0.28900)	0.59326	
			8	(-0.51810, -0.28900)	0.59326	
Prod3 – Rel4	19,83(0,000)	33,17(0,000)	1	(0.93637, -0.00000)	0.93637	M2 9,52 (3, 0,023)
	0,00 (0,972)	34,56 (0,000)	2	(0.53973, 0.49623)	0.73318	3,31 (2, 0,191)
			3	(0.53973, -0.49623)	0.73318	1,07 (1, 0,300)
			4	(-0.43897, 0.45591)	0.63289	
			5	(-0.43897, -0.45591)	0.63289	
			6	(0.02918, 0.55201)	0.55278	
			7	(0.02918, -0.55201)	0.55278	
			8	(0.48587, 0.00000)	0.48587	
Prod4 – Rel4	21,99(0,000)	16,85 (0,000)	1	(1.00432, 0.00000)	1.00432	M1 19,96 (4, 0,001)
	0,39 (0,530)	20,15 (0,000)	2	(0.94530, -0.00000)	0.94530	11,11 (3, 0,011)
			3	(0.40194, -0.60846)	0.72923	10,55 (2, 0,005)
			4	(0.40194, 0.60846)	0.72923	1,58 (1, 0,209)
			5	(-0.26889, 0.49248)	0.56110	
			6	(-0.26889, -0.49248)	0.56110	
Prod5 – Rel4	11,42(0,000)	26,70(0,000)	1	(0.98957, -0.03967)	0.99037	M1 17,49 (4, 0,002)
	9,83(0,002)	28,22 (0,002)	2	(0.98957, 0.03967)	0.99037	2,19 (3, 0,535)
			3	(0.45849, 0.53351)	0.70345	1,69(2, 0,429)
			4	(0.45849, -0.53351)	0.70345	0,67 (1, 0,414)
			5	(0.07514, -0.68976)	0.69384	
			6	(0.07514, 0.68976)	0.69384	
			7	(-0.59995, 0.21245)	0.63646	
			8	(-0.59995, -0.21245)	0.63646	
Prod6 – Rel4	11,42(0,000)	26,70(0,000)	1	(0.95518, 0.00000)	0.95518	M3 4,67 (2, 0,096)
	9,83(0,002)	28,22 (0,002)	2	(0.36347, 0.37540)	0.52253	2,56 (1, 0,110)
			3	(0.36347, -0.37540)	0.52253	
			4	(-0.04355, 0.00000)	0.04355	
Prod7 – Rel4	24,32 (0,000)	22,22(0,000)	1	(0.99069, 0.00000)	0.99069	M1 15,98 (4, 0,033)
	2,19 (0,139)	23,82(0,000)	2	(0.96207, 0.00000)	0.96207	3,64 (3, 0,303)
			3	(-0.07578, 0.76613)	0.76987	2,49(2, 0,288)
			4	(-0.07578, -0.76613)	0.76987	2,08 (1, 0,150)
			5	(-0.63622, 0.00000)	0.63622	
			6	(0.36551, 0.51767)	0.63370	
			7	(0.36551, -0.51767)	0.63370	
			8	(-0.27497, -0.00000)	0.27497	
Prod8- Rel4	16,62(0,000)	12,13(0,000)	1	(0.98679, 0.02725)	0.98716	M1 10,98 (4, 0,008)
	0,00 (0,987)	15,53(0,000)	2	(0.98679, -0.02725)	0.98716	7,75 (3, 0,051)
			3	(0.33352, 0.63255)	0.71509	7,42(2, 0,025)
			4	(0.33352, -0.63255)	0.71509	2,17 (1, 0,141)
			5	(-0.51009, 0.00000)	0.51009	
			6	(0.02164, 0.00000)	0.02164	
Prod9 – Rel4	20,67 (0,000)	18,89(0,000)	1	(0.99810, -0.00000)	0.99810	M1 16,66 (4, 0,002)
	1,76 (0,185)	16,18(0,000)	2	(0.96705, -0.00000)	0.96705	9,63 (3, 0,022)
			3	(0.35549, -0.63413)	0.72697	9,01 (2, 0,011)
			4	(0.35549, 0.63413)	0.72697	2,49 (1, 0,114)
			5	(-0.25773, -0.50091)	0.56332	
			6	(-0.25773, 0.50091)	0.56332	

Notes: The first statistics for weak exogeneity and long-run exclusion stand for the CPI-based relative price series, while figures underneath refer to statistics related to the variable productivity.

Table 3. Estonia, external transmission between differences in productivity differentials, relative prices and he real exchange rate against the foreign benchmark

	Weak exogeneity	Exclusion	Roots			LR test	
	χ^2 (p-value)	χ^2 (p-value)	Number	Root	Absolute value	χ^2 (DGF, p-value)	
D_Prod1 – D_Defl1	6,07 (0,017)	21,16(0,000)	1	(0.72705, 0.09972)	0.73386	M2	5,390(3, 0,145)
	2,49 (0,114)	21,43(0,000)	2	(0.72705, -0.09972)	0.73386		4,07 (2, 0,131)
			3	(0.32934, 0.58188)	0.66862		0,73 (1, 0,394)
			4	(0.32934, -0.58188)	0.66862		
			5	(-0.56422, -0.28762)	0.63330		
			6	(-0.56422, 0.28762)	0.63330		
D_Prod2- D_Defl2	4,45(0,035)	14,08(0,000)	1	(1.01100, 0.00000)	1.01100	M1	5,54 (4, 0,236)
	4,54 (0,033)	14,29 (0,000)	2	(0.32659, 0.00000)	0.32659		2,99 (3, 0,393)
							2,88 (2, 0,236)
							0,84 (1, 0,360)
D_Prod3- D_Defl3	4,67(0,030)	13,89(0,000)	1	(1.01250, 0.00000)	1.01250	M1	5,49 (4, 0,689)
	3,63 (0,056)	13,64 (0,000)	2	(0.33488, 0.00000)	0.33488		2,91 (3, 0,406)
							2,91 (2, 0,234)
							0,52 (1, 0,469)
D_Prod1- D_Rel2	13,44(0,000)	9,04 (0,002)	1	(0.97550, -0.00730)	0.97553	M1	15,19 (4, 0,004)
	1,11 (0,297)	14,32 (0,000)	2	(0.97550, 0.00730)	0.97553		11,55 (3, 0,009)
			3	(0.28445, -0.63091)	0.69206		4,93 (2, 0,085)
			4	(0.28445, 0.63091)	0.69206		0,89 (1, 0,345)
			5	(-0.42293, 0.00000)	0.42293		
			6	(0.14866, 0.00000)	0.14866		
D_Prod1- D_Rel4	9,74(0,002)	11,14(0,000)	1	(1.01021, 0.00000)	1.01021	M1	16,39 (4, 0,024)
	3,09(0,078)	12,16 (0,002)	2	(0.65767, 0.00000)	0.65767		12,31(3, 0,006)
			3	(0.26415, -0.27565)	0.38178		2,49(2, 0,244)
			4	(0.26415, 0.27565)	0.38178		0,59 (1, 0,420)
D_Prod2- D_Rel2	13,86(0,000)	10,85(0,000)	1	(1.00293, -0.00000)	1.00293	M1	11,51 (4, 0,021)
	0,29(0,586)	15,26 (0,002)	2	(0.93382, 0.00000)	0.93382		8,85 (3, 0,031)
			3	(0.30833, -0.62811)	0.69971		2,45 (2, 0,294)
			4	(0.30833, 0.62811)	0.69971		0,04 (1, 0,848)
			5	(-0.12147, -0.35602)	0.37618		
			6	(-0.12147, 0.35602)	0.37618		
D_Prod2- D_Rel4	4,16 (0,041)	8,11(0,004)	1	(1.00000, 0.00000)	1.00000	M1	9,89 (4, 0,042)
	7,41 (0,006)	9,36(0,002)	2	(0.48889, 0.48187)	0.68645		5,14 (3, 0,162)
			3	(0.48889, -0.48187)	0.68645		3,19(2, 0,203)
			4	(-0.00103, 0.00000)	0.00103		0,75 (1, 0,386)
D_Prod3- D_Rel2	14,35(0,000)	11,19(0,000)	1	(1.00286, 0.00000)	1.00286	M1	10,96 (4, 0,027)
	0,15 (0,701)	15,23(0,000)	2	(0.93598, 0.00000)	0.93598		8,31 (3, 0,040)
			3	(0.30403, -0.62797)	0.69769		2,54(2, 0,281)
			4	(0.30403, 0.62797)	0.69769		0,06 (1, 0,809)
			5	(-0.11325, -0.35083)	0.36866		
			6	(-0.11325, 0.35083)	0.36866		
D_Prod3- D_Rel4	8,08 (0,004)	12,94(0,000)	1	(1.01676, -0.00000)	1.01676	M1	9,52 (4, 0,049)
	4,81 (0,028)	12,29(0,000)	2	(0.42408, -0.36193)	0.55753		4,85 (3, 0,183)
			3	(0.42408, 0.36193)	0.55753		3,39 (2, 0,183)
			4	(0.44707, 0.00000)	0.44707		0,91 (1, 0,341)
D_Rel2 – RER_CPI	0,313(0,576)	24,37(0,000)	1	(1.00491, 0.00000)	1.00491	M1	23,75 (4, 0,000)
	23,77(0,000)	22,58(0,000)	2	(0.89163, 0.00000)	0.89163		11,83(3, 0,008)
			3	(0.35997, 0.16767)	0.39710		8,01 (2, 0,018)
			4	(0.35997, -0.16767)	0.39710		3,91 (1, 0,048)

Notes: The first statistics for weak exogeneity and long-run exclusion stand for the CPI-based relative price differential between Estonia and the foreign benchmark, while figures underneath refer to statistics related to the difference in productivity differentials.

Table 4. Foreign benchmark (including 4 countries), internal transmission from productivity to relative prices

	Weak exogeneity	Exclusion	Roots			LR test	
	χ^2 (p-value)	χ^2 (p-value)	Number	Root	Absolute value	χ^2 (DGF, p-value)	
Prod1 – Rel1	15,92 (0,000) 5,16 (0,023)	11,93 (0,000) 18,30 (0,000)	1 2 3 4	(1.01713, -0.00000) (0.37615, 0.00000) (-0.32251, 0.00000) (0.13754, -0.00000)	1.01713 0.37615 0.32251 0.13754	M3	4,31 (2, 0,116) 3,32 (1, 0,069)
Prod1- Rel3			1 2 3 4	(1.01873, 0.00000) (0.42658, -0.00000) (0.07064, -0.06565) (0.07064, 0.06565)	1.01873 0.42658 0.09644 0.09644	M3	2,10 (2, 0,343) 0,51 (1, 0,454)
Prod2 – Rel1	19,05 (0,000) 4,58 (0,032)	13,67 (0,000) 20,61 (0,000)	1 2 3 4	(1.01146, 0.00000) (0.48456, 0.00000) (-0.35859, 0.00000) (0.09300, 0.00000)	1.01146 0.48456 0.35859 0.09300	M3	1,53 (2, 0,467) 0,75 (1, 0,385)
Prod2 – Rel3	9,93 (0,001) 7,95 (0,005)	9,72 (0,000) 14,53 (0,000)	1 2 3 4	(1.00000, 0.00000) (0.60606, -0.00000) (-0.03952, 0.09293) (-0.03952, -0.09293)	1.00000 0.60606 0.10098 0.10098	M3	3,12 (2, 0,210) 2,42 (1, 0,120)
Prod3 – Rel1	16,30 (0,000) 5,34 (0,020)	11,76(0,000) 18,26 (0,000)	1 2 3 4	(1.01613, -0.00000) (-0.33288, -0.00000) (0.32663, -0.00000) (0.23756, 0.00000)	1.01613 0.33288 0.32663 0.23756	M3	3,86 (2, 0,145) 2,89 (1, 0,089)
Prod3 – Rel3	2,17 (0,140) 12,17 (0,000)	8,49 (0,004) 14,73 (0,000)	1 2 3 4 5 6	(1.00000, -0.00000) (0.53929, -0.09349) (0.53929, 0.09349) (0.07090, 0.51283) (0.07090, -0.51283) (-0.51447, 0.00000)	1.00000 0.54733 0.54733 0.51771 0.51771 0.51447	M3	7,74 (2, 0,021) 7,15 (1, 0,007)
Prod1 – Rel2	12,81 (0,000) 3,92 (0,047)	0,84 (0,350) 0,01 (0,340)	1 2	(0.95218, 0.00000) (0.73854, 0.00000)	0.95218 0.73854	M2	11,89 (3, 0,008) 6,29 (2, 0,043) 0,07 (1, 0,787))
Prod1- Rel4			1 2 3 4	(0.98037, 0.00000) (0.49731, -0.11430) (0.49731, 0.11430) (-0.11327, -0.00000)	0.98037 0.51028 0.51028 0.11327	M3	2,23 (2, 0,327) 0,32 (1, 0,572)
Prod2 – Rel2			1 2	(0.95284, 0.00000) (0.73788, 0.00000)	0.95284 0.73788	M2	11. 81 (3, 0,008) 5,87 (2, 0,053) 0,161 (1, 0,688)
Prod2 – Rel4			1 2 3 4	(0.97880, 0.00000) (0.49655, -0.20851) (0.49655, 0.20851) (-0.12991, -0.00000)	0.97880 0.53855 0.53855 0.12991	M3	3,64 (2, 0,162) 1,03 (1, 0,309)
Prod3 – Rel2			1 2	(0.95225, 0.00000) (0.74077, 0.00000)	0.95225 0.74077	M2	11. 07 (3, 0,011) 5,35 (2, 0,069) 0,122 (1, 0,727)
Prod3 – Rel4			1 2	(0.97861, 0.00000) (0.64662, 0.00000)	0.97861 0.64662	M3	5,75 (2, 0,056) 1,43 (1, 0,231)

Notes: The first statistics for weak exogeneity and long-run exclusion stand for the CPI-based relative price series, while figures underneath refer to statistics related to the variable productivity.