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Product Innovations, Process Innovations and Foreign Direct Investment: New Theoretical Aspects and Empirical Findings

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Summary:

The distinction between product innovations and process innovations is crucial for industrialized countries as well as for newly industrialized countries – and only a distinct consideration of product innovations in macroeconomic modeling allows to fully understand Schumpeterian innovation dynamics and their national and international impact. With this focus, initially a simple microeconomic modelling of product versus process innovation is considered in a setting with both inward and outward foreign direct investment, largely following the Bertschek approach. Results from the European Union's Community Innovation Survey are considered as well as relative export unit values – relative to the US EUV – which are a proxy for product innovations in the tradables sector. Regression results show that inward FDI raise both product innovations and process innovations in the EU. The key aspects of both process innovations and product innovations are then considered in an open economy macro model which brings many new insights, including a much better understanding of the links between innovation dynamics, the current account, FDI, the real exchange rate, output and inflation. Product innovations have a different impact on the real exchange rate than process innovations and a dynamic view of the Vernon product cycle is required for an adequate analysis. As regards the demand for money, product innovations affect this demand in a different way to process innovations. Optimal product innovations are also considered. Innovations in Schumpeterian macroeconomics thus gets crucial new perspectives.

Zusammenfassung:

Die Unterscheidung zwischen Produkt- und Prozessinnovationen ist sowohl für Industrie- als auch für Schwellenländer von entscheidender Bedeutung – und nur eine ausgeprägte Berücksichtigung von Produktinnovationen in der makroökonomischen Modellierung erlaubt es, die Schumpeter'sche Innovationsdynamik und ihre nationalen und internationalen Auswirkungen vollständig zu verstehen. Mit diesem Schwerpunkt wird zunächst eine einfache mikroökonomische Modellierung von Produkt- versus Prozessinnovationen in einem Umfeld mit sowohl eingehenden als auch ausgehenden ausländischen Direktinvestitionen betrachtet, wobei weitgehend dem Bertschek-Ansatz gefolgt wird. Die Ergebnisse der Community Innovation Survey der Europäischen Union werden ebenso berücksichtigt wie die relativen Werte der Exporteinheiten – im Vergleich zum EUV der USA –, die ein Näherungswert für Produktinnovationen im Sektor der Handelsgüter sind. Die Regressionsergebnisse zeigen, dass die ausländischen Direktinvestitionen im Inland sowohl Produktinnovationen als auch Prozessinnovationen in der EU steigern. Die Schlüsselaspekte sowohl der Prozess- als auch der Produktinnovationen werden dann in einem Makromodell der offenen Wirtschaft betrachtet, das viele neue Erkenntnisse bringt, darunter ein wesentlich besseres Verständnis der Zusammenhänge zwischen Innovationsdynamik, Leistungsbilanz, ausländischen Direktinvestitionen, realem Wechselkurs, Produktion und Inflation. Produktinnovationen wirken sich anders auf den realen Wechselkurs aus als Prozessinnovationen, und für eine adäquate Analyse ist eine dynamische Sicht auf den Vernon-Produktzyklus erforderlich. Was die Geldnachfrage betrifft, so wirken sich Produktinnovationen anders auf diese Nachfrage aus als Prozessinnovationen. Optimale Produktinnovationen werden ebenfalls berücksichtigt. Innovationen in der Schumpeter'schen Makroökonomie erhalten damit entscheidende neue Perspektiven.

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1. Introduction

Innovation is a key element of economic growth and the Industrial Revolution has certainly played a major role for broader research & development activities and innovations, respectively, as is witnessed by the new institution of patents in Europe and later worldwide and subsequent patent statistics. Process innovations have been considered in the standard Solow growth model where this kind of innovation is usually introduced as labor-augmenting Harrod-neutral progress or as a factor "knowledge" (A) which effectively raises the level of per capita output for a given capital intensity. A rise of the growth rate of knowledge raises the growth rate of per capita output in the steady state. However, for a long time there was little discussion about the drivers of technological progress. The progress function of KALDOR (1957) and later the concept of a knowledge production function (GRILICHES, 1961; MACHLUP, 1962) were the first approaches regarding endogenous innovation and hence growth modeling. Important is the concept of codified knowledge which is transferable nationally and internationally through communication, say via e-mail, versus tacit knowledge (TEECE, 2000) whose transferability rests upon mobility of skilled workers, researchers and engineers who have personally acquired specialist knowledge.

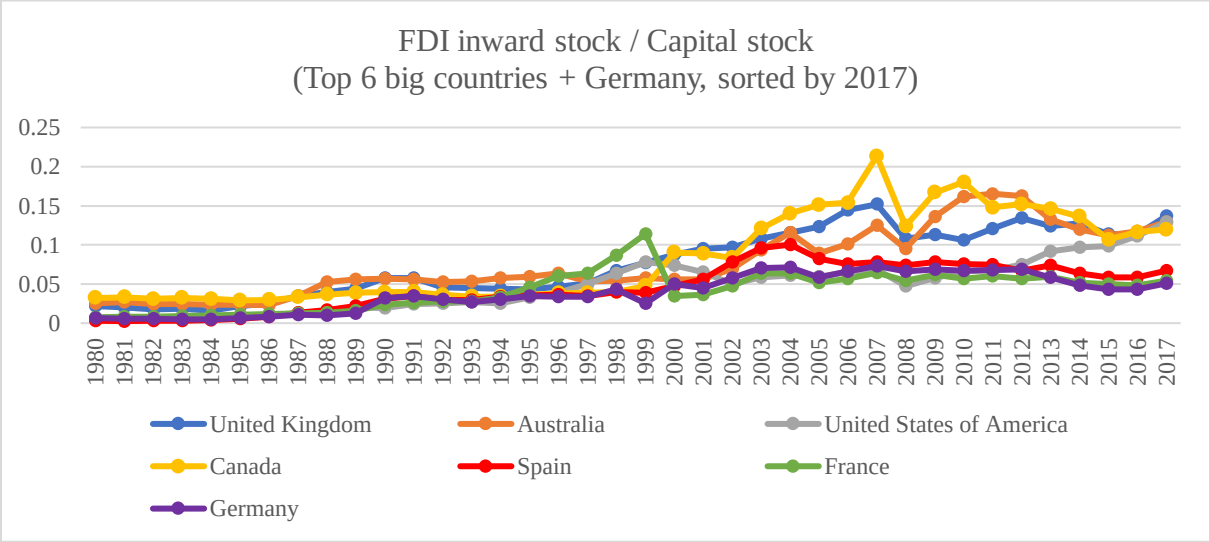
Multinational companies (MNCs) clearly play a critical role for international technology transfers and for the international co-movement of output; CRAVINO/LEVCHENKO (2017) have shown that amongst OECD countries and some Newly Industrialized Countries (NICs) there is positive correlation between sales in the host country of the respective multinational and the sales in the host countries; foreign subsidiaries are assumed to share part of the productivity shock of the respective parent company. A growth of the sales of the headquarter company by 10% is associated with a growth of sales of 2% in the subsidiary abroad. Moreover, the authors show that a shock to the source country accounts for a significant share of the variation in the growth of sales at the source-destination level. For the "average country" in the sample of 34 countries considered, the impact of a foreign shock transmitted by all foreign MNCs combined is about 10% of the aggregate productivity shock so that analysis of the international business cycle transmission should indeed consider multinational companies' activities and innovation dynamics linked to inward (cumulated) foreign direct investment and outward (cumulated) foreign direct investment, respectively.

Analytically, one may have to make a distinction between vertical FDI and horizontal FDI. With more than a half of global trade being intermediate products, MNC's intra-company trade within OECD countries plays a crucial role; but international outsourcing in the world economy is also a ley aspect. The expansion of information & communication technology has made a wider spatial production network easier to establish; and MNCs again play a crucial role for the global allocation of resources.

Cumulated FDI has indeed become more important over time in many countries – with respect to inward FDI as well as outward FDI (see the following figures and also related tables in the appendix). Since the 1980s, Newly Industrialized Countries (NICs) in several cases have become important source countries of FDI so that it is not only OECD countries which are among the key sources of foreign direct investment outflows. On the inflow side, there are also interesting shifts, including the rising role of China since the 1980s.

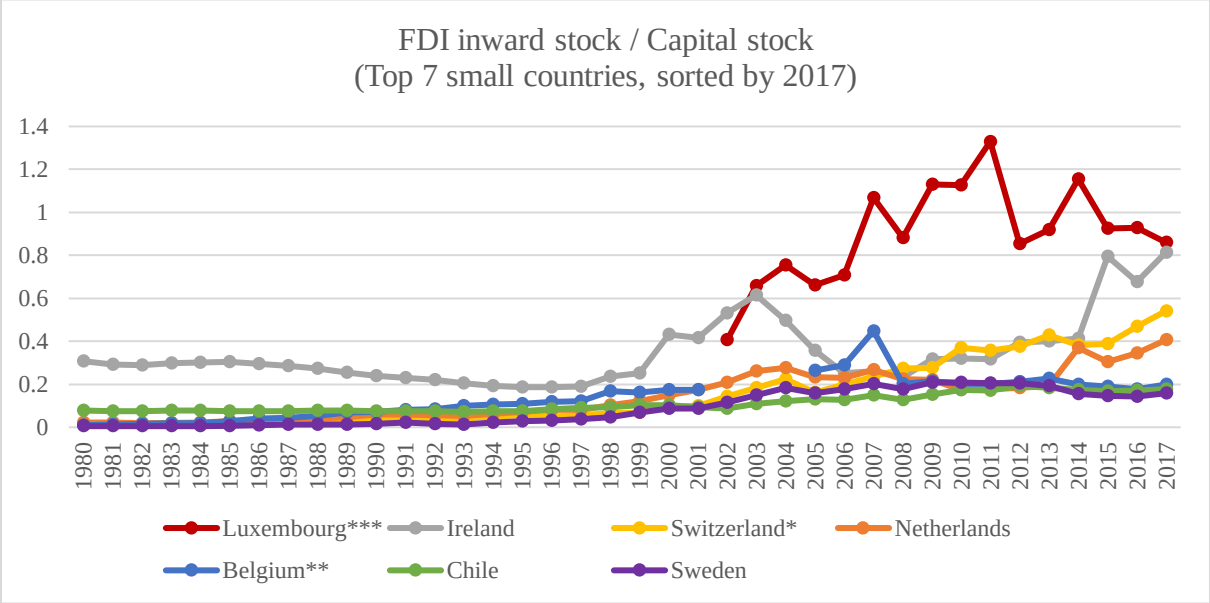
The following figure, Figure 1, shows that the leading large OECD economies have a ratio of FDI inward stock to the host country capital stock which is in the range of 0.05 to 0.15; the four leading countries are the UK, Australia, the US, and Canada - with about 13% in 2017. There is a long-term increase of this ratio over time. The leading small economies generally have, of course, higher ratios than the large countries as can be seen in Figure 2. The phenomenon of holding companies – playing a strong role in Luxembourg and Ireland – partially explains why the ratio in these countries comes close to 100% in some years (for more details see Appendix 4). As regards the ratio of FDI outward stock to the source country capital stock (Figure 3), the leading OECD countries show a general tendency for an increase over time which reflects relatively intensifying globalization in terms of having more production abroad. There is a weaker long-term increase in some of the smaller OECD countries (Figure 4). Luxembourg and Ireland again have somewhat distorted figures in the context of holding company activities in these two countries (for details, see Appendix 4).

Figure 1: FDI inward stock / Capital stock (Top 6 big countries + Germany, sorted by 2017)



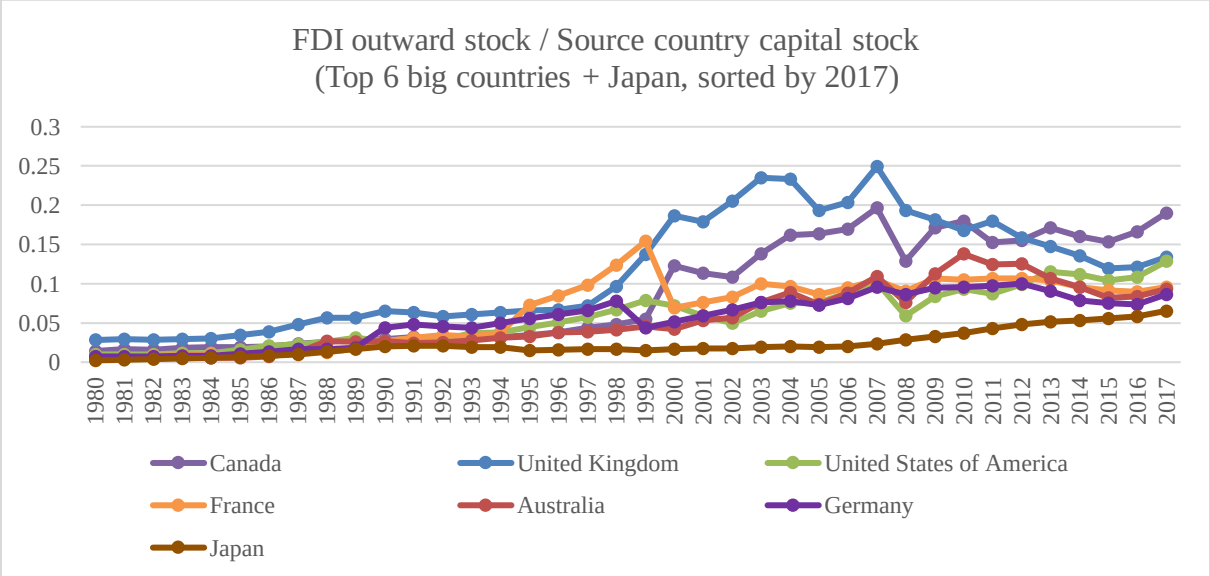
Source: UNCTAD and GGDC data, EIIW calculations

Figure 2: FDI inward stock / Capital stock (Top 7 small countries, sorted by 2017)



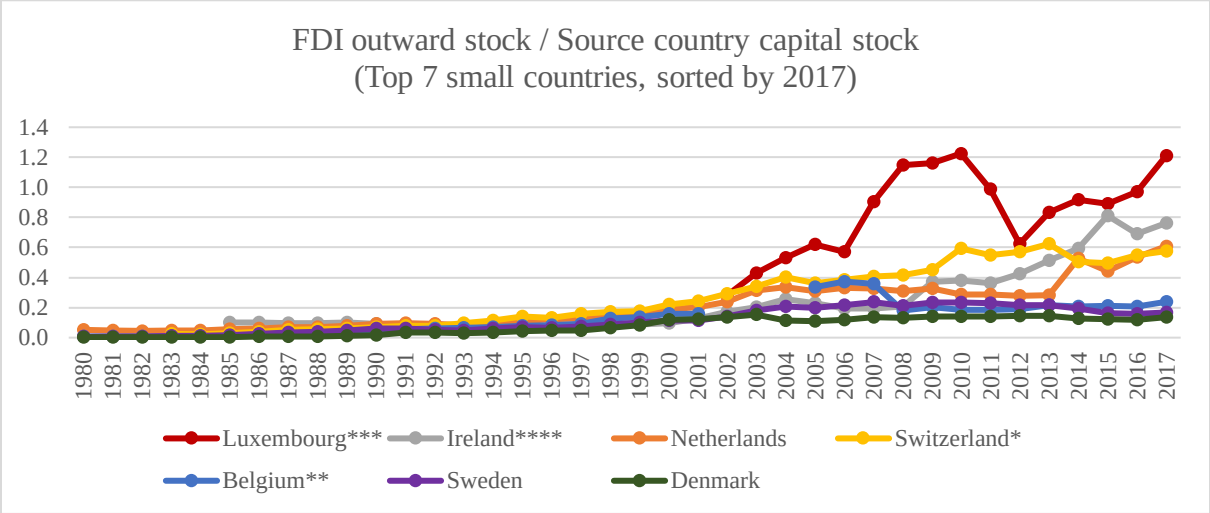
** Switzerland: Switzerland & Liechtenstein*
*** Belgium: missing data 2002-2004*
****Luxembourg: missing data 1980-2001*
Source: UNCTAD and GGDC data, EIIW calculations

Figure 3: FDI outward stock / Source country capital stock (Top 6 big countries + Japan, sorted by 2017)



Source: UNCTAD and GGDC data, EIIW calculations

Figure 4: FDI outward stock / Source country capital stock (Top 7 small countries, sorted by 2017)



** Switzerland: Switzerland & Liechtenstein*
*** Belgium: missing data 2002-2004*
****Luxembourg: missing data 1980-2001*
*****Ireland: missing data 1980-1984*
Source: UNCTAD and GGDC data, EIIW calculations

The role of exogenous productivity shocks is part of the traditional analysis of real exchange rate reactions in open economies. Several authors have exploited sign restrictions (e.g., CORSETTI ET AL., 2014; ENDERS ET AL., 2011) or a combination of short run or long run zero restrictions – in some cases, restrictions on the forecast error variance contribution of technology shocks (LEVCHENKO/PANDALAI-NAYAR, 2020; MIYAMOTO/LAN NGUYEN, 2017, KAMBER ET AL., 2017; NAM/WANG, 2015) to get an identification of exogenous shocks and then estimate the effects in open economies. A number of authors have found that an unanticipated rise of productivity growth brings about a real depreciation (e.g., MIYAMOTO/LAN NGUYEN, 2017), other authors find a real appreciation (ENDERS ET AL., 2011; CORSETTI ET AL., 2014). Several authors have presented different findings for anticipated as opposed to surprise technology shocks – an appreciation follows after an anticipated productivity shock, while a depreciation follows a surprise productivity shock (LEVCHENKO/PANDALAI-NAYAR, 2020; NAM/WANG, 2015). KLEIN/LINNEMANN (2020), referring to these and other authors, present evidence – in the context of anticipated and surprise US productivity shocks - for a real appreciation effect of the currency of the innovation country; however, the authors consider solely process innovations (both anticipated and surprise technological innovations – which means a rise of total factor productivity growth for which the empirical part of the innovative Klein-Linnemann approach uses patents as an instrumental variable; whereby patents could represent process as well as product innovations). If process innovations and product innovations have different effects on the real exchange rate, the distinction between the two types of innovation is crucial: For example, if a rise of the US product innovation rate brings about a real appreciation, while a rise of the US process innovation rate causes a real depreciation, then the relative innovation mix of the US in the long run would be quite important. If the US innovation mix brings about a real appreciation, this implies - taking into account the role of the US dollar as a global reserve currency - that the US

real interest rate will be smaller than in other OECD countries which is an advantage for the United States which will also benefit from international seigniorage gains.

The specific field of "young multinationals" will not be considered here although in some sectors, for example in the area of biotechnology and information & communication technology, they could play a crucial role. Digital firms in particular can be created and could start immediately as micro multinationals since digital offshoring is not difficult and often not very costly. Many points raised by young multinationals with their focus on start-up high-technology dynamics in a given economy quickly will have a broader international context in the digital sectors of the economy. If one follows Schumpeter's approach of innovation and entrepreneurship (SCHUMPETER, 1912), innovation dynamics are part of economic growth and development, respectively, while innovation dynamics cannot really be separated from entrepreneurship. With the outward foreign direct investment stock of many OECD countries coming close to 10 percent of the home country capital stock in 2018, the idea of entrepreneurship has naturally gained an increasing international perspective since the beginnings of modern economic globalization in the 1980s. While multinational company activities have been traditionally associated with large firms' international production, the digital world economy offers new perspectives on internationalization, innovation and entrepreneurship – micro-multinationals (to borrow a term from Hal Varian) can represent international entrepreneurship even with regard to small firms and digital start-ups and digital multinationalization so far stand for a field in which little in the way of research with a joint perspective on these two points has been offered so far. While the Silicon Valley model of entrepreneurship - and innovation - seems to have its limitations (AUDRETSCH, 2018) the topic of ICT innovation dynamics and digital entrepreneurship remain important analytical challenges. As the broad focus in the subsequent analysis is on aggregate FDI, special sectoral perspectives cannot be discussed here.

A crucial focus in the subsequent analysis is on product innovations and process innovations. Indeed, the important distinction of innovation dynamics – which will be considered here in detail - is that between product innovations, which typically raise consumers' willingness to pay, and process innovations, which amount to a downward shift of the marginal cost curve of the individual firm (or of all firms – if applicable). One should note that product innovations in the field of investment goods typically amount to process innovations in consumer goods whose production involves the use of more modern capital equipment. The role of FDI and multinationals, respectively, for innovation will be discussed here in a broad perspective, including some empirical considerations.

Section 2 examines the role of product and process innovations in the context of inward and outward FDI and trade. Section 3 takes an analytical view on product innovation and process innovation statistics. Section 4 considers product innovations and process innovations in the context of an enhanced Mundell Fleming macro model. Section 5 discusses optimal consumption aspects in a setting with innovations and inward FDI. Section 6 presents empirical findings for Europe (and US Firms with subsidiaries active in the EU). The final section offers policy conclusions and considers further research perspectives.

2. Product and Process Innovations in the Context of Inward and Outward FDI plus Trade

Innovations are a key element of the competition process and affect both the supply side and sectoral as well as aggregate demand; to some extent total factor productivity growth is linked to foreign direct investment where both inward FDI as well as outward FDI could contribute to technological progress (AMANN/VIRMANI, 2015; VAN POTTELSBERGHE DE LA POTTERIE/LICHTENBERG, 2001), however one should not rule out that techno-globalization – in the sense of an international division of R&D within MNCs - would bring higher product innovations in host countries parallel to reduced product innovations in the source country. While the latter authors consider OECD countries and do not find significant technology spillovers of inward FDI, the contribution by AMANN/VIRMANI (2015) shows empirical evidence for firms from NICs with FDI in OECD countries that such reverse technology spillovers play a role. VAN POTTERSBERGHE DE LA POTTERIE/LICHTENBERG find evidence that outward FDI in R&D intensive countries brings reverse technology spillovers while inward FDI has no significant effect here.

However, one may point out that the growth rate of total factor productivity growth refers to the trend growth rate of per capita income in the steady state – the authors have not studied to what extent cumulated inward FDI (from technology-intensively producing countries) raises the level of the growth path in the steady state. One should note that total factor productivity growth apparently refers to process innovations, but since per capita real income (or labor productivity) is $(Y^n/P)/L$ – where Y^n is nominal output, P the output price level and L labor input – inadequate hedonic pricing approaches could distort total factor productivity growth via the distorted measurement of the price level and inadequate coverage of quality changes, respectively. This aspect could impair statistical and empirical analysis.

In macroeconomic models, few authors have considered the role of product innovations – among the few exceptions is the case of an enhanced Schumpeterian Mundell Fleming model (WELFENS, 2011) where the rise of product innovations stimulates both consumption and the export of goods and services, while also raising the real demand for money (liquidity demand is raised as households hope for more opportunities to buy new welfare-enhancing products). In a macroeconomic growth model, product innovations should also have a role since the savings rate may be assumed to reduce if more product innovations become available for households. At the same time, product innovations should raise the profitability of firms and hence higher investment should be expected to the extent that novel products can only be produced with new machinery and equipment.

In reality, both product innovations and process innovations play a role. The profitability of firms could rise both in the presence of more own product innovations and when process innovations bring about a higher profitability through cost reductions so that aggregate investment should be a positive function of both product innovations and process innovations; one should, however, not overlook that process innovations often also affect the production of investment goods and in a digital economy this could certainly play a crucial role. As regards consumption, product innovations should enhance consumption as well as exports where the

latter is in line with the product cycle trade approach of VERNON (1966). It should be clear that a higher rate of product innovations will bring about an improved current account balance and therefore a real appreciation of the currency in the current period, but the very logic of product cycle trade suggests that such an appreciation will be followed by a period with a real depreciation of the currency as more and more products in the export bundle of the country considered will enter the diffusion stage and maturity, respectively – and therefore imports from abroad, of the now established product, will increase. Naturally, there is also a link between product innovations and the business cycle (JOVANOVIC/LACH, 1997).

One should, of course, not rule out that product innovations occur with an aggregate profile over time and that the real exchange rate could remain constant – a specific setting for an endogenous growth model. While VERNON's focus on the link between product innovations and the trade balance was an adequate element of modern innovation theory (with process innovations becoming more important in the diffusion stage of the product cycle and even more crucial in the maturity stage), the complementary links between FDI and product innovation dynamics were not considered to any great extent; with the exception of the two major contributions mentioned above. It is unclear whether or not the increasing digitalization of production in OECD countries and NICs has had an effect on the international transferability of knowledge via FDI or trade. As regards technology transfer through imports, COE/HELPMAN (1995) have presented positive empirical evidence that intensive trade with countries with significant levels of production of high technology contributes to output gains; a concept that has been criticized by KELLER (2000).

The ratio of trading costs to fixed R&D costs determines the ratio of foreign subsidiaries' output relative to production in the home country – and thus potential exports. The more complex products are, the higher - according to our assumption - trading costs are, so that the ratio of trading costs to fixed R&D costs is rising and outward FDI becomes profitable; to the extent that demand for rather complex products is a function of real per capita income, product innovations can be expected in high income countries; the complexity of these products, in turn, then gives an incentive for more international outsourcing as well as offshoring so that R&D staff in the headquarter country can specialize even more on high-tech R&D and advanced products or services. BAILEY/LAWRENCE (2005) have shown for the US software sector that there was international outsourcing and offshoring to be observed, particularly, towards India and China, but such dynamics allowed US firms to specialize even more in high-end innovative complex software so that the number of jobs in the US software sector did not decline; even more remarkably, the number of highly skilled software engineers even increased.

In an open economy macroeconomic perspective, one may associate product innovations primarily with the tradable sector so that a shift in favor of the tradable sector – relative to the non-tradable sector – can be interpreted as standing for product innovations. Process innovations are assumed to affect both the tradable and the non-tradable sectors (at least more symmetrically than product innovations). As regards policy intervention, one may assume that a rise of education expenditure reinforces firms' ability to launch both process and product innovations; if government earmarks all R&D support for the tradable sector, one may assume that a relative product innovation effect will dominate in the short term. Finally, one may ask to what extent there are international R&D spillovers. While this generally is a complex issue, one may assume that a rising share of the ICT sector in total output will facilitate international diffusion.

To the extent that there is cumulated inward FDI or cumulated outward FDI, one will have to draw a distinction between real gross domestic product (Y) and real gross national income (Z). Consumption and both exports and imports should depend on product innovations, but at the same time it is clear that all three functions will show proportionality with respect to Z. Denoting the share of cumulated outward investment of country 1 firms abroad (in country 2) by α, the share of cumulated outward investment of country 2 firms in country 1 by α*, and the profit ratio (profits as a share of GDP) in country 1 and country 2 by ß and ß*, respectively, one can write in the case of asymmetric inward FDI for real national income $Z= Y(1-\alpha*ß)$ and in the case of symmetrical FDI real income $Z= Y(1-\alpha*ß) + \alpha ß*Y*q*$, and for Z* in the symmetrical case $Z* = Z*(1-\alpha ß*) + \alpha*ßY/q*$ where q* is the real exchange rate ($q*:=eP*/P$). This approach is compatible with a Cobb-Douglas production function $Y=K^{ß}(AL)^{1-ß}$ in country 1 and $Y*=K*^{ß*}(A*L*)^{1-ß*}$ in country 2 - with K denoting the capital stock, A knowledge and L labor (with $0<ß<1$; $0<ß*<1$). A rise of A should be considered as process innovation and, assuming competition in goods and factor markets – and profit maximization of firms -, implies that the profit share in GDP will be ß in country 1 and ß* in country 2. Product innovations are not broadly covered in the Systems of National Accounts although such innovations play a key role in most OECD countries.

In the System of National Accounts there is some indirect coverage of product innovations to the extent that hedonic price level measurement considers the improvement of quality and enhanced product features as an effective reduction of prices recorded in the markets; while the US, for example, has no data series on product innovation the official statistics have started to move towards hedonic price measurement (MOULTON, 2001), and the IMF (SILVER, 2009) uses hedonic pricing methods for measuring purchasing power parity figures. However, across countries there are large differences in the use of hedonic pricing methods in the official statistics. In principle, one could extract product innovation data from the US' official hedonic price measurement which takes into account quality improvements and thus product innovations: From a theoretical perspective, it holds that the ratio of the notional (normal) price index P to the hedonic price index P^H is equivalent to an indicator for product innovations and quality improvements, respectively. An alternative – at least for the tradables sector – could be the ratio of export unit values (EUV) divided by EUV^{US} of the US which could be taken as a benchmark country. EUV statistics would be rather useful particularly in the field of high-technology and medium-technology and also on the basis of aggregate data in manufacturing industry (there is no such concept for the services sector). In order not to be misled by the sometimes sudden big changes in the EUV of certain countries, one should consider three year moving averages (lagged year, current year plus year ahead). An alternative to such measurement of product innovation is the use of survey data which are available bi-annually for EU countries plus a few other European countries, data which indeed will be used in more detail subsequently.

Relative export unit values are an interesting concept for product innovation analysis (see Table 1); a rise of relative EUV should indicate a quality improvement – possibly also a higher market power of firms from the respective country. Standardizing European countries' EUV relative to the US EUV implies that the impact of common transatlantic process innovations is not distorting the picture – looking at the developments 2002-2017 some European countries are rather strong: e.g. Austria plus Belgium until 2008 and the UK plus Italy, Spain and Switzerland in the overall period among the established OECD countries, but also many post-socialist

transition countries in eastern Europe. Strong entrepreneurship and a high product innovation rate, respectively, drive long term improvements of relative export unit values.

Table 1: 3-year moving average of relative exports unit value between European countries and the US from 2001 to 2018

3-year moving average of relative exports unit value between European countries and the US from 2001 to 2018, base year 2000(=100)

Country	Year															
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Austria	108	119	127	131	135	140	144	141	137	131	131	130	127	125	124	129
Belgium	109	120	130	135	139	145	147	144	141	138	139	137	133	127	124	128
Bulgaria	105	118	131	143	155	169	173	171	169	170	171	167	160	153	149	154
Croatia	98	102	107	113	120	129	132	130	127	126	126	123	118	113	110	114
Cyprus	110	122	132	137	142	152	152	148	140	139	138	134	127	118	112	117
Czech Republic	115	129	140	144	148	155	159	157	154	151	151	150	148	146	145	150
Denmark	108	119	128	132	134	138	139	137	134	132	134	134	132	128	126	129
Estonia	110	119	127	131	136	145	149	147	145	143	144	142	137	132	129	133
Finland	104	113	121	126	133	139	140	136	134	133	133	131	126	120	117	122
France	110	121	130	134	138	144	149	147	143	139	139	139	136	133	131	135
Germany	110	121	129	131	135	139	143	141	139	135	135	136	135	134	133	137
Greece	107	118	128	135	140	149	150	148	146	147	149	145	135	123	116	121
Hungary	107	116	123	123	123	125	127	125	123	120	120	119	116	113	112	116
Ireland	104	110	116	118	119	120	121	120	117	114	113	111	110	109	108	109
Italy	112	124	135	140	146	154	159	158	155	152	154	154	152	150	148	153
Latvia	110	123	133	140	148	160	164	160	155	155	156	155	151	144	140	145
Lithuania	107	119	130	136	145	158	160	158	156	160	165	164	156	147	141	146
Luxembourg	106	113	118	117	117	118	115	109	105	102	102	100	98	94	92	94
Malta	105	113	115	115	118	126	136	142	149	146	145	139	136	133	129	133
Netherlands	104	113	121	126	130	136	137	135	133	133	135	134	130	125	121	125
North Macedonia	98	102	108	114	119	126	133	140	143	144	143	141	140	140	140	140
Norway	97	107	126	150	170	191	188	186	183	196	206	200	179	151	135	143
Poland	112	124	134	140	146	154	157	155	151	147	147	146	143	139	138	142
Portugal	109	119	127	130	133	138	140	137	135	132	133	132	129	125	123	127
Romania	112	125	138	147	154	162	164	162	161	160	161	160	156	152	149	155
Serbia	100	104	112	122	130	138	141	144	146	148	147	145	142	142	141	143
Slovak Republic	108	123	138	145	148	151	152	147	142	135	134	130	125	122	122	128
Slovenia	111	124	134	139	142	148	151	149	145	141	140	138	133	129	126	130
Spain	110	121	132	137	142	149	152	150	146	143	143	142	137	133	130	135
Sweden	105	115	123	126	130	135	135	133	131	130	130	128	123	119	116	119
Switzerland	112	122	129	131	132	137	145	151	156	154	154	155	157	162	.	.
Turkey	101	109	118	124	128	135	136	134	128	128	128	126	125	122	120	119
United Kingdom	107	117	127	134	138	144	145	144	143	144	146	146	143	139	137	141

Note: Montenegro is not included

The demand for money reflects dynamics in all markets of the real economy. Surprisingly, product innovations have not often been considered in the formulation of the real demand for money: Product innovations will enhance the real demand for money as the marginal utility of holding money is raised by product innovations – households interested in buying product innovations will want to hold higher real money balances in an economy with strong product innovation dynamics (WELFENS, 2011) while product innovations could reduce the effective aggregate price level; it should also be noted that the distinction between GNP and GDP is crucial in a setting with inward FDI and outward FDI. Real GNP (Z) is equal to GDP (Y) plus net factor income from abroad which basically means that one has to consider the fact that GNP in host countries is reduced by the profits of foreign subsidiaries transferred to the source country – there, GNP will be higher than GDP if net income received from abroad is positive.

The foreign exchange market is also affected by product and process innovations. Following FROOT/STEIN (1991), net FDI inflows – here with a focus on international mergers & acquisitions (M&A) - should be a positive function of q* if imperfect capital markets are assumed. A real depreciation of the currency of the host country means that foreign investors (bidders in an M&A competition) have higher equity expressed in currency units of the host country so that the probability of foreign bidders launching a successful leveraged takeover bid is enhanced.

The link between the current account position and product innovation dynamics is crucial. In open economies, one will have to consider sectors with current product innovations which, according to VERNON (1966), will bring about a temporary improvement of the current account as the new products are exported, namely at rather high prices in the innovation stage; later, in the expansion stage of the product cycle – as emphasized by the Vernon approach - the product as well as the production process will become more standardized so that part of production is relocated internationally via outward FDI - say, from the US or Germany/France/Japan to some eastern European or Asian country. Thus, the current account balance of the initial product innovation country will deteriorate since imports of the now established "new" product – now being produced abroad – are rising and add to the import bill; note, that the import price will be relatively low in the diffusion and the maturity stages of the product cycle. Structural change in the innovative country could be such that new product innovations raise the average export unit value and hence the price level (with hedonic price measurement, the quality-adjusted price level would, however, reduce).

Under flexible exchange rates – not considered in the Vernon approach – there should be a real appreciation of the currency of the country with the initial product innovation wave, followed later by a nominal and real depreciation of the currency. If one adds the Froot-Stein perspective, one may argue that reduced FDI inflows would thus be followed later by a period of enhanced FDI inflows.

One may add that the speed of the price adjustment can be expected to be rather slow in the innovation stage, but should be faster in the subsequent stages of standardization and maturity, respectively (in the final maturity stage of the product cycle trade, the initial product innovator country will only import from abroad, largely from developing countries and NICs). The sectoral ratio of product to process innovations thus should be crucial for price responsiveness; that ratio, however, has not been much considered in the literature with the particularly notable exception (albeit not in the context of price adjustment speed) - in an early stage of the debate

on the Economics of Innovation – of a contribution by UTTERBACK/ABERNATHY (1975) in Innovation Economics. These authors have argued that in new sectors, product innovations at first are typical while only in a later stage of the product cycle – to refer here to the approach of VERNON (1966) – the role of process innovations will play a bigger role so that the ratio of product innovations to process innovations would indicate the maturity of the respective sector. Product innovations are also considered in endogenous growth modeling where AGHION/HOWITT (1990) do not only consider positive external effects of product innovations but also the effects of induced obsolescence in the loser sectors and for losing firms, respectively; an interesting Schumpeterian growth model extension – with innovation dynamics in the intermediate product market (under monopolistic competition) - is the enhanced Solow growth model (AGHION/HOWITT, 2007). MELITZ (2003) has emphasized the open economy aspects of innovation dynamics, namely that opening up – and thus further globalization – reinforces the role of innovative firms in the economic evolution process. The knowledge production function (GRILICHES, 1979; WELFENS, 2017) is a concept which covers the link between R&D investment/patenting and investment, namely in the sense that more patents of firms quoted on the stock market raise stock market prices which in turn stimulates investment (following the logic of the Q-approach of TOBIN (1969)). New aspects of immaterial capital market accumulation (HASKEL/WESTLAKE, 2018) are also crucial. The Community Innovation Survey of the European Union (EUROPEAN COMMISSION, 2020) gives some indication about product innovations and process innovations in various sectors – based on a bi-annual survey - and the sectoral ratio of product innovations to process innovations for EU member states.

Product Innovations in a Dynamic Market Perspective

Product innovations are not always launched in the country where the respective innovating multinational company has its headquarter, instead the concept of lead markets (BEISE, 2004) shows that innovative companies in the very early stage of the product cycle have a preference for launching product innovations in markets with a high per capita income and a considerable willingness of quality-conscious consumers to quickly adopt new products and thus give a useful feedback to the product innovator (Scandinavian countries, for example, are thus frequently preferred to the UK which has some rather traditional consumption patterns in certain markets).

With respect to the EU, VANDENBUSSCHE (2014) has developed an interesting product innovation approach for export markets – based on the analysis of DI COMITÉ/THISSE/VANDENBUSSCHE (2014) – which gives a simple implicit demand curve for a wider product market s (sector/product variety) where the subscript i refers to the country concerned – the firm has a small market size if the slope is steep; the approach has some similarity to the model of MELITZ/OTTAVIANO (2008) since the parameter γ captures – similar to their model – the extent to which product varieties are rather distant or rather close substitutes from each other from the perspective of consumption (p is the offer price of the firm – or the export unit value - for a particular variety in destination/country i, q the quantity produced of that firm and Q the quantity offered by all other firms with substitution goods. Note that different brands of wine are better substitutes for one another than say wine and beer; and

the parameter is without an index – it is assumed to be constant between varieties in the market and constant across the countries considered):

(1a) $p_{s,i} = \alpha_s - \beta_{s,i} * q_{s,i} - \gamma * Q_{s,i}$

In this approach – and referring to the market structure here – firms are monopolistically competitive by setting their offer price as a monopolist for the respective variety (in line with a CES consumption function as suggested by DIXIT-STIGLITZ, 1977). There is no oligopoly where each firm would react to the price setting of each competitor, rather firms react to market aggregates such as the average price in the respective market. Firms are assumed to be rather small so that an individual firm cannot influence market outcomes actively – firms have the market on their radar and react upon market price changes; $ß_{s,i}$ stands for the market size of a particular product variety. Moreover, α_S stands for the willingness to pay for the first unit of variety s in the destination country i (this parameter thus stands, in the Vandenbussche analysis, for the quality of the product) while $\beta_{S,i}$ here represents the slope of the linear demand function which varies by the variety considered (s) and the destination country i. Finally, the parameter γ stands for the substitutability between varieties and $Q_{s,i}$ is the consumption of all other varieties offered in the differentiated product market in the destination country i (note that DI COMITÉ/THISSE/VANDENBUSSCHE (2014) point out that $\beta_{S,i}$ can be given a quasi-spatial interpretation similar to the "taste mismatch" of a consumer; mismatch is the distance between the preferred variety and the varieties offered in the market. From this perspective the slope of the linear demand can thus be interpreted as the "taste mismatch" between a consumer's ideal variety and the actual variety on offer in the market considered. A flat slope of the linear demand curve points to a variety that is well-liked by local consumers). At the bottom line, the equilibrium price is a positive function of the product quality α_s as well as the marginal cost of production (k'_s), but also a negative function of the quantity $Q_{s,i}$ offered by competitors with substitutes for the respective product in the market considered.

VANDENBUSSCHE (2014) applies this approach to individual EU countries' exports of products to a common destination country so that one obtains distributions of "export quality" – and also of its change over time in 2007-2011 where considerable quality dynamics in the EU market for consumer products and industrial products was identified. Interestingly, quality is sometimes found to run in a different direction to the market share: The highest quality is not necessarily delivered to the largest market; moreover, the estimates of a price elasticity of quality is shown to be positive. From this perspective, it is obvious that quality upgrading can indeed result in a higher willingness to pay by consumers: Firms facing enhanced competition within the EU single market from EU competitors, or from firms in third countries, can thus use quality upgrading as a strategy for escaping sharper international cost competition. This aspect has been relevant, for example, in the context of EU eastern enlargement or when firms from the EU15 were facing enhanced competition from China after 1980 as has been shown with a focus on EU cohesion countries and eastern European EU accession countries by BORBELY (2006) who also gives empirical analysis for different types of markets – ordered according to factor intensities and technology intensity, respectively. More recent interesting findings for the EU, are from GALAR (2015) who shows that intra-OECD is largely concentrated in high-tech product trading while EU countries' trade with China on the EU's import side is rather in the field of medium technology.

Product Innovations and Process Innovations in a Joint Perspective

As a second analytical step for understanding product and process innovations in open economies with trade and both inward and outward FDI, it is useful to consider a compact microeconomic modelling approach – indeed developed in the subsequent section. On this basis, empirical and macroeconomic analysis is presented. The macroeconomic modeling should combine several of the above mentioned aspects and could, for example, allow to better understand why innovative countries are not all facing a nominal and real depreciation of the currency as process innovations – mostly considered in standard macro models – bring cost and price reductions. Rather, the distinction between process and product innovations implies that a wave of product innovations should bring about a transitory or permanent real appreciation for a country with a high product innovation rate. This research has high relevance both for OECD countries and NICs. The main new findings here consider linkages between product innovations - or process innovations – and inward and outward FDI, plus there are new findings on innovation dynamics and the link between product innovation plus process innovation on macroeconomic developments.

A theoretical approach on process and product innovations should take into account the basic microeconomics of such innovations. In a nutshell, such an approach can be found in BERTSCHEK (1995) who also looked into the empirical aspects for firms in German manufacturing, while BLIND/JUNGMITTAG (2004) – largely following that approach – have also presented empirical evidence for German services firms. As regards the latter, the clear finding was that both import competition and the presence of foreign investment stimulate both product and process innovations. The role of outward (cumulated) FDI was, however, considered in neither paper. Clearly, it would be adequate to focus on both inward and outward FDI and also to have a broader range of countries included.

The price of the product – see equation (1) - is assumed to depend negatively on output q_i of firm I and the output (Q_d) from other domestic firms as well as output Q^f of foreign subsidiaries (from country 2) in the respective sector; Q^{*f} is output of country 1's subsidiaries abroad. J is the quantity imported and, by assumption, import competition reduces the market price. Better product quality or product innovation v_i is assumed to raise the market price. The output of foreign firms is simply assumed to be determined by the FDI inward stock (in the respective sector), lagged by one period. Marginal costs c_i is a positive function of the nominal wage rate W_i, product innovation v_i and process innovations v'_i. Fixed costs are assumed – here in contrast to the Bertschek approach - to depend positively on v_i and v'_i, respectively, while both Q^f and Q^{*f} reduce these costs. Based on equations (1) to (3), one can write the equation for profits Π and then consider maximization of profits in equation (5) – actually a condition $d\Pi = 0$ which is the first order condition for profit maximization. BERTSCHEK (1995) had assumed that domestic firms facing foreign company entry will want to maintain profits (hence $d\Pi = 0$) and this assumption indeed will be used here also.

There is, however, a crucial difference to the Bertschek approach since here it is assumed that fixed costs F are not just exogenous, but depend on product innovations, process innovations, the inward FDI stock and the outward FDI stock. By assumption, both FDI stock variables affect F negatively, while v_i and v'_i raise F; indeed, one may argue that multinationals (from OECD countries and certain NICs) with subsidiaries producing abroad will be able to effectively reduce fixed costs of innovation in the home country (country 1), namely through

techno-globalization (JUNGMITTAG, 2020) which means using some form of R&D offshoring which reduces overall R&D costs or through asset-seeking foreign direct investment which successfully targets R&D-intensive firms abroad. The presence of foreign investors in turn should reinforce competition in the respective sectors and efficiency gains in the R&D activities of a domestic firm i should indeed be possible, not least through R&D spillover effects from foreign multinationals with subsidiaries in country 1. As regards the link between product innovation and process innovations, respectively, it should not be considered as unusual if fixed costs would rise in the presence of more innovations; in part of the ICT sector – say the software sub-sector – innovations go along mainly with higher fixed costs while marginal costs are close to zero.

(1) $p_i = p_i(q_i, Q_{-i}^D, Q_i^f, J, v_i)$

The partial derivatives for p_i are negative for the first four arguments in the function, but the derivative of p_i with respect to the product innovation is positive.

(2) $Q_t^f = Q_t^f(FDI'_{t-1})$

(3) $c_i = c_i(W_i, v_i, v'_i)$

(4) $\Pi_i = p_i(q_i, Q_{-i}^D, Q_i^f, J, v_i)q_i - c_i(W_i, v_i, v'_i)q_i - F(v_i, v'_i, Q_i^f, Q^{*f}_i)$

$$
\begin{aligned}
d\Pi_i = & \left(\frac{\partial p_i}{\partial q_i} dq_i + \frac{\partial p_i}{\partial Q_{-i}^D} dQ_{-i}^D + \frac{\partial p_i}{\partial Q_i^f} dQ_i^f + \frac{\partial p_i}{\partial J} dJ + \frac{\partial p_i}{\partial v_i} dv_i \right) q_i \\
& + p_i(\cdot) dq_i - \left(\frac{\partial c_i}{\partial W_i} dW_i + \frac{\partial c_i}{\partial v_i} dv_i + \frac{\partial c_i}{\partial v'_i} dv'_i \right) q_i \\
& - c_i(\cdot) dq_i - \frac{\partial F}{\partial v_i} dv_i - \frac{\partial F}{\partial v'_i} dv'_i - \frac{\partial F}{\partial Q_i^f} dQ_i^f - \frac{\partial F}{\partial Q^{*f}_i} dQ^{*f}_i = 0
\end{aligned}
\tag{5}
$$

Subsequently it is assumed that the marginal impact of Q^f on fixed costs is rather small, so that the partial derivative dv'/dQ^f is positive; this could also imply – as assumed here (see equation (6)) – that higher imports contribute to higher process innovations. Positive process innovation multiplier signs for the stock of inward FDI and of imports are indeed found in the empirical studies of BERTSCHEK (1995) as well as BLIND/JUNGMITTAG (2004). It should be noted that equation (7) – concerning the innovation multipliers for output q - is not in line with Schumpeter's hypothesis that bigger firms are more innovative than smaller firms. One may, however, raise some doubt with respect to the process innovation multiplier: If the induced price reduction is weaker than the marginal cost reduction, process innovations are raised by an increase of output of the respective firm; note that in the case that this condition holds, higher imports will depress process innovations. Moreover, according to equation (8) process innovations should also not benefit from a higher stock of outward FDI. In a broad perspective, this is in line with the empirical findings of VAN POTTELSBERGHE DE LA POTTERIE/LICHTENBERG (2001) for OECD countries – as long as one assumes that part of

the technological progress measured by the authors actually reflects product innovations and process innovations.

One can easily imagine that looking at high-tech countries (e.g. Western Europe, Japan, US, Canada) implies that the firms located there will often have opportunities to combine skilled labor, R&D and an efficient innovation system in a way that product innovations can be achieved. For high-tech countries with rather high wages for both skilled and unskilled labor, process innovations could be more difficult to the extent that the respective sector is characterized by static or dynamic economies of scale while technologies are internationally mobile so that the logic of Vernon's product cycle will hold. However, in immobile Schumpeterian industries – where production and R&D cannot be easily disentangled across space (e.g., high precision machinery and the air & space industry) – process innovations could still be emphasized in the high per capita income countries since firms are aware of the rather limited international offshoring and outsourcing options for intermediate innovative inputs. In the subsequent equations, the effect of process innovations and the marginal cost is, of course, assumed to be negative and it is assumed that the price improvement, after product innovation, exceeds the marginal cost increase from the product innovation which is a plausible assumption for firms with rational R&D strategies.

$$(6)\quad \frac{dv'_i}{dQ_i^f} = \left(\frac{\partial p_i}{\partial Q_i^f} q_i - \frac{\partial F}{\partial Q_i^f}\right) \Bigg/ \left(\frac{\partial c_i}{\partial v'_i} q_i + \frac{\partial F}{\partial v'_i}\right) > 0 \;\; and \;\; \frac{dv'_i}{dJ} = \frac{\partial p_i}{\partial J} q_i \Bigg/ \left(\frac{\partial c_i}{\partial v'_i} q_i + \frac{\partial F}{\partial v'_i}\right) > 0$$

$$(7)\quad \begin{aligned} &\frac{dv_i}{dQ_i^f} = -\left(\frac{\partial p_i}{\partial Q_i^f} q_i - \frac{\partial F}{\partial Q_i^f}\right) \Bigg/ \left(\left[\frac{\partial p_i}{\partial v_i} - \frac{\partial c_i}{\partial v_i}\right] q_i - \frac{\partial F}{\partial v_i}\right) > 0 \;\; if \;\; \left[\frac{\partial p_i}{\partial v_i} - \frac{\partial c_i}{\partial v_i}\right] q_i > \frac{\partial F}{\partial v_i} \;\; and \\ &\frac{dv_i}{dJ} = -\frac{\partial p_i}{\partial J} q_i \Bigg/ \left(\left[\frac{\partial p_i}{\partial v_i} - \frac{\partial c_i}{\partial v_i}\right] q_i - \frac{\partial F}{\partial v_i}\right) > 0 \;\; if \;\; \left[\frac{\partial p_i}{\partial v_i} - \frac{\partial c_i}{\partial v_i}\right] q_i > \frac{\partial F}{\partial v_i} \end{aligned}$$

$$(8)\quad \begin{aligned} &\frac{dv'_i}{dq_i} = (p_i - c_i) \Bigg/ \left(\frac{\partial c_i}{\partial v'_i} q_i + \frac{\partial F}{\partial v'_i}\right) < 0 \;\; if \;\; \left|\frac{\partial c_i}{\partial v'_i} q_i\right| > \frac{\partial F}{\partial v'_i} \;\; and \\ &\frac{dv_i}{dq_i} = -(p_i - c_i) \Bigg/ \left(\left[\frac{\partial p_i}{\partial v_i} - \frac{\partial c_i}{\partial v_i}\right] q_i - \frac{\partial F}{\partial v_i}\right) < 0 \;\; if \;\; \left[\frac{\partial p_i}{\partial v_i} - \frac{\partial c_i}{\partial v_i}\right] q_i > \frac{\partial F}{\partial v_i} \\ &\frac{dv'_i}{dQ*_i^f} = -\frac{\partial F}{\partial Q*_i^f} \Bigg/ \left(\frac{\partial c_i}{\partial v'_i} q_i + \frac{\partial F}{\partial v'_i}\right) > 0 \;\; if \;\; \left|\frac{\partial c_i}{\partial v'_i} q_i\right| < \frac{\partial F}{\partial v'_i} \;\; and \\ &\frac{dv_i}{dQ*_i^f} = \frac{\partial F}{\partial Q*_i^f} \Bigg/ \left(\left[\frac{\partial p_i}{\partial v_i} - \frac{\partial c_i}{\partial v_i}\right] q_i - \frac{\partial F}{\partial v_i}\right) > 0 \;\; if \;\; \left[\frac{\partial p_i}{\partial v_i} - \frac{\partial c_i}{\partial v_i}\right] q_i < \frac{\partial F}{\partial v_i} \end{aligned}$$

In the enhanced approach presented here, the conditions (5) to (8) differ from the BERTSCHEK approach and cover a broader reality with both cumulated inward FDI and cumulated outward

FDI. A higher stock of outward FDI is expected to raise both process innovations and product innovations which also implies that the outward FDI stock will improve the current account as long as the increased export unit value from more product innovations dominates the dampening effect from lower unit costs in the context of process innovations. The ambiguity cannot be solved – on a sectoral basis – if one does not consider the life cycle of the respective sector: Early in the life cycle, the product innovation effect should dominate as in that early stage of the cycle, the ratio of product innovation to process innovation is rather high if one follows the approach of UTTERBACK/ABERNATHY (1975). If the weighted sectors' impact at the aggregate level is such that the (relative) product innovation effects dominate the current account, product innovations will bring about an improvement of the current account position; this would indeed be in line with the VERNON (1966) approach with its emphasis on the product cycle. A more modern aspect which goes in the same direction as the approach of MELITZ (2003) with his argument that opening up an economy brings a pro-innovation selection process of firms in the enhanced competition regime. However, MELITZ makes no distinction between product and process innovations.

As regards the theoretical approach, one may mention some relevant additional aspects. Following SCHERER/HUH (1992), the market structure matters for the individual firm's response and if the market structure is determined endogenously, a rising number of competitors could lead to either decreasing or rising R&D expenditures by the respective firm. If, however, the market structure is exogenous, then a rise in the number of rather symmetrically-positioned competitors will at first cause a rise in the R&D expenditures (active feedback).

If the competition should be enhanced beyond a critical point, R&D expenditures of firms could be reduced or even stopped (submissive reaction of the firm). One may add that the size of the country considered is crucial; in the case of rather small countries, inward FDI could eliminate existing domestic firms in some sectors so that the size of countries – for example, in the context of empirical studies – should be analyzed carefully. Secondly, the market structure as such matters; for example, if a company has achieved a clear lead in a given market, one may argue that competitors will react in a submissive way and not challenge the position of the leader. This does not rule out the case of a dominant and lethargic company which is not a strong innovator until the day arrives when more potent rivals enter in the market – the lethargic innovator could react in a rather aggressive way and also restart his own innovation dynamics. One may argue that a multinational company with many foreign subsidiaries in OECD countries should have broad opportunities to engage in process innovations while international outward FDI is not always an easy starting point for product innovation unless the firm's headquarters pursues a consistent multinational R&D strategy (e.g., before 2010, IBM had many subsidiaries which more or less were smaller editions of the US parent company, but after a major company crisis, IBM switched its strategy and rebuilt IBM as a true network of jointly innovative networked companies – with subsidiaries abroad standing for their own respective comparative innovation advantage and the relevant specialization in R&D, respectively).

As regards the conditions in equation (8), to bring about a positive process innovation multiplier with respect to the outward FDI stock and a positive product innovation multiplier with respect to the outward FDI stock, the necessary and sufficient conditions that the effect of innovation on fixed costs is rather limited may be considered as being quite plausible – possibly with the exception of the software sector. The enhanced Bertschek approach developed above is static,

but it could be extended to a two-period model and a model with infinite time periods. Switching to such a dynamic R&D perspective, with monopolistic competition in the sector of innovative intermediate products, will add one key additional element as – in a basic approach - is shown by AGHION/HOWITT (2007): The role of future profits and hence the role of discounting and, thus, the role of the real interest rate. A decline of the long run real interest rate – raising the value of discounted future profits - stimulates R&D efforts and innovations, respectively.

As regards GDP and GNP statistics, one may point out that not all OECD countries apply hedonic price measurement in a broad way so that product innovations are not symmetrically reflected in official price statistics of the various OECD countries for example. From this perspective, there is certainly room for statistical harmonization across industrialized countries (as well as across NICs).

Finally, one may mention a potential analytical problem which concerns the links between trade and foreign direct investment which are considered as independent variables in the theoretical approach presented above. One aspect concerns the link of investment in the local host country export sector – regardless of the final destination of the exported production (BLANCHARD, 2007) which is partly related to the concept of export platform FDI (EKHOLM ET AL., 2007) where investment and production in a given host country has output sold mainly in third markets, while BLANCHARD/MATSCHE (2015) consider US outward FDI with foreign production partly sold to the home country. A traditional perspective has been developed by MUNDELL (1957) who argues that exports from the FDI source country will be replaced by production in foreign subsidiaries so that FDI and exports are substitutes – with horizontal FDI as the key phenomenon considered. By contrast, KOJIMA (1973) has argued that FDI and exports are complementary: In that framework, an increase in wages in the source country will force firms to invest in low-wage countries and, after this FDI has taken place, the source country will export high-tech and medium-tech components as intermediary inputs to the host country; here, vertical FDI is the main focus. One may add that inward FDI and outward FDI have an impact on GDP and GNP in both the source and host country. Typically, outward FDI in country f will raise potential output and per capita GDP and possibly real GNP there through supply side effects, including international technology transfers (case of international M&As as well as greenfield investment) and a higher capital stock – case of greenfield investment; while a higher real GNP will raise imports from abroad so that outward FDI and exports would be complementary (WELFENS, 2011). Also, in a macro perspective, one may note that outward FDI has an effect on the aggregate price level (WELFENS, 2014).

BLANCHARD (2007) is similar to KOJIMA (1973) in the sense that FDI and trade are complementary, but in the BLANCHARD approach there is mainly an increase in exports from the host country to the source country. Export platform FDI also plays a role in several contributions where most of the output of subsidiaries abroad is exported to third countries (IRAWAN, 2014 (with a focus on the ICT sector in ASEAN countries); EKHOLM ET AL., 2007; HANSON ET AL., 2001; MARKUSEN/MASKUS, 2001; BLONIGEN/DAVIES, 2004). BLANCHARD/MATSCHKE (2015) have argued - and presented empirical evidence for this - that US MNCs with outward FDI in sector j successfully push in the US for enhanced market access which leads to higher exports from foreign subsidiaries to the US.

3. New Analytical View on Product Innovation and Process Innovation Statistics plus Empirical Findings for Europe and US Firms

Data on product innovations and process innovations are not broadly available in OECD countries. However, the European Union offers survey data for 2000 to 2016 for EU member countries plus Switzerland, Norway, Iceland and Turkey. The top seven countries in the field of product innovation in 2016 were the UK, Italy, Germany, Turkey, France, Netherlands and Serbia (see Tables 2 and 3) while the top seven countries in the field of process innovation in 2016 (see Tables 4 and 5) were France, Italy, Turkey, Germany, Spain, UK and Poland.

Table 2: The ratio of product innovation firms to GDP per capita PPP per year of each European country (%), sorted by the number in the year 2016 (in descending order)

Country	Year							
	2000	2004	2006	2008	2010	2012	2014	2016
EU19								
United Kingdom	30.76	0.00	0.00	0.00	15.15	33.41	49.90	41.12
Italy	24.77	23.60	18.39	20.81	34.41	31.14	28.28	33.70
Germany	58.83	44.72	49.25	38.58	40.89	39.51	36.60	32.67
France	15.31	18.07	3.16	21.81	18.31	15.99	15.96	22.45
Netherlands	9.77	6.01	6.97	8.13	10.52	7.42	10.93	12.30
Spain	21.38	24.44	37.86	15.64	12.06	10.93	10.52	9.91
Poland	9.46	12.66	9.23	8.80	7.70	7.91	8.50	6.77
Portugal	10.95	4.30	5.57	4.40	3.80	3.42	4.72	6.17
Hungary	6.13	4.13	3.64	3.37	4.51	3.68	3.66	4.74
Czech Republic	10.17	6.87	6.47	4.95	5.80	5.82	6.56	4.35
Sweden	7.84	6.51	5.22	4.91	6.65	5.89	2.79	2.97
Austria	5.83	2.97	3.51	1.64	2.07	1.76	2.26	2.16
Belgium	6.28	5.07	3.64	3.56	3.87	2.31	1.72	2.03
Denmark	3.54	2.72	1.86	2.93	2.19	2.09	2.02	1.94
Finland	3.38	1.90	2.05	0.94	1.39	1.59	1.72	1.84
Slovak Republic	4.17	1.58	1.86	1.69	1.64	1.42	1.51	1.80
Greece	2.88	0.71	1.68	0.00	0.00	1.22	1.48	1.27
Ireland	0.00	0.87	1.86	0.60	0.67	1.07	0.72	0.79
Luxembourg	0.28	0.21	0.26	0.12	0.12	0.14	0.13	0.21
Other European Countries								
Turkey	0.08	.	21.12	0.00	11.73	14.45	17.90	26.81
Serbia	.	.	.	0.00	5.36	5.85	7.52	11.50
Switzerland	.	.	.	0.00	0.00	0.00	11.74	8.87
Bulgaria	7.28	7.79	6.67	6.58	4.26	4.10	4.41	3.81
Norway	1.75	2.04	1.88	1.77	1.86	1.72	2.70	3.06
Croatia	.	.	0.87	1.50	1.60	1.67	1.61	1.59
Lithuania	2.96	2.61	1.80	0.79	1.36	0.80	0.85	1.19
Romania	5.05	2.56	3.32	3.35	3.14	1.62	1.35	1.13
Slovenia	0.65	0.00	0.22	0.03	0.41	0.25	1.13	1.06
Estonia	2.45	1.82	1.46	0.69	0.97	0.97	0.48	0.95
Latvia	1.63	0.00	0.78	1.00	0.89	0.74	0.63	0.85
North Macedonia	.	.	.	0.00	0.00	0.00	0.78	0.58
Malta	0.18	0.16	0.14	0.10	0.17	0.26	0.23	0.17
Iceland	0.34	0.00	.	0.00	0.46	0.00	0.17	0.14
Cyprus	0.30	0.04	0.01	0.01	0.01	0.07	0.16	0.10

Note: Montenegro is not included; Source: COMMUNITY INNOVATION SURVEY

Table 3: Number of product innovation firms per year of each European countries, ranked by number for 2016

	2000	2004	2006	2008	2010	2012	2014	2016
United Kingdom	11730	0	0	0	6387	14298	22069	18680
Germany	25214	19473	22461	18355	19190	19673	18580	16966
Italy	10717	10464	8300	9332	14751	12985	11340	13828
France	6110	7495	1346	9422	7756	6873	6897	9857
Turkey	12		4067	0	2351	3266	4464	7081
Netherlands	4657	2934	3580	4398	5501	3867	5731	6656
Switzerland	.	.	.	0	0	0	7751	5905
Spain	7445	9120	14742	6151	4511	3918	3792	3821
Portugal	3332	1331	1758	1422	1210	1034	1440	1967
Poland	1534	2315	1857	1977	1846	2023	2281	1945
Norway	980	1218	1163	1104	1119	1048	1658	1900
Serbia	.	.	.	0	775	868	1141	1853
Czech Republic	2548	1967	2100	1718	1943	1961	2258	1610
Sweden	3234	2930	2504	2393	3226	2886	1397	1546
Hungary	1198	971	930	876	1104	911	968	1339
Austria	2726	1451	1796	874	1077	941	1200	1162
Denmark	1733	1376	995	1555	1115	1071	1054	1056
Belgium	2704	2310	1720	1725	1858	1113	838	1015
Finland	1349	829	952	457	638	730	775	847
Bulgaria	742	1035	1030	1164	742	742	825	780
Ireland	0	478	1080	336	357	566	411	579
Slovak Republic	671	306	417	442	427	388	424	541
Croatia	.	.	215	396	385	395	380	404
Lithuania	411	504	414	213	325	220	254	379
Slovenia	172	0	73	12	137	81	374	370
Greece	845	247	619	0	0	350	421	362
Estonia	436	431	420	205	254	284	148	303
Romania	610	407	603	736	635	345	310	286
Luxembourg	273	219	277	135	130	150	145	239
Latvia	210	0	178	247	186	178	159	230
North Macedonia	.	.	.	0	0	0	113	89
Iceland	137	0	.	0	216	0	86	78
Malta	49	45	41	32	52	83	83	67
Cyprus	97	16	5	3	4	26	53	38

Note: Montenegro is not included; Source: COMMUNITY INNOVATION SURVEY

Table 4: The ratio of process innovation firms to GDP per capita PPP per year of each European country (%), sorted by the number in the year 2016 (in descending order)

Country	Year							
	2000	2004	2006	2008	2010	2012	2014	2016
EU19								
France	7.40	51.08	2.80	30.70	21.52	15.72	14.92	36.38
Italy	30.75	70.66	67.40	32.30	31.17	35.50	29.85	34.72
Germany	37.12	35.98	23.13	31.34	17.44	17.21	17.63	21.88
Spain	22.48	53.37	54.30	57.34	43.25	27.40	21.87	20.54
United Kingdom	19.30	0.00	0.00	0.00	4.24	9.01	22.10	18.01
Poland	6.34	25.28	18.43	12.93	10.49	11.32	11.57	13.14
Netherlands	2.71	5.32	5.63	6.74	10.44	4.46	10.44	10.57
Portugal	13.74	13.90	12.89	9.75	10.13	8.05	9.09	10.33
Czech Republic	4.76	11.81	11.33	11.99	5.04	4.96	4.85	5.56
Greece	2.60	3.58	4.26	0.00	0.00	3.75	3.76	3.03
Austria	2.89	4.63	4.89	2.16	2.22	2.46	2.72	2.78
Hungary	3.06	3.87	3.18	3.48	2.49	2.17	2.34	2.66
Belgium	3.36	6.21	4.65	3.40	3.80	2.55	3.62	2.56
Slovak Republic	0.79	2.97	3.16	2.93	2.00	1.27	1.65	2.00
Finland	1.16	1.80	2.72	1.64	1.34	1.51	1.52	1.89
Denmark	1.20	3.08	2.75	2.66	2.91	2.13	2.20	1.83
Sweden	3.05	4.63	1.85	3.43	3.03	1.72	2.72	1.49
Ireland	0.00	1.85	1.71	1.37	1.14	0.83	0.81	0.93
Luxembourg	0.17	0.20	0.10	0.12	0.08	0.15	0.10	0.12
Other European Countries								
Turkey	0.00	.	22.61	0.00	19.44	23.74	31.65	33.93
Switzerland	.	.	.	0.00	0.00	0.00	4.22	5.95
Serbia	.	.	.	0.00	6.03	4.33	7.23	5.32
Croatia	.	.	3.21	4.14	3.42	2.52	2.88	4.03
Bulgaria	1.42	1.24	3.68	6.57	4.12	2.93	3.04	3.14
Norway	0.51	1.25	1.24	1.11	0.97	0.72	1.95	3.08
Lithuania	2.52	4.51	3.33	3.31	1.58	1.18	3.45	3.00
Estonia	1.70	1.94	2.17	1.77	1.55	1.37	0.68	2.55
Romania	3.59	8.38	6.97	9.19	4.70	3.32	2.17	1.87
North Macedonia	.	.	.	0.00	0.00	0.00	1.97	1.83
Latvia	1.75	0.00	1.34	1.40	1.13	1.22	0.88	1.15
Cyprus	0.88	0.93	0.33	0.50	0.41	0.40	0.33	0.33
Slovenia	0.21	0.00	0.92	0.76	0.02	0.56	0.63	0.31
Malta	0.15	0.07	0.33	0.26	0.37	0.47	0.27	0.26
Iceland	0.11	0.00	.	0.00	0.32	0.00	0.14	0.13

Note: Montenegro is not included; Source: COMMUNITY INNOVATION SURVEY

Table 5: Number of process innovation firms per year of each European countries

	2000	2004	2006	2008	2010	2012	2014	2016
France	2953	21183	1193	13265	9114	6758	6449	15978
Italy	13304	31328	30423	14483	13363	14806	11970	14250
Germany	15909	15666	10549	14910	8184	8569	8950	11360
Turkey	0	.	4354	0	3896	5368	7893	8961
United Kingdom	7360	0	0	0	1786	3858	9774	8180
Spain	7830	19918	21142	22544	16172	9819	7881	7917
Netherlands	1291	2595	2889	3644	5460	2325	5474	5717
Switzerland	.	.	.	0	0	0	2787	3959
Poland	1028	4623	3708	2903	2514	2894	3103	3777
Portugal	4179	4301	4070	3154	3225	2431	2772	3294
Czech Republic	1193	3381	3677	4162	1689	1671	1670	2058
Norway	285	744	767	695	585	439	1197	1908
Austria	1350	2263	2499	1156	1156	1316	1450	1492
Belgium	1446	2831	2198	1647	1823	1228	1766	1278
Croatia	.	.	790	1090	826	597	682	1028
Denmark	589	1557	1470	1414	1485	1091	1146	995
Lithuania	351	870	768	890	380	323	1031	959
Finland	463	788	1264	803	616	693	683	871
Greece	764	1249	1570	0	0	1080	1070	866
Serbia	.	.	.	0	871	642	1097	858
Estonia	302	460	625	525	406	400	209	817
Sweden	1259	2084	890	1672	1470	842	1360	776
Hungary	598	909	813	905	609	538	619	751
Ireland	0	1018	994	762	605	441	468	678
Bulgaria	145	165	568	1163	717	531	569	644
Slovak Republic	127	574	706	766	521	346	463	601
Romania	433	1331	1267	2020	951	706	499	471
Latvia	225	0	304	346	236	292	223	313
North Macedonia	.	.	.	0	0	0	284	281
Luxembourg	159	202	112	130	87	160	113	131
Cyprus	291	339	129	201	156	141	108	120
Slovenia	55	0	303	275	6	183	209	108
Malta	40	20	98	81	116	153	95	106
Iceland	46	0	.	0	148	0	68	69

Note: Montenegro is not included; Source: COMMUNITY INNOVATION SURVEY

As regards the ratio of product innovations to process innovations, the top countries were Slovenia, the UK, Serbia, Sweden, Luxembourg, Hungary, Germany, Switzerland and Bulgaria (based on 2016 figures, see Table 7). Table 6 shows a ranking of the countries for the ratio of cumulated product innovations to process innovations in the period 2000-2016.

Table 6: Cumulative number and the ratio of product innovation firms to process innovation firms of each European countries (2000-2016), ranked by ratio (%)

Ranking	Country	Cum Num Product Innovation Only	Cum Num Process Innovation Only	The Ratio of Product Innovation to Process Innovation (%)
1	United Kingdom	73164	30958	236
2	Switzerland	13656	6746	202
3	Sweden	20116	10353	194
4	Germany	159912	94097	170
5	Bulgaria	7060	4502	157
6	Iceland	517	331	156
7	Norway	10190	6620	154
8	Hungary	8297	5742	144
9	Luxembourg	1568	1094	143
10	Serbia	4637	3468	134
11	Netherlands	37324	29395	127
12	Slovenia	1219	1139	107
13	Finland	6577	6181	106
14	Denmark	9955	9747	102
15	Belgium	13283	14217	93
16	Austria	11227	12682	89
17	Slovak Republic	3616	4104	88
18	Czech Republic	16105	19501	83
19	Ireland	3807	4966	77
20	France	55756	76893	73
21	Latvia	1388	1939	72
22	Turkey	21241	30472	70
23	Estonia	2481	3744	66
24	Italy	91717	143927	64
25	Malta	452	709	64
26	Poland	15778	24550	64
27	Romania	3932	7678	51
28	Lithuania	2720	5572	49
29	Portugal	13494	27426	49
30	Spain	53500	113223	47
31	Greece	2844	6599	43
32	Croatia	2175	5013	43
33	North Macedonia	202	565	36
34	Cyprus	242	1485	16
35	Montenegro	0	1	0

Source: COMMUNITY INNOVATION SURVEY (own calculations; countries with zero process innovations were treated as having v=1)

Table 7: The ratio of product innovation firms to process innovation firms per year of each European country* (%), ranked by ratio for 2016

	2000	2004	2006	2008	2010	2012	2014	2016
Slovenia	313	0	24	4	2283	44	179	343
United Kingdom	159	0	0	0	358	371	226	228
Serbia	.	.	.	0	89	135	104	216
Sweden	257	141	281	143	219	343	103	199
Luxembourg	172	108	247	104	149	94	128	182
Hungary	200	107	114	97	181	169	156	178
Germany	158	124	213	123	234	230	208	149
Switzerland	.	.	.	0	0	0	278	149
Bulgaria	512	627	181	100	103	140	145	121
Netherlands	361	113	124	121	101	166	105	116
Iceland	298	0	.	0	146	0	126	113
Denmark	294	88	68	110	75	98	92	106
Norway	344	164	152	159	191	239	139	100
Finland	291	105	75	57	104	105	113	97
Italy	81	33	27	64	110	88	95	97
Slovak Republic	529	53	59	58	82	112	92	90
Ireland	0	47	109	44	59	128	88	85
Belgium	187	82	78	105	102	91	47	79
Turkey	1200	.	93	0	60	61	57	79
Austria	202	64	72	76	93	72	83	78
Czech Republic	214	58	57	41	115	117	135	78
Latvia	94	0	59	71	79	61	71	73
Malta	123	225	42	40	45	54	87	63
France	207	35	113	71	85	102	107	62
Romania	141	31	48	36	67	49	62	61
Portugal	80	31	43	45	38	43	52	60
Poland	149	50	50	68	73	70	74	51
Spain	95	46	70	27	28	40	48	48
Greece	111	20	39	0	0	32	39	42
Lithuania	117	58	54	24	86	68	25	40
Croatia	.	.	27	36	47	66	56	39
Estonia	144	94	67	39	63	71	71	37
Cyprus	33	5	4	1	3	18	49	32
North Macedonia	.	.	.	0	0	0	40	32

Note: Montenegro is not included; Source: Community Innovation Surveys; (own calculations; countries with zero process innovations were treated

According to the VERNON approach, countries which show increasing product innovations over time should experience a rise in net exports. Considering modern ICT goods, one may note a caveat here, namely for product groups characterized by static or dynamic economies of scale. As regards sectoral ratios of product to process innovations, there are several countries witnessing a rise of this ratio over time, particularly in the ICT sector. A broader macroeconomic view is needed to better understand the role of product innovations and process innovations as well as inward FDI and outward FDI.

4. Enhanced Mundell Fleming Modell with Product and Process Innovations

A Schumpeterian Mundell Fleming model with both inward FDI and outward FDI will have to consider both product and process innovations; in an open economy framework, therefore, both the equilibrium conditions for the goods market, the money market and the foreign exchange market will have to be specified accordingly. Subsequently, the first analytical step to be considered is the foreign exchange market equilibrium condition in a medium-term perspective – such a perspective should not be confused with a long-term equilibrium and a growth model, respectively (in the later context, the share α* of cumulated inward FDI in the domestic capital stock K would have to be constant and, if there is outward FDI too, it would have to hold that the share of cumulated outward FDI in the foreign capital stock K* would have to be constant so that for inward FDI inflows, for example, in a setting with zero capital depreciation, it must hold that those FDI inflows/(α*K) = dlnY/dt. Imports as well as consumption is assumed to be proportionate to disposable income, but will also be influenced by product innovations and process innovations. Net FDI inflows are assumed to be positively influenced by the real exchange rate (Froot-Stein effect) as well as product innovations; portfolio net capital inflows are proportionate to the real interest rate differential r-r* (r for the real interest rate).

Considering that total capital flows are the sum of net portfolio inflows H(r-r*) and net FDI inflows H'q* + H"v (with H, H' and H" standing for positive parameters and r for the real interest rate - * for foreign country), one can write the condition for equilibrium in the foreign exchange market with asymmetric cumulated inward FDI as follows (parameter V'>0, V">0) if imports are a negative function of current product innovations v, but a positive function of lagged production innovation v_{-1} (the latter is the Vernon product cycle effect after the innovation stage):

(1) $H(r-r^*) + (H'q^* + H"v) = q^*jY(1-\alpha^*ß) - jv + j"/q^* + V"v_{-1} - x(Y^* + \alpha^*ßY/q^*) - x'v - x"q^* - V'A$

Exports of goods are assumed to be proportionate to foreign real GNP and to be a positive function of product innovation v and the real exchange rate q*:=eP*/P (e is the nominal exchange rate). Exports are also assumed to be a positive function of the level of knowledge A which is considered here to be the same variable as process innovation; it should be emphasized that this switch in notation is simply following the familiar notation of the variable A for knowledge in the standard macroeconomic production function.

A key assumption is that imports are proportionate to Z where Z=Y(1-α*ß); α* is the share of foreign ownership in the capital stock of country 1 and ß is the share of profits in GDP. It has been assumed here that net FDI inflows are a positive function of q* and of product innovations v; the latter variable should be relevant here for FDI flows since a rise of v indicates the availability of skilled labor and R&D sources in the respective (host) country. In equation (1) asymmetrical FDI is assumed, namely only cumulated FDI inflows; imports are assumed to be proportionate to real national income (0<j<1) and to be a negative function of product innovations as well as a negative function of the real exchange rate. Exports are assumed to be

.a positive function of foreign real GNP and a positive function of product innovations as well as a positive function of the real exchange rate q*, product innovation v and process innovation A. If product innovation-related higher net exports and consumption lead to a short-term real appreciation, the exchange rate effect will

- dampen net exports of goods and services in the medium term if a modified Marshall Lerner condition is fulfilled (WELFENS, 2019b: the sum of the absolute import elasticities must exceed unity by a certain critical margin);

- inward FDI will be dampened in line with the Froot-Stein effect – this means an upward shift of the ZZ curve (portraying foreign exchange market equilibrium) in r-Y space;

- an additional effect on product innovation will occur in the context of endogenous product innovations to the extent that the stock of inward FDI raises product innovations (hence a real appreciation will not only lead to lower inward FDI inflows, but the ratio of FDI inward stock to GDP could indeed fall and this will dampen product innovation in an enhanced system with endogenous product innovations – note that a marginal analysis looking at a change of one unit of inward FDI leaves the ratio of inward FDI capital stock in total K of the host country unchanged).

As regards the impact of product innovation on the current account position, it is clear that current product innovation and the Vernon-effect (post-innovation stage; see the parameter V") will create an unclear total medium-term effect, since current product innovation is improving the current account position while the past product innovations – with production relocated abroad already – contribute to a weakening of the current account position. A dynamic view of the Vernon product cycle is required for an adequate analysis.

(1.1) $r = r^* - (V'/H)A + (j''/q^*)/H - (H'/H)q^* - (xY^* + x''q^*)/H - ((j+\underline{x'+H''})/H)v$

$+ (V''/H)v_{-1} + ((jq^*/H)(1-\alpha^*ß) - x\alpha^*ß/(Hq^*)))Y$

(1.2) $r = r^* - (V'/H)A + (j''/q^*)/H - ((H'+x'')/H)q^* - (x/H)Y^* - ((j+\underline{x'+H''})/H)v$

$+ (V''/H)v_{-1} + ((jq^* - \alpha^*ß(jq^* + x/q^*))/H)Y$

Obviously, the slope of the ZZ curve (schedule portraying equilibrium in the foreign exchange market) in this enhanced Mundell Fleming model is smaller than in the standard model without FDI. As long as H is not assumed to be infinity, a rise of v will clearly shift downwards the ZZ curve in r-Y-space within an enhanced Mundell Fleming approach.

STOLERU (1990) has shown that process innovations, in the sense of capital stock vintage effects, can be covered in the case of a Cobb-Douglas production function by an increase of the depreciation rate of capital (δ); his analysis shows that the growth rate of knowledge dlnA/dt raises the depreciation rate in a vintage model of the capital stock and a Cobb-Douglas

production function. Picking up this idea in a modified form, namely assuming that the depreciation rate of capital is a negative function of the level of knowledge (A), and indeed considering gross investment in a Mundell Fleming model with process and product innovations, one can write the goods market equilibrium condition (τ is the income tax rate) as:

(2) $Y = c(1-\tau)(1-\alpha*ß)Y + c'v + G + b(ßY/K - r) + \delta(A)K + xY^* + x'v + x''q^* + V'A - jY - jv - jv''/q^*$

Consumption C is proportionate to disposable national income and C is assumed to be raised by product innovations (c'>0); and gross investment is written as $b(ßY/K - r) + \delta(A)K$. It should be noted that process innovations are now reflected by the variable A. While one could argue that a rise of A will reduce the domestic price level under certain conditions and that there is no need to consider the impact of knowledge on exports, one can indeed argue that process innovations in industry typically also go along with technological progress in transportation so that – following the logic of the standard trade gravity equation (see, e.g., WELFENS/BAIER, 2018) – exports should clearly benefit from process innovations; a more complex specification could also consider an effect of A on imports.

In a model setting with zero expected inflation, the money market equilibrium (M denoting the nominal stock of money) can be written – with the hedonic price index P''=P(1-v''v) where v'' is a positive parameter for expressing the quality effects of product innovations – as follows if a linear specification of the real demand for money is considered:

(3) $M/(P(1-v''v)) = hY - hr + h'v - a'A$

where a' is a positive parameter which expresses the reduced need for firms' demand for money in the presence of process innovations which amounts to buying cheaper intermediate products.

The hedonic price index is defined as P(1-v''v) here (note also – while disregarding A for reasons of simplicity - here: An alternative simple specification of the real demand for money – with h'' denoting a positive parameter - is $M^d = P(1-v''v)hY/(h''r)$, which immediately shows an important insight, namely that product innovation will reduce the real interest rate under non-hedonic price level measurement since we get $r = (1-v''v)Y/(M/P)$; if the central bank follows a monetary policy stabilizing (M/P)/Y, the relative change of the real interest rate would be (assuming v''v to be close to zero) given by: $dr/r = - v''dv$).

With a focus on reality and empirical implementation, one may finally consider the case of an alternative specification of the real demand for money $m = h(1-h''v)A^{-a'}Y^{ß'}/(1+r)^{h'}$) the equilibrium condition for the money market reads (assuming a'>0, ß'>0 and v''v as well as h''v to be close to zero so that the approximation ln(1+x) =x can be used for the case of x close to zero):

(3.1) $\ln M = \ln P + v''v + \ln h - h''v + ß'\ln Y - h'r - a'\ln A$

Hence, we can solve for lnP and get (considering in addition the role of transactions in stock markets where V'' is the turnover ratio for a representative portfolio):

(3.2) $\ln P = -\ln h + \ln M + (-v'' + h'')v - ß'\ln Y + h'r - ß''\ln(V''P'K) + a'\ln A$

Here in (3.2) an additional term ß"ln(V"P'K) could be considered in order to take into account the role of the stock market price index P' and transactions in the stock market, respectively (V" is the turnover rate of the representative portfolio; ß" should be a positive parameter since transactions in the stock market are also assumed to absorb liquidity which is in line with basic arguments from FIELD, 1984).

(3.3) $\ln P = (-\ln h - ß''\ln V'') + \ln M + (-v'' + h'')v - ß'\ln Y + h'r - ß''\ln P' - ß''\ln K + a'\ln A$

If the coefficient for the product innovation variable v is negative, the hedonic influence (parameter v") is obviously dominating the effect of product innovation on the real demand for money (parameter h").

Product and Process Innovation in a Mundell-Fleming Modell with Outward FDI

Subsequently, a Schumpeterian Mundell Fleming model with asymmetric FDI, namely only outward FDI, is considered where foreign GNP can be written as $Z^* = (1 - \alpha ß^*)Y^*$ while Z is expressed by $Z = Y + \alpha ß^* Y^* q^*$; profits abroad have to be multiplied by q* so that foreign good units are transformed into domestic good units. Hence, we can write the goods market equilibrium as:

(1') $Y = c(1-\tau)(Y + \alpha ß^* Y^* q^*) + c'v +$

$+ G + b(ßY/K - r) + \delta(A)K + xY^* + x'v + x''q^* + V'A - jY - jv - jv''/q^*$

Money market equilibrium is given by the following equation:

(2') $M/(P(1 - v''v)) = hY - hr + h'v - a'A$

Foreign exchange market equilibrium is given by the following equation:

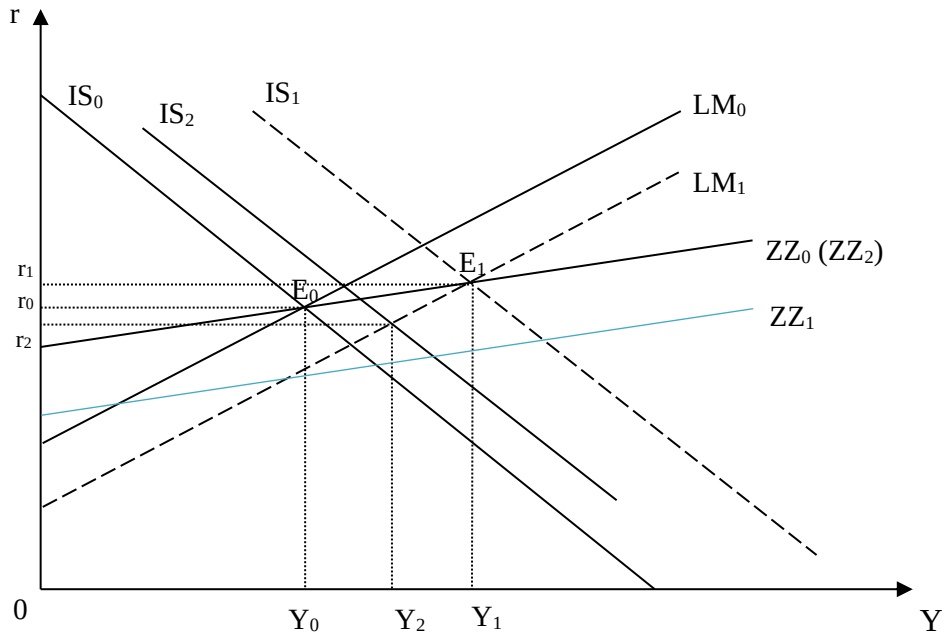
(3') $H(r - r^*) + (H'q^* + H''v) = q^* j(Y + \alpha ß^* Y^* q^*) - jv + j''/q^* + V''v_{-1}$

$- xY^*(1 - \alpha ß^*) - x'v - x''q^* - V'A$

This set of equations determines, in a setting of flexible exchange rates, the variables Y, r and e (q*), while considering the impact of the exogenous variables M, P, G, v, A and α. An increase of product innovations shifts the MM curve downwards in r-Y space, while the IS curve shifts to the right as consumption and exports increase; if this rightward shift is rather strong, there will be an excess supply in the foreign exchange market and therefore a real appreciation of the currency which dampens the rightward shift of the IS curve through the dampening effect on the export of goods (IS_2); a real appreciation in turn will dampen net FDI inflows (Froot-Stein effect) but the inward FDI stock is raised anyway – a critical point is whether or not in the medium term the share of foreign investment in the new overall investment stock will remain constant or will fall which stimulates consumption. The downward shift of the ZZ curve (due

to product innovations) is shown in the following graph (ZZ_1 in Fig. 5), but the medium-term development will bring an upward shift due to the real currency depreciation - after the initial downward shift in the current period; and since the term V"v_{-1} implies a deterioration of the current account curve in the next period.

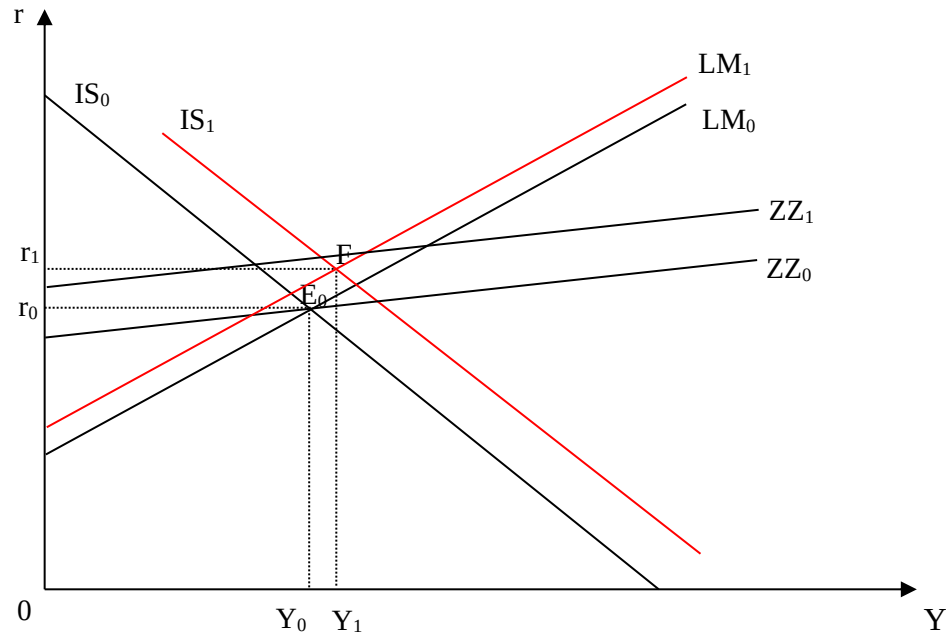
Figure 5: Product Innovations in the Schumpeterian Mundell Fleming Model



Source: Own representation.

By contrast, a rise of knowledge A – read: process innovations - will shift the IS curve to the right and shift the LM curve upwards so that a depreciation of the currency will occur (point F is below the ZZ_1 curve). The real depreciation of the currency will attract higher net FDI inflows (Froot-Stein argument) so that the ZZ curve will shift downwards while the IS curve will shift to the right if the modified Marshall Lerner condition is fulfilled. In a nutshell, this shows that the impact of product innovations and process innovations could be rather different in an open economy – indeed the distinction between product innovations and process innovations is crucial.

Figure 6: Process Innovations in the Schumpeterian Mundell Fleming Model



Source: Own representation.

In principle, there is no problem in endogenizing product innovations; a simple function could be v=v(α, α*, R, b'G, J/Y) where R is real expenditure on research and development and b' is the share of real government expenditures devoted to R&D subsidization for product innovations in the private sector; here, G is defined as G= (1-b')G + b'G. The term R would have to be added to aggregate demand and v could be specified as a simple linear function, namely:

(4') v= Vα + V'α* + r'R + b'G - b"r + z"J/Y

Here it is assumed that product innovations - and the respective R&D - is a negative function of the real interest rate as technology-oriented firms will have to finance part of R&D projects via bank loans or corporate bonds. The import-GDP ratio – this could mean to focus on gross imports relative to GDP or on value-added imports to GDP (both standing for import competition) – is assumed to positively affect v; however, one cannot exclude the case that z" is negative. Hence, there are four endogenous variables in the augmented system (see appendix), namely equations (1') – (4') where v in equations (1')-(3') would be replaced by (4'). As regards a potential positive link between domestic knowledge and foreign knowledge, international spillovers should not be excluded; one might, for example, consider that knowledge A=f(A*) so that intra-MNC technology spillovers could be considered. The share of foreign ownership could affect the function f so that one might write A= f'(…)f(A*) where f'(…) indicates the impact of the share of foreign ownership on international technology transfer.

The new money demand function suggested clearly requires further analysis and indeed introduces an adequate distinction between product innovations and process innovations. For monetary policy, the distinction between process innovations and product innovations has thus far not played a role in the literature, but there are good reasons to carefully consider this

distinction. Even within the Eurozone, the impact of product and process innovations in different Eurozone countries could be crucial, not least if product innovations or process innovations depend on inward FDI stocks and outward FDI stocks, respectively; for example, asymmetrical FDI inflows across Eurozone countries could contribute to differences in national product innovation dynamics of Eurozone member countries and this in turn could lead to different price level changes across countries in the Eurozone (hence intra-Eurozone inflation rates differ).

One should also note that trend inflation rates have different effects on output and inflation in the case of a positive technology shock (ASCARI/ROSSI, 2009): As regards the Calvo model (CALVO, 1983), the finding is that the higher the trend inflation rate is, the higher are both the fall in inflation and the rise of output after a positive technology shock; by contrast, in the Rotemberg model (ROTEMBERG, 1987), it holds that the higher the trend inflation rate is the smaller are both the fall in inflation and the rise in output.

A simple equation system for the Schumpeterian Mundell Fleming model with multiplier analysis is shown in the appendix. While the model is rather simple, it nevertheless gives some new insights in various fields, including aspects of the foreign exchange rate reaction as well as details on the multipliers for fiscal and monetary policy and for outward and inward FDI plus product innovations and process innovations.

To the extent that ICT innovation dynamics are particularly important since the 1990s, it would be interesting to analyze which split of product versus process innovations are relevant in which year or decade. One may point out that a geographically greater outsourcing and offshoring radius in the ICT sector itself – observed, for example, by the ADB (2015) in the second decade of the 21st century in parts of Asia – is equivalent to a higher process innovation rate in the region and possibly a higher rate of product innovation in the leading ICT producing countries of the regional network where firms will be able to specialize more on high-end ICT production than before. Similarly, the US has witnessed international outsourcing and offshoring in the software sector in the 1990s and the following decade where the main effect in the US in the production sphere was that firms specialized on more complex software development so that modestly skilled jobs in the US software sector were lost in the context of this internationalization process while the number of top software jobs has actually increased in the US (BAILEY/LAWRENCE, 2005). In reality, product and process innovations often are linked, but for analytical reasons the distinct analysis for product innovations and process innovations, respectively, is useful.

5. Optimal Consumption Aspects of a Setting with Innovations and Inward FDI

If one considers a standard optimal control approach for maximizing consumption under the side-constraint that output Y is equal to the sum of consumption and gross investment, one can derive – assuming a utility function U(C(t)) (with ε indicating as $1/\varepsilon$ the intertemporal substitution elasticity; ρ is the time discount rate, r is the real interest rate) – the standard

solution for maximizing discounted utility over an infinite time horizon giving a steady state solution for the growth rate of consumption dlnC/dt:

(I) $dlnC/dt = (r - \rho)/\varepsilon$

From this perspective, an initial consideration is that inward FDI (and possibly also outward FDI) can affect the optimal growth rate – maximizing discounted life-time consumption – through a possible increase or decrease of the real interest rate; for example. with MNCs which can share fixed R&D costs through international markets, firms will be more innovative which in turn raises MNCs' profit rates and this drives up the real interest rate. In fact, the model setting becomes more complicated if one considers the case that foreign investors own a share of α^* in the capital stock of country 1.

A rather simple approach with inward FDI is to consider a setting with four elements:

- There is cumulated inward FDI and - for the sake of simplicity - no capital depreciation.
- Companies invest a share of output into R&D which is used to generate product innovations v.
- Multinationals repatriate a share (θ) of the profits of subsidiaries to the headquarter country (country 2).
- Product innovations v add to utility within an additive and separable utility function for per capita consumption and product innovations.

The subsequent analysis will assume that there is growth of the population (population growth rate n). This then leads to a new differential equation for the capital intensity k:=K/L which becomes the relevant constraint for the new maximization problem which can be solved on the basis of the Hamiltonian H – the function to be maximized. The relevant utility function U(…) is maximized over an infinite time horizon; households maximize discounted utility which consists of two separable elements, namely consumption C (alternatively C/L) and product innovations v – whereby the latter stands for product quality. A share (φ) of real GDP is invested in product innovations v. It can be shown that the maximization of discounted life time utility – this is the basic challenge considered here in a representative family (or by a benevolent government) – brings a solution for the long run C/L which says that the growth of per capita consumption is $(r - n - \rho)/\varepsilon$ which is a significant solution derived from the relevant Euler equation. The growth rate of consumption is equal to the growth rate (n) of the population plus $(r - n - \rho)/\varepsilon$; if the real interest rate r is equal to the population growth rate plus the time preference proxy ρ, one has a situation which corresponds to the neoclassical growth model.

The utility function, however, can be modified to also accommodate the quality of consumption and product innovations (v), respectively. Here, the solution for the optimal consumption is not really new, compared to the standard model; but the solution for the optimum product innovation rate v^{opt} is a positive function of the utility function parameter φ' and the product innovation productivity parameter ψ as well as a positive function of inward FDI (parameter α^*) as is shown in the subsequent set of equations; see equation (11) and (12). As regards process innovations, it is not really difficult to add such developments to the model, where one may assume then that process innovations are semi-exogenous in the open economy, namely

that the progress rate a = a_0 + a'α* where a_0 is the purely exogenous part of knowledge growth (dlnA/dt) while a' is a positive parameter. A specific analytical issue is, however, not considered here, namely the extent to which product innovation and process innovations are interrelated. Typically, one would assume that new products cannot be produced on old machinery and equipment, so that product innovation dynamics could drive process innovations.

The relevant set of equations for the new model with consumption and product innovations is considered here where f(k) is the macro production function (with k:=K/L; this is capital intensity; output per capita will be denoted as y:= Y/L). The variable k':= K/(AL) and y':=Y/(AL). Thus, we can first consider a set of equations which include maximization of per capita consumption C/L:=c and product innovation v by households which are consumers and – by assumption – at the same time entrepreneurs (or more simply: consumers emphasize both the quantity of products consumed and the quality of the respective products – product innovation and quality are used as a synonymous word here). The assumption that individuals maximize per capita consumption is adequate in a society where most people live in families; one may also argue that government wants to maximize per capita consumption. The model setting is straightforward as the subsequent set of equations shows which at first gives the standard setting where only C/L is an argument of the utility function and then considers the case of inward FDI and product innovations.

1) $U\left(\frac{C}{L}\right);\ c := \frac{C}{L}$

1') $U\left(\frac{C}{L}\right) = \tilde{\beta}\int_0^{\infty} \frac{C^{1-\varepsilon}-1}{1-\varepsilon}dt;\ \tilde{\beta} = \frac{1}{1+\rho}; \varepsilon > 0;\ -\infty < \varepsilon < 1;\ \eta := 1/\varepsilon$

$\max 1')$

subject to 2)

1'') $U'(c) = c^{-\varepsilon}$

1''') $U''(c) = -\varepsilon c^{-(\varepsilon+1)}$

2) $\frac{dk}{dt} = f(k) - \delta k - nk - \frac{C}{L}$

3) $H = U\left(\frac{C}{L}\right) + \lambda\left(f(k) - (\delta + n)k - \frac{C}{L}\right);\ \frac{Y}{L} := y = f(k);\ k := \frac{K}{L}$

4) $\dot{\lambda} = \rho\lambda - \frac{\partial H}{\partial k}$

4') $\rho\lambda = \lambda\left[f'(k) - (\delta + n)\right] + \dot{\lambda}$

5) $\lim_{t\to\infty} e^{-\rho t}\lambda k = 0$

6) $\frac{\partial H}{\partial c} = 0 \rightarrow \frac{\partial U}{\partial c} - \lambda = 0$

using (4') and (6) gives (assuming $n = \frac{d\ln L}{dt}$):

6') $\frac{U''(c)}{U'(c)}\dot{c} = \rho - \left(f'(k) - \delta - n \right);\ r := f'(k) - \delta$

6'') $-\frac{\varepsilon \dot{c}}{c} = \rho - r + n$

7) $\frac{\dot{c}}{c} = \frac{r - n - \rho}{\varepsilon}$

$\Rightarrow$

8) $\frac{\dot{C}}{C} = \frac{r - \rho}{\varepsilon} + n\left(1 + \frac{1}{\varepsilon}\right)$

Setting with FDI and Product Innovation

1) $U = \int_0^{\infty} \left[\frac{C^{1-\varepsilon}}{1-\varepsilon} + \frac{\varphi' v^{1-\varepsilon'}}{1-\varepsilon'} \right] e^{'\rho t} dt;$

2) $X - q^* J = \theta \alpha^* \beta Y;\ 0 < \theta < 1;\ 0 < \alpha^* < 1;\ 0 < \beta < 1$

2') $v = \psi \varphi y (1 + \alpha^*);\ \psi > 0,\ \varphi > 0$ (φ is the share of output used for R&D in product innovation)

2'') $\frac{dk}{dt} = f(k) - \delta k - \varphi y - nk - \frac{C}{L} - \frac{X - q^* J}{L};$

3) $\frac{X - q^* J}{L} = \theta \alpha^* \beta f(k)$

This equation says that repatriated profits per capita are proportionate to output per capita (y); it is assumed that y=f(k) where k is the capital intensity (in a modified subsequent setting y'=f(k') where y':= Y/(AL) and k':= K/(AL)).

The Hamiltonian is given by:

4) $H = U\left(\frac{C}{L}, v\right) + \lambda\left[(1-\theta\alpha^*\beta) f(k) - (\delta+n)k - (v/(\psi(1+\alpha^*)) - \frac{C}{L}\right];\ k := \frac{K}{L}$

5) $\frac{\partial H}{\partial c} = 0;\ \text{from}\ \frac{\partial H}{\partial c} = 0\ \text{we get}\ \frac{\partial U}{\partial c} - \lambda = 0$

6) $\dot{\lambda} = \rho\lambda - \frac{\partial H}{\partial k}$

6') $\frac{U''(c)}{U'(c)}\dot{c} = \rho - \left((1-\theta\alpha^*\beta) f'(k) - \delta - n\right);\quad f'(k) = r + \delta$

6") $-\frac{\varepsilon\dot{c}}{c} = \rho - (1-\theta\alpha^*\beta)r + \theta\alpha^*\beta\delta + n$

7) $\lim_{t\to\infty} e^{-\rho t}\lambda k = 0$

8) $\frac{\dot{c}}{c} = \frac{r - n - \rho - \theta\alpha^*\beta(\delta + r)}{\varepsilon}$

$\Rightarrow$

9) $\frac{\dot{C}}{C} = \frac{r - \rho - \theta\alpha^*\beta(\delta + r)}{\varepsilon} + n\left(1 - \frac{1}{\varepsilon}\right)$

10) $\frac{\partial H}{\partial v} = 0$

10') $\frac{dk}{dt} = f(k) - \delta k - \frac{v}{\psi(1+\alpha^*)} - nk - \frac{C}{L} - \frac{X - q^*J}{L}$

10") $v^{opt} \to \frac{\partial U\left(\frac{C}{L}, v\right)}{\partial v} - \frac{\frac{\partial U}{\partial c}}{\psi(1+\alpha^*)} = 0$

11) $\varphi'(v^{opt})^{-\varepsilon'} = \frac{\lambda}{\psi(1+\alpha^*)}$

12) $(v^{opt})^{-\varepsilon'} = \frac{\varphi' c^{-\varepsilon}}{\psi(1+\alpha^*)}$

13) $(v^{opt})^{\varepsilon'} = c^{\varepsilon}\frac{\psi(1+\alpha^*)}{\varphi'}$

13') $v^{opt} = c^{\frac{\varepsilon}{\varepsilon'}}\left(\frac{\psi(1+\alpha^*)}{\varphi'}\right)^{\frac{1}{\varepsilon'}}$

$\to g_v = g_c$, if $\varepsilon' = \varepsilon$

Maximum per capita consumption growth is a positive function of the real interest rate and foreign direct investment intensity (parameter α*) – where it is assumed that the capital depreciation rate exceeds the real interest rate r. It is also a positive function of the intertemporal elasticity of substitution. The role of the growth rate of the population is ambiguous – if the intertemporal elasticity of substitution falls short of unity, a higher population growth rate will raise the long run growth rate of consumption and output, respectively.

The optimum product innovation growth is proportionate to per capita consumption in the long run, but there is a parameter restriction for $g_v = g_c$ (where g stands for growth rate). Moreover,

it is a negative function of the parameter φ' and a positive function of the productivity parameter in the R&D sector for product innovations (ψ) as well as a positive function of inward foreign direct investment (parameter α* which indicates the share of foreign investors in K).

The implication that quality is an excellent substitute for quantity of consumption should be adequate in high per capita income countries. In poor countries one might have to reformulate the utility function in an adequate way since a minimum level of per capita consumption is the basis for survival.

6. Regression Results

The empirical findings for the link between product innovation and FDI, on the one hand, and process innovation and FDI, on the other hand, are shown in the subsequent tables. The analysis is based on a panel data approach – results from the Hausman test have been considered for the decision to include country fixed effects. Data from 31 European countries were covered, namely the EU28 countries plus Island, Norway and Turkey (see Tab. 8).

Table 8: Countries Covered in the Regression Analysis

No.	Country	ISO3	Countries in the regression
1	Austria	AUT	YES
2	Belgium	BEL	YES
3	Bulgaria	BGR	YES
4	Cyprus	CYP	YES
5	Czech Republic	CZE	YES
6	Germany	DEU	YES
7	Denmark	DNK	YES
8	Spain	ESP	YES
9	Estonia	EST	YES
10	Finland	FIN	YES
11	France	FRA	YES
12	United Kingdom	GBR	YES
13	Greece	GRC	YES
14	Croatia	HRV	YES
15	Hungary	HUN	YES
16	Ireland	IRL	YES
17	Iceland	ISL	YES
18	Italy	ITA	YES
19	Lithuania	LTU	YES
20	Luxembourg	LUX	YES
21	Latvia	LVA	YES
22	North Macedonia	MKD	NO
23	Malta	MLT	YES
24	Netherlands	NLD	YES
25	Norway	NOR	YES
26	Poland	POL	YES
27	Portugal	PRT	YES
28	Romania	ROU	YES
29	Serbia	SRB	NO
30	Slovak Republic	SVK	YES
31	Slovenia	SVN	YES
32	Sweden	SWE	YES
33	Turkey	TUR	YES

Source: Own representation

The empirical findings for the links between product innovations and FDI, on the one hand, and process innovations and FDI, on the other hand, are shown in the subsequent tables. The analysis is based on a panel data approach analyzing European countries and the Community Innovation Survey, respectively. As regards key findings, the two subsequent tables show crucial results (for a list of variables and the data sources, see the table in the appendix; note that bi-annual EU Community Innovation Survey results have been interpolated based on a linear function; for reasons that are rather unclear, the European Commission had still not published the data for 2018 by mid-September 2020).

The lagged inward FDI stock has a positive effect on product innovation (both in the specification with year dummies and the specification without year dummies). The ratio of value-added imports to gross imports has a negative effect on product innovations which implies that effective import competition is not a driver of more product innovations. Lagged outward FDI stock has a significant negative impact on product innovations which supports the techno-globalization hypothesis (see Tab. 9).

Table 9: Regression Model 1

Product Innovation v= v(per capita GDP PPP, inward FDI stock, LAGGED; imports (value added versus gross imports), outward FDI stock, LAGGED);

VARIABLES	(1) Product innovation	(2) Product innovation
GDP per capita	0.039	0.073
	(0.097)	(0.103)
Lagged IFDI stock	0.020***	0.022***
	(0.003)	(0.004)
Domestic VA imports to Gross imports	-8,689.930**	-8,670.873**
	(3,596.694)	(3,652.136)
Lagged OFDI stock	-0.010***	-0.008***
	(0.003)	(0.003)
Constant	3,668.490	2,397.255
	(3,712.642)	(4,058.133)
Observations	152	152
R-squared	0.261	0.284
Number of id	31	31
Year dummies	NO	YES

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

As regards process innovations, the lagged inward FDI stock significantly raises process innovations (Tab. 10). Lagged outward FDI stock has a negative effect on process innovations which again suggests support for the techno-globalization hypothesis: if subsidiaries abroad create more process innovations, there might be a reduced need for process innovations in the source country as MNCs' global innovation process now allows to rely less on purely domestic process innovations but to also use foreign knowledge (intra-MNC). The R squared here is rather small compared to the findings for product innovations; with year dummies, the R squared is slightly higher in both regressions.

Table 10: Regression Model 2

Process Innovation v'= v'(per capita GDP PPP, inward FDI stock, LAGGED; imports (value added versus gross imports), outward FDI stock, LAGGED);

VARIABLES	(1) Process innovation	(2) Process innovation
GDP per capita	0.169	0.187
	(0.114)	(0.122)
Lagged IFDI stock	0.009**	0.011**
	(0.004)	(0.004)
Domestic VA imports to Gross imports	2,966.054	3,045.138
	(4,238.206)	(4,306.245)
Lagged OFDI stock	-0.008***	-0.007**
	(0.003)	(0.003)
Constant	-5,278.827	-6,122.499
	(4,374.836)	(4,784.958)
Observations	152	152
R-squared	0.108	0.135
Number of id	31	31
Year dummies	NO	YES

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

As regards the significant variables, one may clearly point out that lagged inward FDI stock is highly significant for both product innovations and process innovations. The outward FDI stock always has a negative effect on both types of innovations.

To the extent that higher outward FDI stock reduces product innovations (and process innovations) in the source country, one might want to argue that higher outward FDI is undermining innovation dynamics in Europe (or in the USMCA trade area). However, this conclusion is doubtful, for example, in an integrated three country perspective: If higher inward FDI in country i from country j goes along with higher outward FDI from j to country k, the overall effect of outward FDI flows from country j could actually raise product innovations in the integrated region.

One may argue that there could be interesting links between product innovations and process innovations – for example, electric cars cannot be produced easily on existing assembly lines for traditional fossil fuel cars and hence product innovations could be a driver of process innovations.

7. Policy Conclusions

The distinction between product innovations and process innovations is crucial for a broader innovation analysis as well as for macro modeling, economic growth analysis, monetary policy and innovation policy. According to the analysis presented here, this distinction matters on a sectoral level in industrialized countries as well as in a macroeconomic perspective. Considering the microeconomics of product and process innovations in an enhanced Bertschek approach is a useful analytical step.

A particular feature of the analysis is to explicitly include product innovations and process innovations as arguments in the real money demand, the consumption function as well as in the import and export equations. Moreover, the role of inward and outward FDI has been considered here – looking, for the sake of simplicity, into the cases of asymmetrical outward FDI and asymmetrical inward FDI, respectively. It has been argued that an implicit consideration of the Vernon product cycle approach within a macro model is quite useful and brings additional insights as does the analysis of product versus process innovations and FDI, respectively. In principle, it is of course possible to consider cumulated inward and outward FDI simultaneously. The descriptive insights on product and process innovations in European countries show considerable differences across countries and a basic regression analysis gives further insights into the relevance of innovation dynamics.

Based on the new approaches presented here, there is considerable room for further analysis which could also bring refined arguments for fiscal policy, namely to the extent that part of fiscal policy is associated with changes in R&D promotion for product and process innovations, respectively. Knowledge about international spillover effects of both types of innovations is rather limited, but the general perception in the innovation literature (see, e.g., PERRET, 2014) is that the spillover radius typically could be around 300 km. This spillover radius, however, will typically differ across sectors.

The statistical offices of OECD countries have a broad range of useful hedonic pricing analyses which so far have not been exploited for measuring product innovations although this would be possible in principle. There is a clear need to conduct further analysis in this field while central banks' research agendas should reflect this since a full understanding of the signaling content of official price level statistics is crucial for expectation formation and monetary policy, respectively.

The fact that monetary integration in the European Union (read: the creation of the Eurozone) has reinforced intra-Eurozone FDI suggests – taking into account the positive link between inward FDI and product innovations and between inward FDI and process innovations – that Euro monetary integration contributes to effectively lower inflation rates (considering broad hedonic price level measurement) via a so far neglected innovation channel; this statement holds provided that overall inward FDI stocks have not reduced in the Eurozone after 1999. One may point out that the European Central Bank so far has not presented hedonic pricing measurement analysis relating to the impact of the creation of the Eurozone. Thus, there is ample need for further research. In the Eurozone, the US, the UK, Japan, China, and many other countries, it should also be considered more carefully to what extent a wave of product

innovations brings about a clearly different response of the real interest rate than a wave of process innovations. In a broader perspective, the role of international transfer (be it legal or illegal) has been emphasized here and the crucial impact of both inward and outward FDI. As regards BREXIT effects on the effective UK price level, it will be interesting to see what will be the result of an overlap of anticipated lower FDI inflows in the UK which might also go along with lower FDI outflows.

In high wage economies, such as the countries of Western Europe and most states in the US, an adequate government promotion of production innovations seems to be crucial as well as a broader institutional system design (possibly with a focus on encouraging venture capital industries) in favor of enhanced innovation dynamics. A country with companies with a rather strong product innovation record will record high export unit values and hence companies will be able to pay rather high wages. There is little doubt that in many innovative sectors there will be a relatively high demand for skilled labor; the exact links between product innovation dynamics and the relative demand for skilled labor will have to be analyzed in future studies. The issue of the optimal innovation policy mix – with a focus on both product innovations and process innovations – is a new issue that comes up in the context of the research presented here. If product innovations are crucial for economic prosperity and effectively dampening inflation – the latter effect being related to hedonic price measurement – it seems adequate to consider more carefully the role of outward FDI. Governments might consider to promote inward FDI, namely to the extent that a higher stock of inward FDI stimulates both product innovations and process innovations in the home country. There is naturally a caveat, namely that inward FDI flows into OECD countries from other OECD countries - possibly also certain NICs – bringing positive international technology effects. The attractiveness of countries for inward FDI has been studied recently in a series of research contributions based on FDI gravity modelling which have shown, for example, that the degree of regional integration, relative corporate tax rates and corruption indices (WELFENS/BAIER; BAIER, 2020; ZANDER, 2020) as well as other variables are significant drivers for inward FDI.

At the bottom line, one should integrate inward FDI and outward FDI into existing macro models in an explicit way as well as the distinction between product innovations and process innovations. Improving the statistical coverage for product innovations in OECD countries and NICs seems to be a prime political challenge for the near future. Only with a broad data basis, can further empirical analysis shed more light on the issues raised here. DSGE models of central banks, governments and research institutes should clearly incorporate the analytical elements emphasized here.

Overcoming the Corona recession might be possible in an optimal way only if the distinction between product innovations and process innovations, as well as the role of inward FDI and outward FDI, is observed; and hence a refined definition of capital flows in macro models which would make a distinction between portfolio capital flows and FDI. Finally, inflation analysis will be incomplete and could be misleading if the role of product innovations is not carefully considered; suffice to say that the adjustment speed (read: the Calvo parameter) in a New Keynesian Phillips curve in a setting with more market power – possibly meaning a larger role of multinational companies – is reduced. Special aspects of ICT will also have to be considered in the future, not least because a higher share of digital value-added could mean more product differentiation and possible also more product innovation in the overall economy.

Appendix 1: Data Appendix and List of Countries Covered in the Regression

Table 11: Data Appendix and List of Countries Covered in the Regression

Variables	***Description***	***Source***	***Time period***
Product innovation	Number of product innovative enterprises only	Eurostat	2000-2016
Process innovation	Number of process innovative enterprises only	Eurostat	2000-2016
GDP per capita	GDP per capita, PPP (constant 2017 international $)	World Bank	2000-2016
Inward FDI stock	Inward foreign direct investment in US dollars at current prices in millions	UNCTAD	2000-2016
Outward FDI stock	Outward foreign direct investment in US dollars at current prices in millions	UNCTAD	2000-2016
Domestic VA imports to Gross imports	Domestic value-added share of gross imports	OECD	2000-2016
Export unit values	Export unit value index (2000 = 100)	World Bank	2000-2018

Source: Own representation.

Table 12: Correlation Matrix: Pairwise Correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) Product innovation	1.000							
(2) Process innovation	0.739*	1.000						
(3) Product/Process	0.068	-0.097	1.000					
(4) Lagged IFDI stock	0.718*	0.418*	0.096	1.000				
(5) Lagged OFDI stock	0.677*	0.379*	0.118	**0.962***	1.000			
(6) Gross imports	0.856*	0.633*	0.084	**0.878***	**0.876***	1.000		
(7) Gross exports	0.868*	0.627*	0.097	**0.814***	**0.827***	**0.987***	1.000	
(8) Gross imports to gdp	-0.338*	-0.353*	-0.017	-0.287*	-0.306*	-0.376*	-0.347*	1.000
(9) Gross exports to gdp	-0.292*	-0.335*	0.030	-0.186*	-0.212*	-0.301*	-0.250*	0.966*
(10) VA imp~s/gross imports	0.824*	0.526*	0.115	**0.793***	**0.785***	**0.921***	**0.952***	-0.389*
(11) VA exp~s/gross imports	0.330*	0.308*	0.000	0.277*	0.302*	0.354*	0.318*	**-0.944***
(12) GDP per capita	0.126*	0.069	0.043	0.290*	0.293*	0.182*	0.219*	0.300*

* shows significance at the 0.05 level

Source: Own representation

Appendix 2: Schumpeterian Open Economy Macro Model Under Flexible Exchange Rates in a Setting with Cumulated Outward FDI

The following three variables are endogenous - the real exchange rate (r), real GDP (Y) and the exchange rate (nominal rate e/real exchange rate q*) – while exogenous are: M, G, τ, α, α*, v, A.

We get the following equation in matrix notation (with an exogenous product innovation v):

$$\begin{pmatrix} 1-c(1-\tau)-b\beta/K+j & b & -\alpha\beta^{*}Y^{*}-x''-jv''/q^{*2} \\ h & -h & 0 \\ q^{*}j & -H & -H'+j(Y+2\alpha\beta^{*}Y^{*}q^{*})-j''/q^{*2}-x'' \end{pmatrix} \begin{pmatrix} dY \\ dr \\ dq^{*} \end{pmatrix}$$

$$= \begin{pmatrix} 0 & 1 & -c(Y+\alpha\beta^{*}Y^{*}q^{*}) & \beta^{*}Y^{*}q^{*}c(1-\tau) & 0 & c'+x'-j & \delta K+V' \\ 1/P(1-v''v) & 0 & 0 & 0 & 0 & Mv''/(P(1-v''v)^{2})-h' & a' \\ 0 & 0 & 0 & -q^{*2}\ j\beta^{*}Y^{*}-xY^{*}\beta^{*} & 0 & H''+j+x' & V' \end{pmatrix} \begin{pmatrix} dM \\ dG \\ d\tau \\ d\alpha \\ d\alpha^{*} \\ dv \\ dA \end{pmatrix}$$

$$define: 1-c(1-\tau)-b\beta/K+j =: a''$$
$$-\alpha\beta^{*}Y^{*}-x''-jv''/q^{*2} =: a'''$$
$$-H'+j(Y+2\alpha\beta^{*}Y^{*}q^{*})-j''/q^{*2}-x'' =: a''''$$
$$DET(A) = -a''ha''''-a'''hH+q^{*}jha'''-a''''hb = h[a'''(H+q^{*}j)-a''''(a''+b)]$$

$$\begin{pmatrix} a'' & b & a''' \\ h & -h & 0 \\ q^{*}j & -H & a'''' \end{pmatrix} \begin{pmatrix} dY \\ dr \\ dq^{*} \end{pmatrix}$$

$$= \begin{pmatrix} 0 & 1 & -c(Y+\alpha\beta^{*}Y^{*}q^{*}) & \beta^{*}Y^{*}q^{*}c(1-\tau) & 0 & c'+x'-j & \delta K+V' \\ 1/P(1-v''v) & 0 & 0 & 0 & 0 & Mv''/(P(1-v''v)^{2})-h' & a' \\ 0 & 0 & 0 & -q^{*2}\ j\beta^{*}Y^{*}-xY^{*}\beta^{*} & 0 & H''+j+x' & V' \end{pmatrix} \begin{pmatrix} dM \\ dG \\ d\tau \\ d\alpha \\ d\alpha^{*} \\ dv \\ dA \end{pmatrix}$$

The multipliers for the seven exogenous variables are as follows:

$$\frac{dY}{dM} = -\frac{a'''H + a''''b}{P(1-v''v)DET(A)} = -\frac{a'''H + a''''b}{P(1-v''v)h[a'''(H + q^* j) - a''''(a''+b)]}$$

$$\frac{dY}{dG} = \frac{-a''''}{a'''(H + q^* j) - a''''(a''+b)}$$

$$\frac{dY}{d\tau} = \frac{c(Y + \alpha\beta^* Y^* q^*)a''''}{a'''(H + q^* j) - a''''(a''+b)}$$

$$\frac{dY}{d\alpha} = \frac{a'''(-q^{*2}\ j\beta^* Y^* - xY^*\beta^*) - a''''\beta^* Y^* q^* c(1-\tau)}{a'''(H + q^* j) - a''''(a''+b)}$$

$$\frac{dY}{d\alpha^*} = 0$$

$$\frac{dY}{dv} = -\frac{a'''H[Mv''/(P(1-v''v)^2) - h'] + ha''''(c' + x' - j) - ha'''(H'' + j + x') + ba''''[Mv''/(P(1-v''v)^2) - h']}{h[a'''(H + q^* j) - a''''(a''+b)]}$$

$$\frac{dY}{dA} = -\frac{ha''''(\delta K + V') + a'''a'H - V'ha''' + a''''a'b}{h[a'''(H + q^* j) - a''''(a''+b)]}$$

$$\frac{dr}{dM} = \frac{[1/P(1-v''v)][a''a'''' - q^* ja''']}{h[a'''(H + q^* j) - a''''(a''+b)]}$$

$$\frac{dr}{dG} = \frac{-a''''}{a'''(H + q^* j) - a''''(a''+b)}$$

$$\frac{dr}{d\tau} = \frac{a''''c(Y + \alpha\beta^* Y^* q^*)}{a'''(H + q^* j) - a''''(a''+b)}$$

$$\frac{dr}{d\alpha} = \frac{a'''[-q^{*2}\ j\beta^* Y^* - xY^*\beta^*] - a''''[\beta^* Y^* q^* c(1-\tau)]}{a'''(H + q^* j) - a''''(a''+b)}$$

$$\frac{dr}{d\alpha^*} = 0$$

$$\frac{dr}{dv} = \frac{a''[Mv''/(P(1-v''v)^2) - h']a'''' + a'''h[H'' + j + x'] - q^* j[Mv''/(P(1-v''v)^2) - h']a''' - a''''h[c' + x' - j]}{h[a'''(H + q^* j) - a''''(a''+b)]}$$

$$\frac{dr}{dA} = \frac{a''a'a'''' + a'''hV' - q^* ja'a''' - a''''h[\delta K + V']}{h[a'''(H + q^* j) - a''''(a''+b)]}$$

$$\frac{dq^*}{dM} = \frac{bq^* j + Ha''}{P(1-v''v)h[a'''(H+q^* j) - a''''(a''+b)]}$$

$$\frac{dq^*}{dG} = \frac{q^* j - H}{a'''(H+q^* j) - a''''(a''+b)}$$

$$\frac{dq^*}{d\tau} = \frac{c(Y+\alpha\beta^* Y^* q^*)[H - q^* j]}{a'''(H+q^* j) - a''''(a''+b)}$$

$$\frac{dq^*}{d\alpha} = -\frac{a''[-q^{*2}\ j\beta^* Y^* - xY^*\beta^*] + [\beta^* Y^* q^* c(1-\tau)]H - q^* j[\beta^* Y^* q^* c(1-\tau)] + [-q^{*2}\ j\beta^* Y^* - xY^*\beta^*]b}{a'''(H+q^* j) - a''''(a''+b)}$$

$$\frac{dq^*}{d\alpha^*} = 0$$

$$\frac{dq^*}{dv} = \frac{-a''h[H''+ j + x'] + b[Mv''/(P(1-v''v)^2) - h']q^* j - [c'+x'- j]hH}{h[a'''(H+q^* j) - a''''(a''+b)]}$$
$$+\frac{q^* jh[c'+x'- j] + H[Mv''/(P(1-v''v)^2) - h']a'' - [H''+ j + x']hb}{h[a'''(H+q^* j) - a''''(a''+b)]}$$

$$\frac{dq^*}{dA} = \frac{-a''hV' + ba'q^* j - [\delta K + V']hH + q^* jh[\delta K + V'] + Ha'a'' - V'hb}{h[a'''(H+q^* j) - a''''(a''+b)]}$$

If one endogenizes v (see equation 4' which endogenizes product innovations), the new equation system with four equations will read as follows where only the multipliers for M, G, τ and α are considered here:

$$(1'')Y = c(1-\tau)(Y + \alpha ß^* Y^* q^*) + c'(V\alpha + V'\alpha^* + r'R + b'G - b''r + z''J/Y) + G + b(ßY/K - r)$$
$$+\delta(A)K + xY^* + x'(V\alpha + V'\alpha^* + r'R + b'G - b''r + z''J/Y) + x''q^* + V'A - jY - j(V\alpha + V'\alpha^*$$
$$+r'R + b'G - b''r + z''J/Y) - jv''/q^*$$

$$(2'')M/\left(P\left(1-v''[V\alpha + V'\alpha^* + r'R + b'G - b''r + z''J/Y]\right)\right)$$
$$= hY - hr + h'(V\alpha + V'\alpha^* + r'R + b'G - b''r + z''J/Y) - a'A$$

$$(3'')H(r - r^*) + \left(H'q^* + H''(V\alpha + V'\alpha^* + r'R + b'G - b''r + z''J/Y)\right)$$
$$= q^* j(Y + \alpha ß^* Y^* q^*) - j(V\alpha + V'\alpha^* + r'R + b'G - b''r + z''J/Y)$$
$$+j''/q^* + V''v_{-1} - xY^*(1 - \alpha ß^*) - x'(V\alpha + V'\alpha^* + r'R + b'G - b''r + z''J/Y) - x''q^* - V'A$$

$$(4')\; v = V\alpha + V'\alpha^* + r'R + b'G - b''r + z''J/Y$$

$$\begin{pmatrix} 1 - c(1-\tau) + c'z''J/Y^2 + x'z''J/Y^2 + j - jz''J/Y^2 & c'b'' + b + x'b'' - jb'' & -\alpha\beta^* Y^* - x'' - jv''/q^{*2} \\ h - \dfrac{Mv''z''J}{P[1 - v''(V\alpha + V'\alpha^* + r'R + b'G - b''r + z''J/Y)]^2 Y^2} - h'z''J/Y^2 & -h - \dfrac{Mv''b''}{P[1 - v''(V\alpha + V'\alpha^* + r'R + b'G - b''r + z''J/Y)]^2} - h'b'' & 0 \\ q^* j + H''z''J/Y^2 + jz''J/Y^2 + x'z''J/Y^2 & -H + H''b'' + jb'' + x'b'' & -H' + j(Y + 2\alpha\beta^* Y^* q^*) - j''/q^{*2} - x'' \\ z''J/Y^2 & b'' & 0 \end{pmatrix} \begin{pmatrix} dY \\ dr \\ dq^* \end{pmatrix}$$

$$= \begin{pmatrix} 0 & 1 + b' & -c(Y + \alpha\beta^* Y^* q^*) & \beta^* Y^* q^* c(1-\tau) + (c' + x' - j)V & (c' + x' - j)V' & \delta K + V' \\ \dfrac{1}{(P(a''))} & \dfrac{Mv''b'}{P[a'']^2} - h'b' & 0 & \dfrac{Mv''V}{P[a'']^2} - h'V & \dfrac{Mv''V'}{P[a'']^2} - h'V' & a' \\ 0 & (H'' + j + x')b' & 0 & -q^{*2}\, j\beta^* Y^* - xY^* \beta^* + (H'' + x' + j)V & (H'' + j + x')V' & V' \end{pmatrix} \begin{pmatrix} dM \\ dG \\ d\tau \\ d\alpha \\ d\alpha^* \\ dA \end{pmatrix}$$

Define:

$$1 - v''(V\alpha + V'\alpha^* + r'R + b'G - b''r + z''J/Y) =: a''$$

$$1 - c(1-\tau) + (c' + x' - j)z''J/Y^2 + j =: z_1$$

$$(c' + x' - j)b'' + b =: z_2$$

$$-\alpha\beta^* Y^* - x'' - jv''/q^{*2} =: z_3$$

$$h - \frac{Mv''z''J}{P[a'']^2 Y^2} - h'z''J/Y^2 =: z_4$$

$$-h - \frac{Mv''b''}{P[a'']^2} - h'b'' =: z_5$$

$$q^* j + (H'' + j + x')z''J/Y^2 =: z_6$$

$$-H + (H'' + j + x')b'' =: z_7$$

$$-H' + j(Y + 2\alpha\beta^* Y^* q^*) - j''/q^{*2} - x'' =: z_8$$

$$\begin{pmatrix} z_1 & z_2 & z_3 \\ z_4 & z_5 & 0 \\ z_6 & z_7 & z_8 \end{pmatrix} \begin{pmatrix} dY \\ dr \\ dq^* \end{pmatrix}$$

$$= \begin{pmatrix} 0 & 1 + b' & -c(Y + \alpha\beta^* Y^* q^*) & \beta^* Y^* q^* c(1-\tau) + (c' + x' - j)V & (c' + x' - j)V' & \delta K + V' \\ \dfrac{1}{(P(a''))} & \dfrac{Mv''b'}{P[a'']^2} - h'b' & 0 & \dfrac{Mv''V}{P[a'']^2} - h'V & \dfrac{Mv''V'}{P[a'']^2} - h'V' & a' \\ 0 & (H'' + j + x')b' & 0 & -q^{*2}\, j\beta^* Y^* - xY^* \beta^* + (H'' + x' + j)V & (H'' + j + x')V' & V' \end{pmatrix} \begin{pmatrix} dM \\ dG \\ d\tau \\ d\alpha \\ d\alpha^* \\ dA \end{pmatrix}$$

$$DET(A) = [1-c(1-\tau)+(c'+x'-j)z"J/Y^2+j][-h-\frac{Mv"b"}{P[a"]^2}-h'b"][-H'+j(Y+2\alpha\beta*Y*q*)]$$

$$+[-\alpha\beta*Y*-x"-jv"/q*^2][h-\frac{Mv"z"J}{P[a"]^2Y^2}-h'z"J/Y^2][-H+(H"+j+x')b"]$$

$$-[q*j+(H"+j+x')z"J/Y^2][-h-\frac{Mv"b"}{P[a"]^2}-h'b"][-\alpha\beta*Y*-x"-jv"/q*^2]$$

$$-[-H'+j(Y+2\alpha\beta*Y*q*)-j"/q*^2-x"][h-\frac{Mv"z"J}{P[a"]^2Y^2}-h'z"J/Y^2][(c'+x'-j)b"+b]$$

$$=(z_1z_5z_8)+(z_3z_4z_7)-(z_6z_5z_3)-(z_8z_4z_2)$$

$$\frac{dY}{dM}=\frac{z_3z_7-z_8z_2}{P(a")[(z_1z_5z_8)+(z_3z_4z_7)-(z_6z_5z_3)-(z_8z_4z_2)]}$$

$$\frac{dY}{dG}=\frac{(1+b')z_5z_8+\left(\frac{Mv"b'}{P[a"]^2}-h'b'\right)(z_3z_7-z_8z_2)-(H"+j+x')b'z_5z_3}{(z_1z_5z_8)+(z_3z_4z_7)-(z_6z_5z_3)-(z_8z_4z_2)}$$

$$\frac{dY}{d\tau}=\frac{-c(Y+\alpha\beta*Y*q*)z_5z_8}{(z_1z_5z_8)+(z_3z_4z_7)-(z_6z_5z_3)-(z_8z_4z_2)}$$

$$\frac{dY}{d\alpha}=\frac{[\beta*Y*q*c(1-\tau)+(c'+x'-j)V]z_5z_8+[q*^2\ j\beta*Y*+xY*\beta*+(H"+x'+j)V]z_5z_3}{(z_1z_5z_8)+(z_3z_4z_7)-(z_6z_5z_3)-(z_8z_4z_2)}$$

$$+\frac{\left(\frac{Mv"V}{P[a"]^2}-h'V\right)(z_3z_7-z_8z_2)}{(z_1z_5z_8)+(z_3z_4z_7)-(z_6z_5z_3)-(z_8z_4z_2)}$$

$$\frac{dY}{d\alpha*}=\frac{V'z_5[(c'+x'-j)z_8-(H"+j+x')z_3]+\left[\frac{Mv"V'}{P[a"]^2}-h'V'\right](z_3z_7-z_8z_2)}{(z_1z_5z_8)+(z_3z_4z_7)-(z_6z_5z_3)-(z_8z_4z_2)}$$

$$\frac{dY}{dA}=\frac{(\delta K+V')z_5z_8+z_3a'z_7-V'z_5z_3-z_8a'z_2}{(z_1z_5z_8)+(z_3z_4z_7)-(z_6z_5z_3)-(z_8z_4z_2)}$$

$$\frac{dr}{dM}=\frac{z_1z_8-z_6z_3}{P(a")[(z_1z_5z_8)+(z_3z_4z_7)-(z_6z_5z_3)-(z_8z_4z_2)]}$$

$$\frac{dr}{dG}=\frac{\left(\frac{Mv"b'}{P[a"]^2}-h'b'\right)(z_1z_8-z_6z_3)+z_3z_4(H"+j+x')b'-z_8z_4(1+b')}{(z_1z_5z_8)+(z_3z_4z_7)-(z_6z_5z_3)-(z_8z_4z_2)}$$

$$\frac{dr}{d\tau} = \frac{z_8 z_4 c(Y + \alpha\beta^* Y^* q^*)}{(z_1 z_5 z_8) + (z_3 z_4 z_7) - (z_6 z_5 z_3) - (z_8 z_4 z_2)}$$

$$\frac{dr}{d\alpha} = \frac{(z_1 z_8 - z_6 z_3)\left(\frac{Mv"V}{P[a"]^2} - h'V\right) + z_3 z_4\left[-q^{*2}\ j\beta^* Y^* - xY^*\beta^* + (H"+x'+j)V\right]}{(z_1 z_5 z_8) + (z_3 z_4 z_7) - (z_6 z_5 z_3) - (z_8 z_4 z_2)}$$
$$- \frac{z_8 z_4\left[\beta^* Y^* q^* c(1-\tau) + (c'+x'-j)V\right]}{(z_1 z_5 z_8) + (z_3 z_4 z_7) - (z_6 z_5 z_3) - (z_8 z_4 z_2)}$$

$$\frac{dr}{d\alpha^*} = \frac{\left[\frac{Mv"V'}{P[a"]^2} - h'V'\right](z_1 z_8 - z_6 z_3) + z_3 z_4 (H"+j+x')V' - z_8 z_4 (c'+x'-j)V'}{(z_1 z_5 z_8) + (z_3 z_4 z_7) - (z_6 z_5 z_3) - (z_8 z_4 z_2)}$$

$$\frac{dr}{dA} = \frac{z_1 a' z_8 + z_3 z_4 V' - z_6 a' z_3 - z_8 z_4(\delta K + V')}{(z_1 z_5 z_8) + (z_3 z_4 z_7) - (z_6 z_5 z_3) - (z_8 z_4 z_2)}$$

$$\frac{dq^*}{dM} = \frac{z_2 z_6 - z_7 z_1}{P(a")[(z_1 z_5 z_8) + (z_3 z_4 z_7) - (z_6 z_5 z_3) - (z_8 z_4 z_2)]}$$

$$\frac{dq^*}{dG} = \frac{(z_1 z_5 - z_z z_2)(H"+j+x')b' + (z_2 z_6 - z_7 z_1)\left(\frac{Mv"b'}{P[a"]^2} - h'b'\right)(z_4 z_7 - z_6 z_5)(1+b')}{(z_1 z_5 z_8) + (z_3 z_4 z_7) - (z_6 z_5 z_3) - (z_8 z_4 z_2)}$$

$$\frac{dq^*}{d\tau} = \frac{(z_6 z_5 - z_4 z_7) c(Y + \alpha\beta^* Y^* q^*)}{(z_1 z_5 z_8) + (z_3 z_4 z_7) - (z_6 z_5 z_3) - (z_8 z_4 z_2)}$$

$$\frac{dq^*}{d\alpha} = \frac{(z_4 z_2 - z_1 z_5)\left[q^{*2}\ j\beta^* Y^* + xY^*\beta^* + (H"+x'+j)V\right] + (z_4 z_7 - z_6 z_5)\left[\beta^* Y^* q^* c(1-\tau) + (c'+x'-j)V\right]}{(z_1 z_5 z_8) + (z_3 z_4 z_7) - (z_6 z_5 z_3) - (z_8 z_4 z_2)}$$
$$+ \frac{(z_2 z_6 - z_7 z_1)\left(\frac{Mv"V}{P[a"]^2} - h'V\right)}{(z_1 z_5 z_8) + (z_3 z_4 z_7) - (z_6 z_5 z_3) - (z_8 z_4 z_2)}$$

$$\frac{dq^*}{d\alpha^*} = \frac{(z_1 z_5 - z_4 z_2)(H"+j+x')V' + (z_2 z_6 - z_7 z_8)\left[\frac{Mv"V'}{P[a"]^2} - h'V'\right] + (z_4 z_7 - z_6 z_5)(c'+x'-j)V'}{(z_1 z_5 z_8) + (z_3 z_4 z_7) - (z_6 z_5 z_3) - (z_8 z_4 z_2)}$$

$$\frac{dq^*}{dA} = \frac{(z_1 z_5 - z_4 z_2)V' + (z_2 z_6 - z_7 z_8)a' + (z_4 z_7 - z_6 z_5)\delta K + V'}{(z_1 z_5 z_8) + (z_3 z_4 z_7) - (z_6 z_5 z_3) - (z_8 z_4 z_2)}$$

Appendix 3: The Price Level and Product Innovation plus Process Innovation Dynamics

A Eurozone/European panel data analysis can be useful with respect to price level dynamics; it is often remarkable how different national price developments are in the Eurozone – for example, in the corona shock year 2020 when the inflation rate was 0.1 % in Germany in August, after 0.0% in July, which is much in contrast with Austria with 1.4% and 1.8% for the harmonized consumer price index, respectively (clearly, Germany's VAT rate reduction in the second half of 2020 cannot explain this significant difference as Eurostat figures show).

As regards the price level in country i, one should expect for the Eurozone countries a simple link between national price level developments (consumption price index P^C; alternatively, the GDP deflator could be considered) and innovation dynamics as well as capacity utilization (or price level expectations at the wholesale market level), the ratio of national product innovation relative to that of the US and the intensity of import competition (J_i/Y_i) plus the role of electricity price index for firms (e"); product innovations – lagged by one year - should raise the domestic price level P (unless P is fully measured with hedonic pricing measurement), process innovations should reduce P in country i while a higher capacity utilization will raise the price level as one should a higher export unit value (EUV, calculated as a three year moving average) relative to the US export unit while more import competition should dampen P:

(1") $\ln P^C_i = a_0 + a_1 \ln v_i(t-1) + a_2 \ln v'_i(t-1) + a_3 C''_i(\text{CapacityUtilization}) + a_4 \ln(EUV_i/EUV^{US}) + a_5(J_i/Y_i) + a_6 \ln e'' + \text{error term}$

Depending on Hausman test results, time fixed effects and country fixed effects should be considered in a panel data regression for European countries. A particularly crucial coefficient is a_1 since this is an implicit parameter for the ratio of the hedonic price level relative to the "standard" price level measurement.

Appendix 4: FDI Stocks to Capital Stocks, 1980-2017

Table 13: FDI inward stock / Capital stock (1980-1999), sorted by 2017

Country	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2017
Luxembourg																					0,859
Ireland	0,308	0,293	0,288	0,297	0,302	0,303	0,296	0,286	0,273	0,255	0,239	0,229	0,220	0,206	0,194	0,187	0,188	0,190	0,236	0,252	0,815
*Switzerland**				0,010	0,009	0,012	0,022	0,030	0,028	0,028	0,037	0,038	0,035	0,040	0,049	0,057	0,051	0,057	0,066	0,070	0,541
Netherlands	0,023	0,022	0,020	0,020	0,022	0,029	0,036	0,044	0,042	0,047	0,060	0,060	0,057	0,053	0,062	0,073	0,082	0,080	0,104	0,120	0,407
Belgium	0,010	0,013	0,015	0,017	0,018	0,027	0,040	0,043	0,053	0,068	0,072	0,082	0,085	0,100	0,107	0,109	0,118	0,122	0,168	0,162	0,199
Chile	0,077	0,075	0,076	0,078	0,077	0,076	0,074	0,076	0,077	0,078	0,076	0,076	0,075	0,072	0,074	0,076	0,084	0,091	0,092	0,102	0,178
Sweden	0,005	0,005	0,005	0,005	0,005	0,007	0,009	0,013	0,013	0,014	0,015	0,021	0,015	0,014	0,022	0,029	0,032	0,039	0,048	0,068	0,159
United Kingdom	0,022	0,020	0,018	0,019	0,016	0,022	0,025	0,035	0,039	0,044	0,058	0,057	0,046	0,045	0,044	0,043	0,046	0,051	0,067	0,077	0,137
Iceland		0,001	0,002	0,001	0,002	0,003	0,003	0,003	0,003	0,004	0,005	0,005	0,004	0,004	0,004	0,004	0,006	0,010	0,013	0,013	0,133
Australia	0,025	0,027	0,024	0,024	0,024	0,023	0,023	0,035	0,053	0,056	0,057	0,056	0,052	0,054	0,058	0,060	0,063	0,053	0,054	0,058	0,129
Estonia													0,002	0,005	0,009	0,013	0,016	0,022	0,035	0,048	0,129
United States of America	0,004	0,005	0,006	0,007	0,007	0,009	0,011	0,012	0,015	0,020	0,020	0,024	0,025	0,027	0,026	0,033	0,039	0,050	0,064	0,078	0,129
New Zealand	0,018	0,017	0,016	0,016	0,012	0,014	0,015	0,019	0,019	0,029	0,043	0,057	0,065	0,076	0,101	0,110	0,143	0,132	0,141	0,141	0,122
Canada	0,032	0,033	0,031	0,032	0,031	0,029	0,030	0,033	0,037	0,039	0,040	0,040	0,036	0,034	0,034	0,036	0,038	0,039	0,040	0,048	0,120
Israel	0,016	0,016	0,015	0,015	0,015	0,015	0,015	0,015	0,016	0,016	0,016	0,015	0,013	0,014	0,011	0,014	0,016	0,018	0,020	0,033	0,110
Norway	0,018	0,019	0,020	0,020	0,019	0,018	0,019	0,019	0,019	0,021	0,027	0,035	0,030	0,030	0,035	0,039	0,041	0,042	0,046	0,051	0,094
Poland											0,000	0,001	0,002	0,003	0,004	0,009	0,012	0,015	0,022	0,024	0,090
Slovakia														0,002	0,003	0,004	0,007	0,007	0,016	0,018	0,086
Finland	0,001	0,002	0,002	0,002	0,002	0,003	0,004	0,006	0,006	0,007	0,009	0,008	0,008	0,008	0,012	0,014	0,015	0,017	0,029	0,032	0,082
Austria	0,009	0,007	0,007	0,006	0,005	0,007	0,009	0,011	0,011	0,014	0,016	0,016	0,015	0,014	0,016	0,020	0,020	0,021	0,024	0,024	0,078
Denmark	0,010	0,008	0,006	0,007	0,007	0,009	0,011	0,013	0,013	0,015	0,020	0,030	0,029	0,028	0,033	0,041	0,038	0,037	0,058	0,077	0,078
Portugal	0,011	0,011	0,011	0,010	0,010	0,011	0,011	0,011	0,012	0,015	0,017	0,019	0,020	0,022	0,022	0,023	0,024	0,026	0,033	0,029	0,069

Czechia														0,004	0,004	0,006	0,007	0,008	0,012	0,015	0,068
Spain	0,003	0,003	0,003	0,003	0,004	0,006	0,008	0,014	0,016	0,022	0,031	0,035	0,030	0,029	0,034	0,036	0,036	0,034	0,040	0,039	0,067
Hungary											0,002	0,006	0,009	0,015	0,018	0,028	0,032	0,044	0,051	0,057	0,066
Lithuania													0,001	0,002	0,004	0,004	0,008	0,011	0,016	0,019	0,060
France	0,008	0,008	0,009	0,009	0,010	0,011	0,011	0,012	0,014	0,016	0,024	0,026	0,028	0,028	0,033	0,045	0,060	0,063	0,087	0,114	0,054
Mexico		0,001	0,002	0,003	0,004	0,005	0,006	0,007	0,009	0,010	0,011	0,014	0,016	0,017	0,013	0,015	0,017	0,019	0,021	0,027	0,053
Germany	0,006	0,006	0,005	0,005	0,005	0,007	0,008	0,011	0,010	0,013	0,032	0,034	0,030	0,027	0,031	0,034	0,034	0,034	0,043	0,025	0,051
Latvia													0,002	0,002	0,005	0,007	0,010	0,014	0,016	0,018	0,044
Slovenia													0,014	0,014	0,010	0,012	0,013	0,014	0,017	0,015	0,037
Italy	0,002	0,002	0,002	0,002	0,003	0,005	0,007	0,008	0,009	0,011	0,012	0,012	0,009	0,009	0,009	0,010	0,011	0,012	0,016	0,017	0,026
Korea, Republic of	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,006	0,006	0,008	0,004	0,008	0,015	0,026
Turkey	0,008	0,007	0,007	0,007	0,007	0,007	0,007	0,007	0,008	0,008	0,009	0,010	0,011	0,011	0,012	0,012	0,012	0,011	0,011	0,011	0,024
Greece	0,007	0,008	0,009	0,011	0,013	0,014	0,015	0,016	0,017	0,018	0,007	0,008	0,008	0,009	0,009	0,009	0,010	0,011	0,011	0,013	0,014
Japan	0,000	0,000	0,000	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,002	0,002	0,002	0,002	0,003	0,009

** Switzerland: Switzerland & Liechtenstein*
Source: UNCTAD; Penn World Table, version 9.1, Feenstra, Robert C., Robert Inklaar and Marcel P. Timmer (2015), "The Next Generation of the Penn World Table" American Economic Review, 105(10), 3150-3182, available for download at www.ggdc.net/pwt; own calculations

Table 14: FDI inward stock / Capital stock (2000-2017), sorted by 2017

Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Luxembourg			0,406	0,658	0,753	0,660	0,707	1,067	0,882	1,131	1,128	1,329	0,855	0,919	1,156	0,926	0,928	0,859
Ireland	0,430	0,417	0,531	0,616	0,498	0,358	0,253	0,261	0,232	0,315	0,319	0,318	0,396	0,399	0,412	0,794	0,678	0,815
*Switzerland**	0,096	0,100	0,143	0,183	0,224	0,161	0,198	0,236	0,273	0,277	0,370	0,357	0,375	0,428	0,382	0,388	0,469	0,541
Netherlands	0,150	0,173	0,209	0,260	0,275	0,232	0,228	0,267	0,224	0,219	0,174	0,177	0,184	0,191	0,371	0,305	0,343	0,407
Belgium	0,173	0,176				0,264	0,290	0,448	0,203	0,215	0,201	0,203	0,211	0,228	0,200	0,191	0,178	0,199
Chile	0,104	0,094	0,089	0,109	0,121	0,131	0,127	0,148	0,127	0,152	0,175	0,172	0,193	0,185	0,174	0,169	0,172	0,178
Sweden	0,088	0,087	0,114	0,149	0,184	0,160	0,178	0,202	0,177	0,209	0,208	0,206	0,205	0,193	0,154	0,147	0,142	0,159
United Kingdom	0,087	0,095	0,097	0,108	0,116	0,123	0,144	0,152	0,108	0,113	0,107	0,121	0,134	0,124	0,128	0,114	0,113	0,137
Iceland	0,013	0,016	0,019	0,027	0,043	0,089	0,143	0,328	0,146	0,134	0,232	0,256	0,193	0,125	0,125	0,119	0,136	0,133
Australia	0,056	0,056	0,070	0,093	0,115	0,089	0,101	0,125	0,096	0,136	0,162	0,165	0,162	0,133	0,119	0,112	0,117	0,129
Estonia	0,052	0,060	0,083	0,120	0,153	0,146	0,128	0,146	0,126	0,118	0,111	0,106	0,120	0,133	0,121	0,110	0,112	0,129
USA	0,074	0,065	0,050	0,058	0,061	0,059	0,065	0,068	0,047	0,058	0,067	0,067	0,074	0,091	0,097	0,099	0,111	0,129
New Zealand	0,099	0,079	0,111	0,137	0,151	0,140	0,146	0,163	0,118	0,149	0,154	0,160	0,163	0,157	0,143	0,118	0,119	0,122
Canada	0,090	0,089	0,083	0,121	0,140	0,151	0,154	0,213	0,124	0,167	0,180	0,148	0,152	0,146	0,136	0,107	0,116	0,120
Israel	0,036	0,031	0,029	0,037	0,041	0,049	0,064	0,069	0,065	0,077	0,082	0,086	0,092	0,096	0,089	0,094	0,097	0,110
Norway	0,052	0,054	0,071	0,078	0,120	0,101	0,115	0,189	0,120	0,145	0,152	0,148	0,158	0,137	0,111	0,098	0,095	0,094
Poland	0,030	0,036	0,041	0,048	0,066	0,062	0,081	0,119	0,097	0,106	0,105	0,088	0,101	0,111	0,095	0,078	0,075	0,090
Slovakia	0,028	0,031	0,050	0,084	0,098	0,092	0,103	0,117	0,113	0,114	0,109	0,108	0,106	0,105	0,079	0,072	0,072	0,086
Finland	0,042	0,042	0,061	0,088	0,093	0,080	0,092	0,113	0,091	0,087	0,088	0,088	0,089	0,082	0,086	0,076	0,072	0,082
Austria	0,032	0,036	0,048	0,060	0,069	0,075	0,088	0,121	0,101	0,108	0,099	0,088	0,084	0,087	0,081	0,068	0,061	0,078
Denmark	0,118	0,116	0,129	0,150	0,100	0,094	0,102	0,118	0,097	0,095	0,082	0,078	0,078	0,072	0,072	0,068	0,069	0,078
Portugal	0,035	0,040	0,051	0,066	0,068	0,057	0,066	0,076	0,065	0,069	0,061	0,057	0,059	0,068	0,058	0,057	0,053	0,069
Czechia	0,018	0,023	0,033	0,037	0,044	0,043	0,050	0,066	0,062	0,070	0,074	0,065	0,070	0,067	0,058	0,056	0,055	0,068
Spain	0,048	0,056	0,078	0,096	0,100	0,083	0,075	0,078	0,074	0,078	0,075	0,074	0,067	0,074	0,064	0,059	0,058	0,067

Hungary	0,052	0,054	0,073	0,089	0,108	0,101	0,113	0,121	0,096	0,098	0,088	0,080	0,090	0,088	0,080	0,065	0,058	0,066
Lithuania	0,022	0,023	0,035	0,039	0,050	0,061	0,071	0,084	0,064	0,072	0,063	0,065	0,066	0,068	0,057	0,052	0,050	0,060
France	0,035	0,037	0,047	0,064	0,063	0,052	0,057	0,065	0,055	0,062	0,056	0,060	0,057	0,060	0,052	0,050	0,049	0,054
Mexico	0,038	0,052	0,055	0,054	0,057	0,059	0,063	0,068	0,060	0,065	0,066	0,056	0,063	0,064	0,060	0,059	0,053	0,053
Germany	0,050	0,045	0,057	0,071	0,071	0,059	0,066	0,073	0,066	0,069	0,067	0,067	0,069	0,058	0,048	0,043	0,043	0,051
Latvia	0,019	0,020	0,022	0,025	0,035	0,033	0,037	0,052	0,044	0,051	0,046	0,043	0,043	0,048	0,041	0,042	0,037	0,044
Slovenia	0,013	0,014	0,023	0,034	0,034	0,029	0,034	0,042	0,043	0,040	0,036	0,037	0,034	0,031	0,031	0,030	0,031	0,037
Italy	0,018	0,017	0,020	0,027	0,031	0,029	0,033	0,037	0,029	0,030	0,029	0,029	0,026	0,025	0,024	0,022	0,021	0,026
Korea, Republic of	0,015	0,017	0,019	0,018	0,021	0,021	0,021	0,020	0,015	0,019	0,022	0,022	0,024	0,026	0,023	0,022	0,022	0,026
Turkey	0,011	0,012	0,014	0,023	0,023	0,037	0,035	0,043	0,021	0,040	0,043	0,031	0,036	0,025	0,025	0,020	0,018	0,024
Greece	0,012	0,012	0,013	0,018	0,021	0,021	0,024	0,029	0,020	0,022	0,019	0,017	0,012	0,011	0,009	0,010	0,010	0,014
Japan	0,003	0,003	0,005	0,005	0,005	0,005	0,005	0,006	0,009	0,009	0,010	0,010	0,009	0,008	0,008	0,008	0,009	0,009

** Switzerland: Switzerland & Liechtenstein*
Source: UNCTAD; Penn World Table, version 9.1, Feenstra, Robert C., Robert Inklaar and Marcel P. Timmer (2015), "The Next Generation of the Penn World Table" American Economic Review, 105(10), 3150-3182, available for download at www.ggdc.net/pwt; own calculations

Table 15: FDI outward stock / Source country capital stock (1980-1999), sorted by 2017

Country	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2017
Luxembourg																					1,212
Ireland						0,102	0,099	0,095	0,096	0,100	0,094	0,088	0,083	0,077	0,073	0,071	0,070	0,071	0,077	0,087	0,760
Netherlands	0,051	0,047	0,045	0,046	0,047	0,056	0,060	0,071	0,070	0,079	0,092	0,096	0,091	0,084	0,095	0,109	0,125	0,129	0,144	0,163	0,608
*Switzerland**				0,024	0,022	0,030	0,040	0,052	0,054	0,059	0,071	0,080	0,079	0,095	0,114	0,141	0,133	0,157	0,169	0,178	0,576
Belgium	0,008	0,008	0,007	0,009	0,009	0,014	0,022	0,028	0,034	0,045	0,050	0,057	0,063	0,067	0,070	0,078	0,083	0,090	0,126	0,136	0,238
Canada	0,014	0,017	0,016	0,018	0,019	0,019	0,020	0,023	0,026	0,028	0,030	0,032	0,029	0,030	0,032	0,035	0,038	0,043	0,048	0,055	0,190
Sweden	0,006	0,007	0,009	0,010	0,011	0,016	0,024	0,034	0,038	0,049	0,061	0,063	0,054	0,048	0,060	0,069	0,067	0,073	0,087	0,099	0,167
Denmark	0,005	0,005	0,003	0,004	0,004	0,005	0,006	0,007	0,009	0,013	0,016	0,032	0,033	0,030	0,036	0,043	0,047	0,047	0,064	0,083	0,134
United Kingdom	0,028	0,030	0,029	0,029	0,030	0,034	0,039	0,048	0,056	0,057	0,065	0,064	0,058	0,061	0,064	0,066	0,067	0,072	0,097	0,137	0,134
Norway	0,002	0,002	0,002	0,002	0,002	0,003	0,004	0,005	0,009	0,011	0,024	0,027	0,026	0,028	0,038	0,046	0,050	0,053	0,043	0,052	0,130
United States of America	0,010	0,010	0,010	0,012	0,012	0,016	0,021	0,023	0,026	0,031	0,027	0,030	0,029	0,037	0,038	0,044	0,051	0,057	0,066	0,079	0,129
Finland	0,002	0,001	0,001	0,002	0,003	0,004	0,005	0,010	0,011	0,014	0,019	0,020	0,018	0,018	0,022	0,025	0,031	0,037	0,052	0,060	0,111
France	0,006	0,007	0,008	0,009	0,010	0,010	0,011	0,013	0,013	0,018	0,027	0,031	0,034	0,033	0,037	0,073	0,085	0,098	0,124	0,154	0,096
Australia	0,005	0,005	0,005	0,005	0,006	0,006	0,007	0,012	0,027	0,026	0,026	0,024	0,025	0,028	0,031	0,032	0,038	0,039	0,041	0,045	0,093
Austria	0,001	0,002	0,002	0,002	0,001	0,002	0,002	0,002	0,002	0,004	0,007	0,008	0,008	0,009	0,011	0,012	0,014	0,015	0,018	0,020	0,092
Germany	0,007	0,008	0,008	0,008	0,008	0,011	0,013	0,016	0,017	0,018	0,044	0,048	0,045	0,044	0,050	0,056	0,061	0,066	0,078	0,044	0,087
Israel	0,000	0,001	0,002	0,002	0,002	0,003	0,003	0,004	0,004	0,004	0,004	0,005	0,006	0,008	0,009	0,008	0,007	0,009	0,010	0,012	0,086
Chile	0,000	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,003	0,004	0,007	0,009	0,011	0,013	0,017	0,021	0,083
Iceland						0,002	0,002	0,002	0,002	0,002	0,003	0,003	0,003	0,004	0,005	0,006	0,007	0,008	0,009	0,012	0,069
Japan	0,002	0,003	0,004	0,004	0,006	0,006	0,008	0,010	0,013	0,017	0,020	0,021	0,021	0,020	0,019	0,015	0,016	0,016	0,016	0,015	0,065
Spain	0,001	0,001	0,002	0,002	0,002	0,003	0,004	0,005	0,005	0,006	0,007	0,009	0,008	0,009	0,010	0,012	0,014	0,017	0,020	0,030	0,058
Estonia													0,001	0,001	0,001	0,001	0,002	0,004	0,004	0,006	0,042
Korea, Republic of	0,000	0,000	0,000	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,002	0,002	0,003	0,003	0,004	0,005	0,005	0,006	0,007	0,007	0,041

Italy	0,002	0,002	0,002	0,002	0,004	0,005	0,007	0,008	0,009	0,009	0,012	0,013	0,012	0,013	0,014	0,016	0,017	0,020	0,025	0,026	0,033
New Zealand			0,000	0,003	0,003	0,004	0,005	0,008	0,011	0,012	0,024	0,031	0,032	0,022	0,027	0,033	0,038	0,024	0,023	0,030	0,029
Portugal	0,002	0,002	0,002	0,002	0,002	0,002	0,001	0,001	0,001	0,001	0,001	0,002	0,003	0,003	0,003	0,004	0,005	0,007	0,011	0,012	0,029
Hungary											0,000	0,000	0,000	0,000	0,001	0,001	0,001	0,002	0,002	0,002	0,021
Mexico	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,002	0,001	0,002	0,002	0,002	0,002	0,002	0,002	0,019
Slovenia													0,004	0,004	0,003	0,003	0,003	0,003	0,004	0,004	0,016
Czechia														0,000	0,000	0,000	0,000	0,000	0,001	0,001	0,014
Lithuania															0,000	0,000	0,000	0,000	0,000	0,000	0,013
Poland		0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,001	0,001	0,001	0,001	0,001	0,001	0,011
Greece							0,005	0,004	0,004	0,004	0,004	0,003	0,003	0,003	0,003	0,002	0,002	0,003	0,002	0,003	0,008
Slovakia														0,001	0,001	0,000	0,001	0,001	0,002	0,002	0,007
Latvia													0,004	0,004	0,003	0,003	0,002	0,002	0,003	0,002	0,005
Turkey						0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,002	0,005

** Switzerland: Switzerland & Liechtenstein*
Source: UNCTAD; Penn World Table, version 9.1, Feenstra, Robert C., Robert Inklaar and Marcel P. Timmer (2015), "The Next Generation of the Penn World Table" American Economic Review, 105(10), 3150-3182, available for download at www.ggdc.net/pwt; own calculations

Table 16: FDI outward stock / Source country capital stock (2000-2017), sorted by 2017

Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Luxembourg			0,282	0,431	0,530	0,620	0,571	0,903	1,149	1,161	1,225	0,988	0,624	0,831	0,918	0,891	0,970	1,212
Ireland	0,095	0,127	0,171	0,203	0,256	0,228	0,195	0,193	0,208	0,373	0,380	0,362	0,426	0,515	0,593	0,812	0,691	0,760
Netherlands	0,187	0,203	0,237	0,315	0,335	0,309	0,332	0,329	0,310	0,328	0,286	0,288	0,280	0,282	0,526	0,442	0,537	0,608
*Switzerland**	0,220	0,242	0,292	0,339	0,403	0,361	0,385	0,405	0,415	0,451	0,595	0,547	0,571	0,623	0,506	0,494	0,547	0,576
Belgium	0,159	0,157				0,334	0,373	0,358	0,180	0,203	0,184	0,183	0,190	0,215	0,208	0,210	0,205	0,238
Canada	0,123	0,113	0,108	0,138	0,162	0,164	0,170	0,197	0,129	0,172	0,180	0,153	0,155	0,171	0,160	0,153	0,166	0,190
Sweden	0,116	0,116	0,141	0,180	0,206	0,200	0,214	0,236	0,212	0,232	0,232	0,229	0,218	0,214	0,192	0,165	0,159	0,167
Denmark	0,117	0,121	0,135	0,153	0,114	0,112	0,117	0,134	0,132	0,142	0,140	0,139	0,145	0,145	0,126	0,121	0,118	0,134
United Kingdom	0,187	0,179	0,205	0,235	0,234	0,194	0,204	0,249	0,194	0,181	0,168	0,180	0,158	0,147	0,136	0,120	0,121	0,134
Norway	0,058	0,062	0,078	0,090	0,128	0,128	0,147	0,165	0,141	0,161	0,162	0,160	0,161	0,129	0,116	0,120	0,127	0,130
USA	0,072	0,059	0,050	0,065	0,076	0,076	0,088	0,101	0,059	0,083	0,093	0,087	0,099	0,116	0,112	0,105	0,108	0,129
Finland	0,091	0,091	0,115	0,133	0,137	0,120	0,125	0,144	0,125	0,133	0,140	0,131	0,139	0,134	0,108	0,088	0,098	0,111
France	0,069	0,076	0,083	0,100	0,096	0,086	0,094	0,105	0,091	0,107	0,105	0,107	0,107	0,104	0,096	0,092	0,090	0,096
Australia	0,042	0,053	0,057	0,076	0,089	0,074	0,088	0,109	0,076	0,113	0,138	0,125	0,125	0,107	0,096	0,082	0,084	0,093
Austria	0,026	0,030	0,046	0,058	0,068	0,066	0,085	0,114	0,103	0,109	0,112	0,111	0,107	0,113	0,100	0,088	0,080	0,092
Germany	0,051	0,059	0,067	0,076	0,078	0,073	0,081	0,096	0,086	0,095	0,096	0,097	0,100	0,091	0,079	0,075	0,074	0,087
Israel	0,016	0,015	0,017	0,022	0,030	0,037	0,058	0,070	0,074	0,078	0,092	0,096	0,088	0,086	0,078	0,080	0,085	0,086
Chile	0,025	0,025	0,026	0,028	0,034	0,038	0,041	0,049	0,053	0,063	0,067	0,079	0,093	0,089	0,085	0,080	0,083	0,083
Iceland	0,017	0,020	0,030	0,039	0,084	0,191	0,261	0,502	0,149	0,159	0,226	0,233	0,229	0,161	0,134	0,116	0,084	0,069
Japan	0,017	0,018	0,018	0,019	0,020	0,019	0,020	0,024	0,029	0,032	0,037	0,043	0,048	0,052	0,053	0,056	0,059	0,065
Spain	0,039	0,045	0,050	0,062	0,070	0,066	0,071	0,078	0,074	0,077	0,078	0,078	0,064	0,066	0,056	0,054	0,053	0,058
Estonia	0,005	0,008	0,013	0,018	0,022	0,025	0,036	0,055	0,052	0,047	0,040	0,031	0,038	0,041	0,036	0,035	0,036	0,042
Korea, Republic of	0,007	0,006	0,006	0,007	0,008	0,008	0,009	0,012	0,015	0,019	0,023	0,028	0,031	0,034	0,034	0,035	0,037	0,041
Italy	0,024	0,024	0,025	0,029	0,031	0,030	0,033	0,041	0,040	0,040	0,044	0,042	0,037	0,037	0,032	0,029	0,027	0,033

New Zealand	0,035	0,028	0,035	0,043	0,048	0,037	0,037	0,041	0,037	0,036	0,043	0,047	0,044	0,038	0,033	0,030	0,029	0,029
Portugal	0,020	0,023	0,027	0,039	0,046	0,041	0,043	0,048	0,042	0,042	0,036	0,036	0,032	0,036	0,027	0,027	0,025	0,029
Hungary	0,003	0,004	0,006	0,009	0,014	0,016	0,021	0,026	0,023	0,023	0,023	0,026	0,034	0,032	0,032	0,027	0,018	0,021
Mexico	0,003	0,010	0,014	0,013	0,012	0,014	0,017	0,018	0,014	0,016	0,020	0,016	0,021	0,019	0,018	0,017	0,016	0,019
Slovenia	0,004	0,005	0,009	0,013	0,014	0,013	0,017	0,029	0,031	0,032	0,027	0,025	0,021	0,018	0,016	0,014	0,014	0,016
Czechia	0,001	0,001	0,001	0,002	0,003	0,003	0,003	0,005	0,007	0,008	0,009	0,007	0,009	0,010	0,009	0,009	0,009	0,014
Lithuania	0,000	0,000	0,001	0,001	0,003	0,005	0,007	0,008	0,010	0,014	0,011	0,013	0,014	0,014	0,012	0,012	0,011	0,013
Poland	0,000	0,000	0,000	0,000	0,001	0,001	0,003	0,005	0,005	0,007	0,009	0,010	0,013	0,015	0,013	0,011	0,011	0,011
Greece	0,005	0,006	0,008	0,010	0,010	0,010	0,013	0,017	0,019	0,023	0,023	0,027	0,021	0,015	0,012	0,010	0,008	0,008
Slovakia	0,002	0,003	0,003	0,004	0,004	0,002	0,004	0,005	0,007	0,007	0,008	0,008	0,009	0,009	0,004	0,004	0,004	0,007
Latvia	0,000	0,000	0,000	0,001	0,002	0,002	0,002	0,004	0,004	0,004	0,004	0,003	0,004	0,005	0,004	0,004	0,004	0,005
Turkey	0,002	0,003	0,004	0,004	0,004	0,004	0,003	0,003	0,005	0,006	0,005	0,006	0,006	0,006	0,005	0,005	0,005	0,005

** Switzerland: Switzerland & Liechtenstein*
Source: UNCTAD; Penn World Table, version 9.1, Feenstra, Robert C., Robert Inklaar and Marcel P. Timmer (2015), "The Next Generation of the Penn World Table" American Economic Review, 105(10), 3150-3182, available for download at www.ggdc.net/pwt; own calculations

Appendix 5: ICT Sector

The contribution of total factor productivity growth (TFP) to value added growth has been covered for several EU countries and the US only since about 1996 and in some cases since 2000. This contribution has shown considerable volatility over time as is shown, for example, by the figures for the US. As regards the contribution of ICT capital to economic growth, there has been a considerable effect across almost all countries over many years. Italy stands out as an EU country which has recorded rather low ICT capital contributions to growth for the twelve years since 2003. This also holds for the growth contribution of ICT capital services in Italy while most other countries shown in the subsequent table show a rather high contribution of ICT services. Comparing the growth contribution of ICT capital and ICT services, the last table in this block indicates that the contribution of ICT services in most countries has exceeded the growth contribution of ICT capital. As services productivity is rather difficult to measure there is, however, some uncertainty with respect to the exact growth contribution of ICT services.

Table 17: A) The contribution of TFP to value added growth, ICT sector (percentage points), sorted by descending order 2015[a]

Country	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
LUX																5,71	5,10	0,86	-8,20	-16,65	-1,19	28,67
DNK			6,38	10,19	0,18	3,66	3,91	0,01	7,91	8,70	1,3 0	0,70	-0,74	7,54	6,10	3,61	2,91	1,84	3,61	8,69	5,50	7,01
UK					2,78	7,73	10,56	3,44	1,37	5,17	5,27	4,64	-0,50	4,44	2,61	-2,81	5,53	-2,51	3,66	-0,64	-3,27	5,83
BEL							1,54	0,37	1,72	-1,52	7,70	0,81	2,77	2,82	0,39	-0,49	-0,22	-2,25	0,55	-4,67	-1,32	5,71
USA						0,00	-10,24	3,02	10,44	3,78	7,42	3,52	0,11	7,01	2,83	-1,42	2,56	-0,14	1,23	2,43	-1,74	3,70
NL								3,88	8,36	7,43	2,92	2,55	3,77	3,25	0,82	-1,82	2,43	0,43	0,10	2,36	0,69	2,70
FIN**	5,05	2,71	3,98	7,35	10,57	4,83	4,26	5,23	0,01	-0,81	12,15	-1,41	1,89	9,65	-0,23	1,53	3,34	5,83	5,54	0,86	2,93	2,52
EU16																-1,78	2,34	1,50	1,04	-0,11	1,03	2,20
EU12								3,60	3,68	0,61	4,19	1,09	3,07	4,68	1,84	-1,81	2,41	1,50	1,00	0,09	1,12	2,02
SVK												3,68	7,89	10,62	-6,37	7,83	-12,12	4,90	17,17	-21,20	-3,69	1,16
DE			5,88	8,29	9,72	5,53	2,60	5,37	3,34	-9,14	6,60	-2,95	8,30	10,17	4,73	-0,78	0,76	7,08	2,72	2,62	3,27	0,77
ESP			-3,46	-2,19	-4,97	-4,15	3,44	1,96	1,81	3,35	0,03	3,36	0,18	3,65	-0,96	-1,24	3,30	-3,71	2,06	2,86	6,30	0,31
AUT			3,37	-5,99	0,03	-1,34	-8,32	6,55	3,59	0,87	-0,77	8,99	3,66	3,75	-0,89	-4,24	-0,92	1,41	1,67	-0,48	-5,84	0,08

FRA*	1,25	1,09	0,55	4,02	3,56	2,22	0,42	0,81	6,25	2,13	2,40	-1,50	5,03	1,03	-0,50	-5,48	1,18	3,83	0,00	-1,82	2,79	-1,55
CZ			-0,33	-2,15	-15,68	-7,49	-2,46	-2,40	4,90	6,06	1,52	10,36	6,77	7,50	0,18	-4,62	-0,27	-13,55	-35,18	-7,21	5,93	
SWE	2,19	3,10	-4,68	3,65	0,45	2,54	-1,31	-1,42	-1,72	5,97	8,52	4,21	5,51	1,91	2,36	-0,48	5,45	4,21	2,65	0,45	3,16	
ITA			5,66	-1,70	0,25	4,81	3,47	7,73	5,90	-0,17	2,33	0,51	-0,19	2,49	1,72	1,97	1,85	0,28	-3,07	-3,28	0,79	
LVA																-17,25	1,71	-0,62	3,57	-0,01	-6,75	
SVN																-11,71	1,53	-2,77	-2,10	1,93		

[a] sorted by descending order 2014 where no data for 2015 are available
* Data for France start in 1981 (1,44; 1982: 4,31; 1983: -0,68; 1984: 0,19; 1985: 3,03; 1986: 1,98; 1987: -1,61; 1988: 0,91; 1989: 2,46; 1990: -1,78; 1991: -0,91; 1992: -2,09; 1993: -2,24)
** Data for Finland start in 1985 (-3,34; 1986: 4,71; 1987: 2,63; 1988: 2,70; 1989: 2,78; 1990: 1,14; 1991: -3,28; 1992: 3,17; 1993: 1,51)
Source: EU KLEMS

Table 18: B) The contribution of ICT capital services to value added growth (total industries, percentage points), sorted by descending order 2015 in table A[a]

Country	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
LUX																0,30	0,11	-0,05	0,05	0,14	-0,28	-0,37
DNK			0,54	0,34	0,58	0,46	0,24	0,22	0,19	0,20	0,26	0,22	0,42	0,09	0,16	0,04	0,20	0,24	0,09	0,06	0,09	0,15
UK					0,27	0,61	0,22	0,20	0,09	0,49	0,17	0,26	0,25	0,19	0,23	-0,04	0,03	0,07	0,12	0,11	0,16	0,02
BEL							0,42	0,53	0,37	0,38	0,31	0,35	0,26	0,26	0,23	0,15	0,15	0,12	0,08	0,04	0,10	0,09
USA						0,83	0,66	0,37	0,23	0,25	0,35	0,24	0,35	0,20	0,26	0,11	0,16	0,12	0,14	0,17	0,10	0,15
NL								0,32	0,21	0,18	0,18	0,22	0,26	0,29	0,26	0,12	0,10	0,14	0,13	0,09	0,13	0,14
FIN**	0,13	0,56	0,19	0,16	0,33	0,33	0,27	0,17	0,05	0,25	0,18	0,23	0,19	0,29	0,21	0,05	0,04	0,06	0,06	0,05	0,09	0,05
EU16																0,12	0,08	0,12	0,11	0,09	0,11	0,09
EU12								0,31	0,29	0,30	0,09	0,25	0,28	0,22	0,23	0,12	0,08	0,12	0,11	0,08	0,12	0,09
SVK												0,48	0,01	0,34	0,71	0,02	0,40	-0,42	-0,27	1,84	-0,39	-0,12
DE			0,57	0,67	1,46	1,04	0,59	0,36	0,66	0,41	-0,22	0,38	0,57	0,29	0,29	0,35	0,12	0,23	0,09	0,10	0,10	0,10
ESP			0,35	0,46	0,52	0,57	0,57	0,51	0,42	0,36	0,34	0,33	0,34	0,37	0,37	0,21	0,13	0,14	0,13	0,12	0,14	0,15
AUT			0,21	0,21	0,26	0,38	0,23	0,33	0,25	0,18	0,21	0,01	0,09	0,06	0,05	0,04	0,12	0,17	0,08	0,16	0,09	0,09
FRA*	0,02	0,10	0,15	0,19	0,26	0,38	0,26	0,32	0,08	0,21	0,24	0,21	0,13	0,18	0,22	0,07	0,13	0,10	0,15	0,08	0,13	0,18
CZ			0,54	0,41	0,22	0,12	0,34	0,19	0,08	0,24	0,06	0,11	0,31	0,46	0,35	0,04	0,00	0,27	0,67	0,07	0,10	
SWE	0,14	0,38	0,53	0,39	0,41	0,59	0,58	0,54	0,28	0,06	0,17	0,29	0,40	0,39	0,40	0,33	0,05	0,10	0,27	0,09	0,08	
ITA			0,20	0,25	0,26	0,27	0,30	0,21	0,16	0,05	0,03	0,05	0,04	0,07	0,05	-0,07	-0,04	-0,04	-0,02	0,00	0,03	
LVA																-0,15	-0,16	0,57	-0,13	-0,59	0,53	
SVN																-0,14	-0,08	-0,03	-0,10	-0,14		

[a] sorted by descending order 2014 where no data for 2015 are available
* Data for France start in 1981 (0,96; 1982: 0,34; 1983: 0,38; 1984: 0,39; 1985: 0,64; 1986: 0,54; 1987: 0,70; 1988: 0,79; 1989: 1,01; 1990: 1,23; 1991: 0,53; 1992: 0,85; 1993: 0,53)
** Data for Finland start in 1985 (1,27; 1986: 1,08; 1987: 1,26; 1988: 1,35; 1989: 1,61; 1990: 0,89; 1991: 0,25; 1992: 0,13; 1993: -0,21)
Source: EU KLEMS

Table 19: C) The contribution of non-ICT capital services to value added growth (total industries, percentage points), sorted by descending order 2015 in table A[a]

Country	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
LUX																0,89	4,01	0,78	-0,06	0,54	1,57	0,97
DNK			1,06	0,50	0,71	0,57	0,67	0,54	0,12	0,61	0,46	0,37	0,83	0,51	-0,27	0,54	2,76	0,18	0,01	0,29	0,26	0,28
UK					1,30	0,76	0,76	0,86	0,29	0,93	0,60	1,07	-0,15	1,11	0,38	-1,32	0,56	0,63	0,05	0,52	0,29	0,67
BEL							0,85	0,80	0,60	0,43	0,59	0,82	0,66	0,86	0,92	0,22	0,13	0,28	0,13	0,10	0,21	0,37
USA						1,07	0,92	0,62	0,82	0,77	1,29	0,94	0,62	0,51	0,45	-0,51	0,65	0,33	0,42	0,80	0,35	0,35
NL								0,50	0,27	0,24	0,01	0,02	0,24	0,33	0,44	0,07	-0,06	0,25	0,28	0,05	0,01	-0,02
FIN**	-0,15	0,11	0,35	0,33	0,68	0,78	0,79	0,81	0,41	0,24	0,27	0,34	0,24	0,70	0,68	0,09	0,00	0,11	0,15	-0,13	0,01	-0,04
EU16																0,14	0,46	0,38	0,22	0,27	0,16	0,36
EU12								0,94	0,71	0,77	0,64	0,72	0,48	0,96	0,60	0,12	0,45	0,38	0,22	0,26	0,14	0,34
SVK												2,63	1,50	-0,21	3,91	1,48	0,62	1,10	0,95	1,09	1,71	1,80
DE			0,46	0,51	0,80	0,71	0,57	0,71	0,53	0,43	0,33	0,13	0,20	0,75	0,75	0,19	0,20	0,25	0,27	0,21	0,28	0,36
ESP			1,19	1,20	1,32	1,47	1,52	1,49	1,39	1,36	1,43	1,47	1,55	1,49	1,25	0,90	0,47	0,36	0,24	0,10	0,07	0,14
AUT			0,83	0,78	0,71	0,85	0,89	0,51	0,79	0,80	0,73	0,62	0,82	1,03	0,35	0,23	0,61	0,34	0,37	0,59	0,51	0,49
FRA*	0,56	0,69	0,53	0,40	0,75	1,15	0,87	0,89	0,84	0,93	0,61	0,83	0,53	0,91	0,13	0,45	0,59	0,31	0,25	0,36	0,11	0,31
CZ			3,18	2,77	1,73	1,55	1,73	2,27	1,64	0,72	1,65	1,61	0,88	2,68	1,86	0,94	2,90	2,45	2,76	1,69	-0,24	
SWE	0,15	0,51	1,02	1,65	1,28	1,30	1,62	2,36	1,09	0,78	0,97	0,89	1,00	1,23	1,46	1,26	0,48	0,73	0,81	0,77	0,76	
ITA			0,67	0,67	0,75	0,87	1,11	1,12	1,16	0,93	0,88	0,80	0,86	0,89	0,66	0,36	0,25	0,24	-0,12	-0,18	-0,31	
LVA																1,83	-0,49	-0,21	0,58	-0,24	1,16	
SVN																0,26	-0,17	0,01	-0,22	-0,24		

[a] sorted by descending order 2014 where no data for 2015 are available
* Data for France start in 1981 (0,96; 1982: 0,34; 1983: 0,38; 1984: 0,39; 1985: 0,64; 1986: 0,54; 1987: 0,70; 1988: 0,79; 1989: 1,01; 1990: 1,23; 1991: 0,53; 1992: 0,85; 1993: 0,53)
** Data for Finland start in 1985 (1,27; 1986: 1,08; 1987: 1,26; 1988: 1,35; 1989: 1,61; 1990: 0,89; 1991: 0,25; 1992: 0,13; 1993: -0,21)
Source: EU KLEMS

Table 20: D) Difference between the contribution of ICT capital services to value added growth and the contribution of Non-ICT capital services to value added growth (total industries, percentage points), sorted by descending order 2015 in table A[a]

Country	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
LUX																-0,58	-3,90	-0,84	0,12	-0,39	-1,86	-1,33
DNK			-0,52	-0,15	-0,13	-0,10	-0,44	-0,33	0,07	-0,41	-0,20	-0,15	-0,42	-0,42	0,43	-0,51	-2,55	0,05	0,08	-0,23	-0,18	-0,13
UK					-1,03	-0,15	-0,53	-0,67	-0,20	-0,45	-0,43	-0,81	0,40	-0,91	-0,15	1,28	-0,53	-0,56	0,07	-0,41	-0,13	-0,65
BEL							-0,43	-0,26	-0,23	-0,04	-0,28	-0,47	-0,40	-0,60	-0,69	-0,07	0,02	-0,17	-0,04	-0,06	-0,12	-0,28
USA						-0,24	-0,27	-0,25	-0,60	-0,52	-0,93	-0,70	-0,27	-0,31	-0,19	0,63	-0,49	-0,21	-0,28	-0,63	-0,25	-0,19
NL								-0,18	-0,06	-0,05	0,17	0,20	0,02	-0,05	-0,19	0,04	0,16	-0,11	-0,14	0,04	0,12	0,16
FIN**	0,28	0,44	-0,16	-0,17	-0,35	-0,45	-0,52	-0,64	-0,35	0,00	-0,09	-0,10	-0,06	-0,41	-0,46	-0,04	0,04	-0,05	-0,10	0,18	0,09	0,10
EU16																-0,02	-0,38	-0,27	-0,12	-0,17	-0,05	-0,27
EU12								-0,63	-0,42	-0,47	-0,55	-0,47	-0,20	-0,74	-0,37	0,00	-0,37	-0,26	-0,11	-0,18	-0,03	-0,25
SVK												-2,15	-1,49	0,55	-3,20	-1,46	-0,23	-1,52	-1,22	0,75	-2,09	-1,92
DE			0,11	0,16	0,66	0,32	0,02	-0,35	0,13	-0,01	-0,55	0,26	0,37	-0,47	-0,46	0,16	-0,07	-0,02	-0,18	-0,10	-0,18	-0,26
ESP			-0,84	-0,73	-0,80	-0,90	-0,95	-0,98	-0,98	-1,00	-1,09	-1,14	-1,21	-1,12	-0,89	-0,68	-0,34	-0,22	-0,11	0,03	0,07	0,02
AUT			-0,61	-0,56	-0,45	-0,47	-0,65	-0,19	-0,54	-0,62	-0,51	-0,60	-0,73	-0,97	-0,31	-0,20	-0,49	-0,17	-0,29	-0,43	-0,43	-0,40
FRA*	-0,54	-0,60	-0,38	-0,21	-0,49	-0,77	-0,61	-0,57	-0,76	-0,72	-0,37	-0,62	-0,40	-0,73	0,09	-0,38	-0,46	-0,21	-0,09	-0,28	0,02	-0,13
CZ			-2,64	-2,37	-1,51	-1,42	-1,38	-2,08	-1,56	-0,48	-1,59	-1,50	-0,56	-2,22	-1,52	-0,91	-2,90	-2,18	-2,09	-1,63	0,34	
SWE	-0,01	-0,13	-0,50	-1,26	-0,87	-0,71	-1,04	-1,82	-0,81	-0,71	-0,80	-0,60	-0,61	-0,84	-1,06	-0,93	-0,43	-0,62	-0,55	-0,68	-0,68	
ITA			-0,46	-0,42	-0,48	-0,60	-0,81	-0,91	-1,00	-0,88	-0,85	-0,75	-0,82	-0,82	-0,62	-0,42	-0,29	-0,29	0,10	0,19	0,34	
LVA																-1,98	0,33	0,79	-0,71	-0,35	-0,63	
SVN																-0,40	0,09	-0,04	0,12	0,10		

[a] sorted by descending order 2014 where no data for 2015 are available
* Data for France start in 1981 (-0,83; 1982: -0,28; 1983: -0,28; 1984: -0,24; 1985: -0,50; 1986: -0,54; 1987: -0,47; 1988: -0,54; 1989: -0,79; 1990: -0,89; 1991: -0,39; 1992: -0,79; 1993: -0,52)
** Data for Finland start in 1985 (-0,94; 1986: -0,93; 1987: -1,17; 1988: -1,23; 1989: -1,49; 1990: -0,70; 1991: -0,15; 1992: -0,04; 1993: 0,33)
Source: EU KLEMS

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