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Strengthening scientific and research capacity of the Institute of Economics, Zagreb as a cornerstone for Croatian socioeconomic growth through the implementation of Smart Specialisation Strategy

Work package:	WP2 Development of Twinning Strategy for EIZ
Deliverable Title:	D2.2 Report about the state of the art
Task 2.2:	Update of state–of–the art of methodology described in proposal in the field of EMIT in relation to the defined TAIs
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1. Introduction

Background of this report

The key motivation for SmartEIZ project is based on several facts. Croatia's innovative position relative to the other EU members might be considered unfavourable; relevant public institutions that provide support for R&D cannot provide effective technological and innovative services and there is a growing awareness of the importance of topics related to Research, Development and Innovation among researchers in Croatia. There is a growing need to change the mode of growth from consumption and low-tech services-driven to knowledge-driven growth economy. In turn, this requires better understanding on how RDI and technology operate in the economic system. Research in the area of Economics and Management of Innovation and Technology (EMIT) has become increasingly important for the Institute of Economics, Zagreb (EIZ) to improve its scientific excellence, enhance its policy advice capacity, with a special attention to the Research and Innovation Smart Specialization Strategy (RIS3), and strengthen its regional reputation. There is a growing need for EIZ researchers to improve methodological and analytical skills. This project aims to strengthen the scientific and research capacity and narrow networking gaps and deficiencies of EIZ in the field of EMIT, which might improve its research capabilities, help it analyse, design and evaluate public policies more effectively, empower EIZ to contribute to the implementation of National Smart Specialisation Strategy and strengthen the cooperation between EIZ and leading research institutions in the EU. Activities in this project include WP1 – Coordination and Project Management; WP2 – Development of Twinning Strategy for EIZ; WP3 – Designing Twinning Tools; WP4 – Capacity Building Activities; WP5 – Fostering Regional Network Capacity in the field of EMIT; WP6 – Dissemination of Results.

Work package 2 – Development of Twinning Strategy for EIZ

The major objective of Work Package 2 (WP2) is to prepare and develop in-depth Twinning strategy for EIZ. The aim is to analyse EIZ research needs in relation to the Croatian Innovation Policy involving Croatian Ministry of Economy (MINGO) and Croatian Agency for Investments and Competitiveness (AIK). More specifically, WP2 seeks to (1) identify and map EIZ research needs in relation to the Croatian Innovation Policies and RIS3; (2) analyse the state–of–the art methodology used for research and policy design and implementation;

(3) identify relevant Croatian academic and non–academics stakeholders; and (4) prepare Twinning strategy for EIZ. WP2 is coordinated by UB/CRIOS (Universita Commerciale Luigi Bocconi, Italy) in collaboration with UCL (University College London, United Kingdom) and UNU–MERIT (Universiteit Maastricht, Netherlands) with the close involvement of EIZ.

Task 2.2. In-depth analysis of research needs of EIZ and Croatian innovation policies

Task 2.2 will review and analyse the state–of–the–art of methodologies in the field of EMIT for each area defined as gap in Table 4.2 – EIZ research achievements, preferences and stakeholders' needs - in D2.1. This task will summarize the relevant scientific information and the relevant updates in scientific literature referring gaps reported.

EIZ research achievements (based on their past studies) were compared with stakeholders' needs (based on top three research issues identified by three interviews) and EIZ research preferences (topics indicated by ten EIZ researchers). EIZ research preferences were determined by asking researchers actively involved in the SmartEIZ project for which topics they have preferences for gaining new knowledge. EIZ researchers indicated the determination to do research in those fields.

EIZ has experience in three policy-driven issues that were indicated as the most important by stakeholders: Science – Industry links; skills and technical change: policy issues (SMART skills); assessing innovation policy. However, just a few studies were conducted in those areas, and EIZ researchers (as in the field of SMART skills) are just at the beginning of learning the methodology, as they just started or just recently finished projects related to these issues. Furthermore, only a few issues were covered with those studies.

The gap between policy needs and EIZ achievements (where EIZ has experience) were identified in the following areas:

- Clusters;
- GVC;
- Policies for attracting FDI and foster Strategic Alliances for RIS3;
- Technology, growth and productivity;
- National innovation system.

The most important objective of this report is to clarify research needs in the context of SmartEIZ strategy. This objective is important, as it enables further implementation of the project, especially within the working packages WP3 and WP4.

We analysed and update in respect to the proposal, the state of the art of the first 4 topics listed above (Clusters and RIS3, GVC and RIS3, Policies for attracting FDI and foster Strategic Alliances for RIS3, Technology, growth and productivity) with particular focus to the last topics. In fact, technological change drives long-term economic growth, productivity and improvement in living standards. At the same time, the emergence and diffusion of new ideas, products and
production techniques throughout the economy entails a process of "creative destruction". New
technologies destroy jobs in some industries, especially among the low-skilled, while creating jobs which are often in different industries and require different skills. Understanding this topic could lead EIZ to give appropriate policy advise to stakeholders for the implementation of RIS3.
As for the National Innovation System it will be covered under the T2.3, for the relations that this topic has for the academics and non-academics, national and international stakeholders.
Additional topics, that partners judged as relevant for EIZ, will be covered before the end of WP2: Skills and technical change: policy issues (SMART skills); Science-Industry link; Technology, employment and skills.

2. The state of the art of academic literature on main topics stated by EIZ as gaps.

The role of clusters in RIS3

The importance of clusters stems from the understanding of innovation as an interactive process (Freeman and Soete, 1997). Clusters are traditionally viewed as an important driver of innovation and regional economic development. The wealth–building potential of clusters and their impact on national innovation system and economic growth is well acknowledged: according to the European Commission (2010), clusters represent an important component of regional smart specialisation strategies, since they offer policymakers the opportunity to better streamline different policies towards the objective of stimulating growth through

innovation as well as providing a fertile combination of entrepreneurial dynamism and contributing to the building of a knowledge-based economy. OECD (2013) sees innovative clusters as a key policy tool for boosting national competitiveness and as drivers of national economic growth.
From the EU perspective, EC (2008a) states that cluster policy development is gaining momentum. While different instruments and mechanisms in support of clusters are being applied in different places, they are increasingly being used to foster structural change, and to provide a framework for other policies such as research, innovation and regional policy. Strong clusters offer a fertile combination of entrepreneurial dynamism, intensive linkages with top–level knowledge institutions and increased synergies among innovation actors. The definitions and types of clusters vary.

Whereas definitions aiming at conceptualising clusters are either descriptive or abstract in order to capture the broad range of elements characterising clusters, legal definitions are necessarily defined in stricter and more technical terms (EC, 2008b). For example, Porter (1998) consider them as ‘geographically proximate groups of interconnected companies and associated institutions in a particular field linked by commonalities and complementarities’, but according to the “Community Framework for State Aid for Research and Development and Innovation” of the European Union clusters are “groupings of independent undertakings — innovative start-ups, small, medium and large undertakings as well as research organisations — operating in a particular sector and region and designed to stimulate innovative activity by promoting intensive interactions, sharing of facilities and exchange of knowledge and expertise and by contributing effectively to technology transfer, networking and information dissemination among the undertakings in the cluster.”

This can be found in section 2.2 on page 10 of the text of the Community Framework for State Aid for Research and Development and Innovation, which is published in the Official Journal of the European Union (2006/C 323/01) of 30.12.2006.

Industrial cluster formation reflects very much the historical, cultural, geographical, institutional and technical (i.e. patterns emerging according to industry characteristics) conditions of country or region. Therefore, clusters from countries and/or regions at different stages of development may differ along several dimensions. A variety of factors may favour the emergence of clusters, such as: (i) location and space factors, i.e. geographic proximity and sectorial specialisation; (ii) social and cultural factors, i.e. human capital, family's central role, high level of social mobility and aptitude towards entrepreneurship; (iii) economic and organisational factors, i.e. the possibility of reaching high levels of specialisation, the balance between cooperation and competition; (iv) political and institutional factors, i.e. both public and private (or mixed) bodies that play a support role in the construction of clusters such as regional agencies, service centres, entrepreneurial associations (Consolati, 2006).

Cluster policies have been the traditional instrument whereby policymakers have encouraged the formation of clusters; now this has been changing in favour of more comprehensive smart specialization strategies. The literature on clusters and RIS3 is thus still limited, but it is growing, and the most critical elements of RIS3 are already visible. However, it is difficult to draw simple conclusions about actions and outcomes since clusters, cluster policies and smart specialisation strategies differ from one another.

According to Aranguren and Wilson (2013), RIS3 and cluster policies are different in terms of scale, focus and instruments. However, they also highlight potential synergies between the two, given that both: i) seek to facilitate forms of cooperation among firms and a range of other agents that develop related/complementary economic activities; ii) rely on constructing strategies and activities that build from available place- based assets and capabilities; iii) aim to be transformative in the sense of strengthening existing – and building new – competitive advantages, something that requires processes of prioritization and selection. Also Perlo (2015) underlines the strict interrelation between clusters and RIS3: clusters can play a significant role in smart specializations strategies and at the same time RIS3 is important for supporting cluster initiatives.

Hassink (2010) instead argues that cluster policies can be too specialized, carrying the risk of leading regions to remain locked-in and overly focused on currently successful but declining sectors. That is why there has been a shift from specific cluster policies to smart specialisation strategies, as opposed to the specialized (cluster) strategies in which best practice approaches were not always adapted to the real preconditions of the regions where they were implemented: the "smartness" of smart specialization strategies is geared towards doing exactly this (Moodysson *et al.* , 2015).

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Several studies link smart specialisation to clusters and cluster initiatives looking at several regional and national experiences. Both Aranguren and Wilson (2013) and Del Castillo *et al.* (2013) bring the Basque country as an example of a region that has implemented cluster policies and that has been recently launching also new smart specialisation strategies. Both highlight the positive role that previous cluster policies and the existing clusters can, and probably will, play in the process of definition, implementation and monitoring of the new RIS3 strategies. In particular, whereas Aranguren and Wilson (2013) stress the importance to look at the existing policy landscape to tailor and implement smart specialisation strategies effective for the region where they will be adopted, Del Castillo *et al.* (2013) point to the contribution clusters can give in the areas of prioritization and rationalization of RIS3.

Nijkamp and Kourtit (2014) look instead at clusters in the aviation sector across Europe. They observe the presence of an emerging interest in aviation and aerospace activities as a spearhead for new technological pathways characterized by a high degree of innovativeness and creativeness, in accordance with the principle of smart specialisation. Zhelev (2014) analyse the Bulgarian context, concluding that due to the lack of clear focus and prioritisation, Bulgaria's cluster policy proved to be highly inefficient. For the future, it should interconnected with other policies and measures designed to foster the technological modernization and innovation potential of the economy. In this regard, RIS3 could prove effective.

In general, there is the need to implement cluster policies with a focus on specific cluster/regional context. Particularly, talking about different characteristics of clusters, some of them have been selected as the most relevant in the field of RIS3 (EC, 2013). The analysis of clusters usually starts by considering the strengths and weaknesses of the regions' environment in order to implement cluster–based initiatives (Sölvell *et al.* 2003).

Based on the identified strengths and potentials of Croatia, and taking into account the EU priorities, the following six thematic priority areas have been selected as the focus of the RIS3:

- Transport and Mobility;
- Energy and Sustainable Environment;
- Security;

- Bio–economy;
- Health and Quality of Life;
- Agro–food.

Moreover, there are several crosscutting themes that are additional criteria for prioritising clusters/thematic fields, and support them in the process of value–creation. These are: Tourism, Creative and cultural industries and KETs.

Regarding RIS3 in Croatia, Bečić and Švarc (2015) argue that the conceptualization of RIS3 has undergone significant improvements from the early-stage RIS3, which was based mostly on selected business clusters, going toward a RIS3 based on a cross-cutting approach which tends to link the identified priority thematic areas with interdisciplinary cross-cutting themes such as KETs, ICT, tourism or green technologies. However, despite the conceptual progress, the authors are concerned that in Croatia RIS3 has been performed so far in a reduced form that would not sufficiently include specialisation in key technologies and their knowledge base and skills.

The narrow concept of smart specialisation is perceived as inferior to the concept of smart specialisation that emphasises technology specialisation since it tends to leave the regions/countries captured in uncompetitive industries with low profit and weak employment abilities. It lacks understanding which fundamental knowledge and generic technologies foster the evolution and expansion of selected priority areas into the industries with higher value added (Bečić and Švarc, 2015).

After having identified RIS3 in Croatia, there is the need to recognise the knowledge base that can be exploited in new activity domains. This action would help to see how clusters are collocated and if there are positive spillovers among different knowledge domains. Usually, three main methods for cluster initiatives are used: "mapping of employment patterns and benchmarking against other regions, surveys of perceived areas of strength in the region, and open calls for proposals for funding of collaboration projects" (EC, 2013). There is the need to analyse the performance of existing clusters and TPs, since clusters are one of the core priorities of RIS3 and could positively impact country's socioeconomic growth and development of Croatia.

Public Policies for the attraction of FDI and foster Strategic Alliances for RIS3

FDI is typically expected to bring about a valuable positive impact on the domestic industrial structure, as well as leading to expert enhancement, increase of foreign exchange reserves, job creation, and regional expansion (See Bogovac and Hodžić (2014) and references therein. Bogovac and Hodžić (2014) highlight that foreign direct investment can contribute to regional innovation in many ways: i) research and development activities of multinational directly increase innovative outputs in the region; ii) R&D activities in foreign firms may produce spillovers that, as such, lead to higher innovation performance in the corresponding regions; iii) the presence of these firms may induce more competition in the industrial sector they operate in; iv) multinational enterprises are usually characterised by advanced managerial practices and innovative management of the production process, and these “best practices” could be adopted also by local firms, enhancing the efficiency of R&D activities.

Moreover, in developing countries FDI contributes also to the productivity of innovation (Fu, 2008). A positive effect on productivity growth by means of FDI for the Central and Eastern European region is also found by Bijsterbosch and Kolasa (2010), who document also a strong convergence effect in productivity both at the country and at the industry level, i.e. productivity growth in a country or industry depends positively on its gap vis-à-vis the euro area. However, empirical evidence on positive effects of FDI on economic performances is mixed and “remarkably ambiguous”, because of, among others, methodological and data quality issues (Deutsche Bank Research, 2014).

According to Bellak *et al.* (2010), FDI has desirable effects on the host country’s economic performance, especially for South–East European Countries (SEECs) – including Croatia (FIPA, 2008). Yet Kurtishi-Kastrati (2013) highlights also the potential drawbacks of FDI for developing and transition countries, such as adverse consequences on employment, competition, and the balance of payments, as well as potential concerns for environmental impact and for workers’ conditions. Estrin and Uvalic (2014) explore the determination of FDI and its effects on economic performances for the SEECs and for other transition Central European Countries. Their data show that FDI has contributed quite substantially to capital accumulation in all the SEECs from 2003 onwards, as well as having played an important role in enterprise restructuring in the whole transition region during privatizations. In

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particular, they consider the Balkan transition economies – Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Macedonia, Montenegro, Romania and Serbia. However, this last effect has occurred mainly in the new EU member states and much less in SEECs (Kalotay (2010); the same has occurred regarding the creation of new employment, since FDI has not provided a meaningful contribution in SEECs. They show that FDI is influenced not only by exogenous, predetermined, factor, but also by endogenous, policy-induced measures (Simões et al., 2015), and, with regards to SEECs, that FDI cannot be fully explained by economic characteristics of the region, such as smaller size of domestic markets and greater distance from the investing economies – in comparison with other transition economies. They conclude that there is a negative regional effect due to insufficient policy actions, and hence that SEECs countries have been experiencing lower levels of FDI with respect to other transition economies and to what they could – in principle – attract.

This confirms the important role of public policy for the attraction of FDI within SEECs, which has become a policy goal for regional development of SEECs (Bellak et al., 2010). Governments can rely on a wide set of policies to attract FDI: those aimed at ensuring and improving access to, respectively, foreign markets and imported inputs, commercial facilities, and incentives of various types (Chirila Donciu, 2014, and references therein).

Other measures include production–related material infrastructure and institutional environment favourable to FDI (Bellak *et al.* , 2010) – e.g. legal certainty and macroeconomic stability, the privatization of state-owned companies (Kurtishi-Kastrati, 2013), as well as the establishment of investment promotion agencies to provide foreign investors and potential investors with information and assistance (Sauvant and Mallampally, 2015; Chirila Donciu, 2014). Among the incentives a government can provide to multinational enterprise to attract their capital, it is possible to distinguish between regulatory, financial and fiscal incentives: regulatory incentives usually consist in derogation from national or regional rules and regulation, financial incentives may range from providing physical infrastructures to easing credit conditions, and finally tax incentives include lower taxation rates (Romić, 2010).

Several studies have addressed the question of FDI and its major determinants, aiming at providing policy recommendations and identify which, among the aforementioned policies, are the most effective. It is generally acknowledged in the literature that the quality of institutions and of the business environments is a major factor for the attraction of FDI.

Demekas *et al.* (2007) conduct econometric analyses, finding policies that promotes macroeconomic stability, with respect for the law and contracts, is expected to stimulate all private investment, including FDI. Campos and Kinoshita (2008) analyse the impact of structural reforms on FDI, showing a strong positive relation. However, they also document that foreign investors are attracted to countries with more stable macroeconomic environment, higher levels of economic development, and infrastructure. In relation to SEECs, Bellak *et al.* (2010) empirically demonstrates the potential gains in terms of FDI that could originate from the improvement in institutions and infrastructures.

Bogovac and Hodžić (2014), who focus on Croatia, conduct interviews with managers of Croatian multinational enterprises to understand the key drivers behind the decision of establishing business activities abroad: what emerges is that legal certainty plays a crucial role, whereas other factors such as tax incentives are less decisive. They are not the first to study the impact of tax and fiscal policies on FDI.

For instance, Gondor and Nistor (2012) offer some evidence pointing to fiscal policy being a determinant of FDI, and Simões *et al.* (2015), in a survey of the literature on fiscal policy and FDI, highlight how fiscal policies affect foreign investment decisions, in particular when other economic and social policies are convergent. Bellak *et al.* (2008) and Bellak *et al.* (2010) argue that that the scope for tax policies aimed at increasing FDI is almost exhausted in the SEECs, suggesting that a reduction of tax rates may be effective only given certain level of taxation. As policy recommendation to increase FDI in Eastern European countries, both Bellak *et al.* (2008) and Bijsterbosch and Kolasa (2010) suggest the adoption of policies aimed at increasing the human capital in the region, found to particularly important for multinational enterprises.

Worldwide experience shows that FDI is usually complemented by strategic alliances, including also technological alliances. Even if in developing countries there is less evidence of technological alliances, their number has recently increased. Defining alliances as “collaborative agreements for common interests between independent industrial partners”, there has been an increase in the number of alliances for three decades. FDI and alliances

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involving EU countries aim to exploit the existing factor endowments and cumulated abilities of the economies of countries involved, in order to address their gaps and weaknesses. FDI usually comprehends packages of skills, tools and organisational capabilities; on the other hand, alliances are based on complementarities among partners. To better understand the real content of technological transfers within FDI and alliances it is important to consider specific competences and firm's profiles. Different types of alliances, depending on the country's characteristics, are possible: R&D alliances, Production alliances and Marketing alliances (Radosevic and Dyker, 1996). Exploring the scope for public policies can help in understanding how to better attract FDI, related to RIS3 in Croatia.

Global Value Chains and RIS3

The concept of global value chain (GVC) describes the full range of activities that firms and workers perform to bring a product from its conception to end-use and beyond, including activities such as design, production, marketing, distribution and support to the final consumer. The GVC framework, by examining the structure and dynamics of different actors involved in a given industry, allows the understanding of how global industries are organized (Gereffi and Fernandez-Stark, 2011). In fact, globalisation allows firms to fragment their production in the GVC, and the rise of a GVC approach is useful to explain the fact that specialisation no longer takes places just in industries but also in specific functions or activities in the value chain: the relevant focus of the analysis is not simply the industry but rather the "business function" that firms carry out within the supply chain.

The analysis of GVCs is key to understand the international creation and distribution of value, as well as the capacity of countries to prosper in an increasingly interdependent world. The pervasiveness of GVCs impacts strongly on trade, productivity and labour market developments but also on topics like inequality, poverty and the environment (Amador and Cabral, 2016). discusses Also, GVCs have become more and more important for economic and social welfare , and changes in the governance of GVCs are crucial for global development (Gereffi, 2014).

Amador and Cabral (2016) underline how the high complexity and the different scales of analysis make it virtually impossible to define, measure and map GVCs in a single way.

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Therefore, the literature has developed across different strands of research, with the exploitation of different concepts, methods and terminologies.

For instance, the work by Humphrey and Schmitz (2002) has been important in shaping the discourse within the value chain literature on technical change and innovation, making the distinction between four forms of industrial upgrading (process, product, functional and sector upgrading). A key contribution by Gereffi, Humphrey and Sturgeon (2005) identify instead five different modes of governance (hierarchical, captive, relational, modular and market–based) and linked them to the product or sector's knowledge base and the degree of codification of knowledge.

Amador and Cabral (2016) present a detailed exposition of different methods and data sources employed in the empirical trade literature to map and measure GVCs at the sectorial level.

These are the main methodological approaches that they have identified:

- International trade statistics on parts and components. This is the simplest approach to measure fragmentation, consisting in a comparison between international trade statistics of parts and components with trade in final products. Its main advantage is given by the high coverage and low complexity of the data and the comparability across countries, allowing the identification of bilateral trading partner relations. However, these measures suffer from low accuracy and from a heavy reliance on the product classifications of trade statistics.
- Customs statistics on processing trade. These statistics include information on trade associated with customs arrangements where tariff exemptions or reductions are granted in accordance to the domestic input content of imported goods. Outward and inward processing trades are considered a narrow measure of fragmentation because they captures only the cases where components or materials are, respectively, exported and imported for processing, respectively, abroad and internally, and then, respectively, reimported and exported. However, trade in these goods is recorded accurately at a highly disaggregated level since data is administered by customs.
- International trade data combined with input-output (I-O) tables. Usually, these measures use information from classical I-O tables, but their accuracy depends crucially on the product breakdown available. However, such data is typically

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unavailable since the characteristics of the production chain are not identified and tracked properly, hence accurate cross-country and/or time-series analyses are generally unfeasible. Therefore, a relatively aggregate product breakdown has been used for the identification of countries with important fragmentation activities as well as the assessment of their main trends. I-O tables tend to provide the most appropriate source of sectorial information, although they are not available for many countries and not so readily updated. Two types of measures based on I-O data have been traditionally implemented, one based on the foreign content of domestic production – it considers the share of (direct) imported inputs in production or in total inputs –, the other focused on the (direct and indirect) import content of exports – labelled as "vertical specialization" formulated by Hummels *et al.* (2001). Several recent studies generalize this notion and capture different dimensions of international flows of value-added (Noguera, 2012; Daudin et al., 2011; Koopman et al., 2014), which is important given that the study of the potential of export of an industry needs to consider both its integration in GVCs and the role of trade in intermediate inputs: hence the analysis of gross trade flows needs to be integrated with the analysis of trade in value-added, tracking down the original source country of the value-added.

- Firm level data. The literature based on firm level data is relatively scarce but has recently been expanding rapidly. Micro-data are obtained basically from two sources, i.e. surveys or international trade data. See Amador and Cabral (2016) for a discussion.

Another recent study aimed at examining the position of countries within international production networks is De Backer and Miroudot (2014). Their paper introduces different indicators to give a more accurate picture of the integration and position of countries in GVCs, such as the "GVC participation index", indicating the extent to which a country is involved in a vertically fragmented production process (in relative and absolute terms), or the index of the number of production stages, showing the length of GVCs and highlighting their domestic and international part, or the distance to final demand, pointing out the "upstreamness" of countries and their position in the GVC.

Regarding studies on GVCs at the European level, Amador *et al.* (2015), following the approach of Koopman *et al.* (2014), studies the role of GVC in the process of economic integration of Europe, finding evidence of an increasing share of foreign value added in exports for the euro area as a whole, with some cyclical patterns testified by a strong reduction during the crisis, as well as showing that the euro area is the main source of foreign value added in exports for most member countries.

Ederer and Reschenhofer (2015) adopt a GVC perspective to study macroeconomic imbalances within EU, and among their contributions, they disentangle the effects of changing (domestic and foreign) final demand on the one side and of changes in global production patterns (value chains) on the other. Disentangling these effects allows the assessment of the nature of imbalances, i.e. if they have become 'structural' – as a consequence of a transformation of GVCs – or if they can be adjusted by final demand shifts. Their results highlight that the major part of the changes in trade balances stemmed from shifts in final demand.

Some studies focus in particular on Eastern European countries. Damijan *et al.* (2013) analyse empirically the importance of the "global supply chains" concept for export restructuring and productivity growth in Central and Eastern European countries (CEECs) in the period 1995-2007. Using industry-level data and accounting for technology intensity, they show that FDI has significantly contributed to export restructuring in CEECs, although in an heterogeneous way: whereas more advanced core CEECs managed to increase exports in higher-end technology industries, non-core CEECs stuck with export specialization in lower-end technology industries.

Smith and Pickles (2015) analyse the developments in the clothing industry for CEECs, arguing that such developments require a reconsideration of GVC models focused primarily on upgrading trajectories: on the one hand it is necessary to consider the full range of agents involved as well as their positional power in GVCs, to fully understand the dynamics of GVCs; on the other hand it is needed the awareness of the wider political economy that structures the forms of capitalist relations in GVCs, of the lower contract prices and higher quality requirements between buyers and suppliers, as well as the implications for workers.

Cieślik (2014) focus on European post-communist countries, showing that they have become important links in cross-border production process and that there are stronger connections in terms of trade and capital flows in advanced sectors as well as a growing interdependence

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among these countries. The study finds that: i) the degree of post-communist states' participation in GVCs is diverse, with countries with greater connections to Western European countries being more integrated; ii) a large share of exported goods from the post-communist states passes through GVCs in Western Europe; iii) exporters from Central and Eastern Europe are usually located more in the downstream segments of production than in the upstream markets. Grodzicki (2014) studies GVCs in Poland, Hungary, Slovakia and Czech Republic. In particular, the work exploits the World Input-Output Database, to compute the value of GVC income of particular industries for these countries, and shows that they have become increasingly integrated in GVCs: they have imported more and more intermediate inputs for manufacturing industries as well as steadily increasing their contribution to GVC production. The key aspect one should consider concerning GVC is how much value is captured by the country in terms of jobs, income, technology diffusion and sustainable development. Participating in global trade further and greatly enhances growth and development, and it is inevitably linked to its ability to efficiently join GVC. Therefore, a far more accurate measure to assess competitiveness would be to examine what position is taken in the GVC. A country's competitiveness can be assessed at three levels:

1. Capacity to join GVCs;
2. Remain part of GVCs;
3. Move up the value chain within GVCs;

A further issue is a country's potential capacity to disrupt a GVC; though it is a statement that requires several considerations. Trade in integrated regions – the European Union for instance – is more attractive to GVC lead firms. This is due to easier flows, along with a reduction in costs. GVC lead firms carry brands and sell branded products or services in final markets. Buyers can be either customers, other businesses or government agencies. They are called lead firms because they initiate the process from the very beginning. Starting with placing orders with suppliers, and giving countries market power over suppliers. In this context lies the reason why integrated regions might be more attractive: a region like the European Union could develop a number of competitive industries through the creation of Regional Value Chains. For example, this has already been carried about by Airbus, in the aerospace industry: the assembly of the Airbus 350 Wing was located in different European regions. More specifically, the subassembly lines were in Spain, UK, Scandinavia and Germany, and all reported to Broughton (UK). While the final assembly line was more of a "sub sequential" delegation of tasks: it started from Broughton, went through Germany, and finished in Toulouse, France. Interestingly, a large number of value chains are regional: a clear example is the automotive industry. It should be born in mind that it has been argued that the main purpose is, once again, to capture an important part of the chain's value-added by providing regional bunds of tasks at specific points of the Global Value Chain, exactly where the best opportunities can arise and be exploitable.

Technology, Growth and Productivity

Productivity

Productivity is a measure for how much output the economic process generates per unit of input. Because human labour is an important input into economic production, productivity (especially labour productivity) correlates strongly to economic well-being. In its barest form, it is a measure of how much wealth the economic system can produce with the available human and other resources. At the same time, productivity can be measured and defined at many different levels of analysis, including individual firms, sectors, and countries. Fried *et al.* (2008) provide an overview of the basic notions of productivity, and many of the issues surveyed here.

Economists have been tempted to analyse productivity by using the so-called production function, which is a theoretical and mathematical concept that describes the relationships between inputs and output of a production process. Such a production function usually includes a term that is broadly referred to as "technology," and which corresponds to the actual productivity in the process that the production function describes.

Technology

In this sense, "technology" is defined as everything that is not reflected in the (other) inputs itself, which are usually labour and capital (i.e., machines and other equipment, buildings, and land). Such an economists' notion of technology is a somewhat different one than the notion of technology that, for example, an engineer would propose. But work has been done to bring the more common notion of technology and technological change into economics, both in a direct way by including engineering principles into the production function (Chenery, 1964; Wibe, 2004), and by linking the productivity term in the production function to activities aimed explicitly at technological innovation, such as Research and Development (R&D) (Griliches, 1979, 1980), indicators from innovation surveys (Crepon et al., 1998), or Information and Communication technology (ICT) (Brynjolfsson and Hitt, 1996).

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Productivity and technology

The production function framework has also been criticized, both in general terms (Felipe and McCombie, 2014), and specifically with regard to the way it incorporates technological change (Nelson and Winter, 1977). With regard to technological change, two main criticisms stand out. First, by its nature every production function specifies two sources of labour productivity growth: an increased use of capital per worker (so-called substitution) and an increase in the amount of available knowledge. In reality, however, these two factors are very difficult or even impossible to separate, because they are causally linked (Rosenberg, 1998).

Second, technological change does not only depend on the quantity or quality of the inputs that can be incorporated into the production function. It also depends on the interaction in the innovation system, something which cannot easily be quantified into a production function (Lundvall, 1992).

Nevertheless, the production function remains an important element in the theoretical and empirical analysis of productivity growth. Below, we will survey a number of recent research lines in the analysis of productivity and its relationship to innovation and technological change.

The production function also plays an important part in the theory of economic growth. In some part of the literature on this topic, the production function is complemented with a number of other equations, including a utility function and equations describing the R&D process, to form a comprehensive theory of economic growth (Romer, 1990; Jones, 1995).
But another part of the growth literature starts from the criticism of the production function and formulates alternative growth theories (Nelson and Winter, 1982). Whether or not the basic predictions from these two sides of the growth literature differ substantially is a matter that is open for debate (Castellacci, 2007). We will also briefly survey the growth literature below.

Recent analysis of technology and productivity

Before the role of innovation and technology in productivity analysis can be discussed, it is necessary to briefly survey some conceptual issues in productivity measurement. This will be done under two main headings.

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The first is the measurement of prices. This is important because productivity measures should not include pure price movements, either on the output side or the input side. The second issue is the formulation of a conceptual model for productivity measurement. The definition of productivity as output per unit of input in itself is already a conceptualization. But beyond this, also other issues matter a great deal. The discussion here will include how to account for productivity when there is more than a single input, and on how to use the production function to characterize different forms of productivity increases. After these topics, the relationship between technology, innovation and productivity can be discussed.

Price indices and related matters

Productivity is a concept that relies on measurement in actual quantities, both at the input and the output side. But when aggregating products or services, quantities can no longer be compared, and we have to rely on values, i.e., quantities multiplied by prices. But if prices can move independently of productivity, the movement of prices must be accounted for in productivity measures. This holds both for productivity comparisons over time, i.e., when prices change over time, and for productivity comparisons between units of analysis (countries, firms, sectors). In both cases, an important issue is whether price changes are somehow the result of qualitative differences between the quantities that are being measured.

This has given rise to so-called hedonic price indices, which try to account for differences in quality between the products for which prices are being compared (Griliches, 1961, 1971; Berndt et al., 1995). For example, if one would observe that the average computer sold in one year was $1,000, and in the next year the average computer sold would also be $1,000, the naive conclusion would be that the price index for computers would not have changed. However, a hedonic price index would also ask what the average quality of computers was in both year.

If average quality increased, the conclusion should be that the price index of computers, in per quality unit terms, fell rather than remained constant. Hedonic price indices work by defining a number of attributes that can be used to define quality, and regressing these on the price, where the units that are traded are the observations. For example, the price of a computer may be regressed on CPU speed, hard disk size, size of screen, etc. Using the regression results, the portion of a price change that occurred between two periods may be explained by a change in the attributes. The use of hedonic price indices requires a lot of data and additional work. It is also difficult to implement in many cases, because the attributes to measure quality by are not very easy to determine. Therefore, hedonic price indices do not have a wide use. Nevertheless, they were introduced in the national accounts of the US in 1990s, specifically for computer equipment. This had a large impact on productivity data for the US economy (Bratanova, 1998; Wyckoff, 1995; Triplett, 2006; Schreyer, 2002).

Another major issue with regard to the impact of quality changes on price indices relates to the introduction of completely new products or services. Take mobile phones as an example: when mobile phones were first introduced there was no comparable product on the market. This causes problems for measuring price changes in the statistical aggregate where mobile phones fit, e.g., telecommunications apparatus. The default statistical procedure would be to use quantity weights to calculate an aggregate price index for the group. If these weights would be the quantities before the introduction of the mobile phone, this new invention would not count at all. On the other hand, if weights would change to a period after introduction of the mobile phone, no price data would be available for the period before introduction. In such a case, a solution has been to correct the standard price index by a ratio of the relevance of the new products (1 minus the share of expenditures on new products) to the relevance of the products that disappeared. The main idea is to treat the reservation price of a new product, i.e., the price at which the demand is null, as the price in the period when this product was not available in the market. Therefore, the first observed price of a new product can be interpreted as a "falling price" comparing with the immediately preceding period. On the contrary, the prices of products that disappear are interpreted as cases of increasing prices, hence shifting the demand to zero.

However, the size of the correction depends ultimately on the estimation of the elasticity of substitution. Indeed, if the new/disappearing product has no close substitute in the economy the size of the correction needs to be sizeable. By contrast, new/disappearing products that are slight variations of existing products will not produce deviations from the evolution of prices of existing goods and services (Feenstra, 1994). The problem of new products has been somewhat exacerbated by the introduction of search engine services, social networks or could storage. Some productivity researchers argue that the low price of these goods is not aligned with the utility that they provide, or at least that the deviation is higher than in

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older products, therefore causing a problem of missing output in productivity statistics. The measurement of the potential problem has been addressed through the estimation of consumer surplus in internet-based consumption (Syverson, 2016) Similar issues with regard to price indices arise when comparing internationally in addition to comparing intertemporally. In this case, the original value data for the countries for which output and inputs are measured are likely to be in different currencies, so exchange rates must be used as a first step to make data comparable. However, the data also show that there may be significant differences between countries in terms of the prices that are charged for different products and services, especially when the countries are at very different levels of development.

Usually, the costs of living are lower in countries at lower development levels, which means that a correction must be implemented in order to be able to make a useful comparison of living standards or other productivity measures. There are two routes that can be taken here, which are largely comparable but differ by the perspective taken. The first, and most often applied route is that of purchasing power parities (Deaton and Heston, 2010; Feenstra *et al.* , 2013).

This starts at the demand side (e.g., consumption), and asks which exchange rate would make the prices of a common basket of goods and services exactly equal between two countries. This is called the purchasing power parity exchange rate, and can be used instead of the actual exchange rate to make data (e.g., GDP) comparable between the two countries.

The alternative approach (Feenstra and Romalis, 2014) starts from the supply side, and asks which products or services are supplied in both countries. By comparing prices of this basket of products or services, again an exchange rate can be calculated that equates the price of the basket. This approach is called the unit value ratio approach, and it has the drawback that the overlap of products and services that are produced in the two countries can be small, especially if the countries are at very different levels of development. The unit value ratio approach is the only way to go when productivity measures instead of living standard measures are required.

Most often, researchers interesting in estimating or using productivity data will not define or construct the price indices or exchange rates that are used in their data. But because the

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choices made by those who constructed the data will affect the outcomes of the analysis, productivity researchers must have at least a basic understanding of these issues.

Conceptual models for measurement

In essence, productivity is a simple concept which consists of dividing outputs by inputs. It becomes slightly less simple when multiple inputs are involved. This has given rise to the idea of multi-factor productivity or total factor productivity. In this approach, the multiple inputs, for example, labour and capital, were essentially aggregated into a single input. Microeconomic theory, based on the assumptions of maximization and equilibrium, can be used to define the weights used in this aggregation as the share in total payments for inputs. For example, at the level of the aggregate economy, an aggregate input can be constructed by weighting employment with the share of wages in GDP, and the capital stock by the share of profits in GDP. The share of wages and profits in GDP will add up to one. This makes the growth rate of total factor productivity equal to the growth rate of GDP minus the growth rate of employment multiplied by the wage share, minus the growth rate of the capital stock multiplied by the profit share (Solow, 1957).

Defined in this way, the growth rate of total factor productivity is essentially a residual: it is the part of the GDP growth that is not "explained" by growth of the inputs. This has given rise to the criticism (Abramovitz, 1956) that total factor productivity is not a pure measurement of the impact of technology on output growth, which is how Solow (1957) introduced it. The concept also includes all kinds of other sources, such as measurement errors. Thus, for a while, squeezing the residual by accounting for the quality and quality changes of the inputs has been an important tendency in the literature (Jorgensen et al., 1987; Timmer *et al.,* 2007).

More recently, conceptual work on productivity measurement has shifted in a different direction (Aigner *et al.,* 1977). This has been aimed mostly at the microeconomic level of firms, although the techniques can also be applied to countries or sectors. The focus of this recent literature is to distinguish different kinds of productivity increases, by making a distinction between movements of the production possibilities frontier, and movements towards the frontier. The production possibilities frontier, which is a common microeconomic concept, describes the maximally possible production level at any given moment in time, given the amount of inputs available.

It is commonly observed that not all firms have the same productivity level, even if they work in the same country and industry. This means that some firms, those with lower productivity levels, are not producing the maximally possible output given the inputs they use. Raising productivity in those firms means that they move closer to the production possibilities frontier. Defined in a loose way, one could argue that this kind of productivity growth is associated to the diffusion of existing knowledge, rather than the creation of new knowledge. This does not necessarily imply that using existing knowledge is easier than creating new knowledge, as the application of knowledge that is new to the firm although not new to the world will also require specific firm capabilities.

The crucial step in this kind of analysis is the definition of the production possibilities frontier. Here there are two main traditional approaches. The first is data envelopment analysis (DEA), which is essentially a non-parametric technique that outlines the frontier directly from the data, by observing the maximum level of output at any observed level of input, and joining the observations by linear interpolation (Banker *et al.,* 1984; Emrouznejad, 2008). This method implicitly assumes that there is no noise in the collection process of the data that allows for estimating the frontier, which in the case of firm-level surveys is a strong assumption. The second technique is the stochastic frontier analysis (SF) (Aigner *et al.*, 1977), a parametric approach that allows noise in the data sources. However, since it assumes a functional form for the frontier function and estimates its parameters from the data, introduces potential estimation bias from the production function specification errors.

Recently, a combination of both approaches has been introduced to the productivity analysis. The stochastic semiparametric frontier analysis allows easing the restriction of the functional form of the frontier, while at the same time producing robust estimates in the presence of an unknown distribution of inefficiencies and measurement errors (Kumbhakar *et al.*, 2007). In short, this approach imposes only a localized version of parametric form of the frontier to each firm, therefore considering the firms in a similar context, to extract produce the frontier.

Using any of these methods, one can calculate proper TFP indexes that allow splitting aggregate productivity increases into a part that is due to the movement of the frontier, and a part that is due to the movement towards (or away from) the frontier (O'Donnell, 2012).Both the calculation of total factor productivity and the application of frontier models is routinely done by productivity researchers. Mastering the techniques at a level that will enable the researcher to make these calculations and/or apply the available software in the field is a prerequisite for productivity analysis.

Technology, innovation and productivity

There are two main traditions in relating productivity growth to specific indicators of innovation and technology. The first and oldest relies on R&D data, and is applied at a wide range of aggregation, i.e., from the firm level to international country comparisons. The second is applied to microeconomic data, usually from so-called innovation surveys. The R&D-based approach (Griliches, 1979, 1980) relies to a very large extent on the production function. It usually specifies a production function that incorporates a stock of knowledge. This stock of knowledge is then approximated by accumulated R&D expenditures. There are various practical issues in such an approach that all require careful attention, and for which decisions will be crucial for the final outcomes of the analysis (Mohnen et al., 2010).

A basic choice concerns the type of production function that is used, and whether a production function or a cost function will be used. The use of costs functions (Bernstein and Nadiri, 1991) arises from the idea that firm behaviour may be approximated by either profit maximization or cost minimization, and that the two perspectives are formally equivalent (this is the so-called duality of the maximization problem). In either case, a specific function must be chosen, each of which has specific assumptions made about the nature of the production process, and the role of knowledge and other production factors in it.

An often used function is the Cobb-Douglas production function. It has the drawback that the degree to which production factors, including the R&D stock, can substitute for each other is fixed and non-estimable. The constant elasticity of substitution production function also fixes this, but allows this quantity to be estimated. The translog production function (Christensen *et al.* , 1975; Verspagen, 1995) is a very flexible form that makes almost no assumptions about substitutability and other parameters, and estimates these in a flexible way from the data.

Another issue is the way in which R&D expenditures data are accumulated into a stock (Bernstein and Mamuneas, 2006). Conceptually, it is the stock of knowledge that determines productivity, not just the recent additions to the stock (i.e., current R&D expenditures). The most common approach uses is the so-called perpetual inventory method, which assumes that a fixed proportion of the stock depreciates every period, while current R&D expenditures add to the stock. This requires fairly long time series for R&D expenditures, and also requires fixing the depreciation rate of knowledge. As an alternative to using an actual knowledge or R&D stock, current R&D expenditures can be used as an approximation of the growth rate of the stock.

An important topic in this literature is the existence of spillovers, i.e., the impact of R&D expenditures by one firm on the productivity of other firms (Griliches, 1992). Such spillovers arise because knowledge cannot be appropriated perfectly by those who create it. Two types of spillovers have been identified: rent spillovers and pure knowledge spillovers (Griliches, 1979). Rent spillovers arise between two parties who are engaged in a transaction (e.g., buying and selling of an investment good), and they occur because the seller is unable to appropriate all improvements of the product due to competition. As a result, the quality of the product rises more than the price that the buyer pays. Technically, such a rent spillover is not an externality, but it can be seen as spillover. Pure knowledge spillovers are externalities, and hence their existence is a reason for R&D policy. Knowledge spillovers arise because knowledge cannot be appropriated, i.e., can be imitated, and because knowledge is used as an input in the production of new knowledge. Furthermore, spillover are not homogeneous. Whether because of economic or technological proximity, R&D developed in one sector can be more useful for some sectors, therefore producing higher spillovers, than for others. The heterogeneity of the spillovers is also present when studying the same sectors but in different economic environments. The study of the latter has been approached through technology flow matrix which essentially are tables that resemble input-output matrices, but based (generally) on patent data capturing how much the R&D efforts in one sector have a traceable use the others (Van Pottelsberghe De La Potterie, 1997).

The literature generally comes to the conclusion that R&D spillovers are sizeable (Wieser, 2005; Hall, 1996), and hence that R&D policy (subsidies or tax cuts) may raise economic wellbeing (the market produces too little R&D). But the degree of spillovers varies greatly between studies, as a result of different methods used, different levels of aggregation, and differences with regard to countries, sectors and time periods which are studied.

The literature also concludes that the returns to R&D are positive and high (Hall and Mairesse, 1995; Hall, 1996; Verspagen, 1997), which is a basic result that confirms the relationship between productivity and technological change and innovation. A recent topic in this literature is the rate of return to public science, i.e., whether public science raises aggregate productivity in a country (Guellec and van Pottelsberghe, 2004; Kahn and Luintel, 2006). This has been estimated with the R&D production function methods surveyed here, generally leading to the conclusion that the returns to public science depend greatly on other variables, for example those related to the absorption capability of firms, and to the efficiency of knowledge flows between firms and public research institutes including universities. As these factors are hard to measure at the aggregate level, there remains work to be done on this topic.

The second approach to estimating the relationship technology, innovation and productivity is known as the CDM model (Crepon et al., 1998; Hall *et al.,* 2008). This is an econometric model that specifies the relationship as a multi-stage process, at the firm level. First, there are a number of firm characteristics that determine how much, if anything, the firm will invest in innovation. These investments may take the form of R&D, but also other innovation expenditures, as specified in the community innovation survey, which is the most commonly used data source for estimating a CDM-type model. In the second stage, the innovation expenditures of the firm determine its likelihood of actually making an innovation.

Again, a distinction between different types of innovation may be made, according to the available data. In the final step, innovation outcomes determine the labour productivity level of the firm, where the hypothesis is that more innovative firms have higher productivity. The difficulty of estimating the CDM model lies in the fact that the theory suggests that the main variables are endogenous, and hence the estimation method must account for this 8 (Crepon et al., 1998). Various methods have been used, and the outcomes generally suggest that a significant equation can be estimated for each of the stages in the theoretical model. Hence, productivity at the firm level does seem to depend on investments in innovation and technology. The problem with both approaches is that they have a rather linear view of the innovation process and its outcomes. In both cases, there is a clear causality from investments in technology to innovation outcomes and productivity.

The approaches leave no space for the modelling of innovation as a more interactive process. Another topic that has been the subject of analysis of several scholars has been the role of ICTs in productivity growth. The ICT definition regularly refers to the study of

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hardware, software, internet and telecommunication. Primarily, ICTs may affect the productivity levels of an economy through the process of innovation and productivity growth in ICT-producer sectors, just like another capital-producer activity in the economy. However, the adoption of ICTs has broader effects in the economy. Indeed, ICTs are considered General Purpose Technologies (GPT) that ease productivity growth in the rest of the economy. This is, its characteristics allow it to be increasingly adopted in other sectors (pervasiveness), it shows accelerated quality development and decreasing costs (improvement), and facilitate the management, communication, coordination and diffusion of knowledge, all of them conducting to innovation (innovation spawning) (Rousseau and Jovanovic, 2005).

Since Robert Solow popularized the notion of a computer productivity paradox- “you can see the computer age everywhere but in the productivity statistics” (Solow, 1987), the improvements on the measurement of ICT capital in national accounts have allowed getting a better understanding of the role of ICTs in aggregated productivity growth. At the macro level growth accounting techniques, based on Cobb-Douglas production function that separate the productivity gains from innovation in the ICT-producers sector from the benefits of ICT adoption in the remaining sectors of the economy, are among the most used by scholars. In this approaches, the general TFP of the economy is decomposed between ICT and non-ICT producer sectors, and the contribution of capital deepening is disentangled between the changes in the intensity of the use of ICT capital and non-ICT capital (Cardona *et al.* , 2013).

Parametric approaches have also been used to test the significance of the impacts of ICT on productivity, particularly at the firm level. Also mostly based on Cobb-Douglas production functions, these models add ICT as an explanatory factor of the observed output of a firm/industry/country. Similar to what has been done in the study of R&D and innovation, structural models and instrumental variables has been used to address the endogeneity issues that arise from productivity and ICT adoption/investments.

Overall, it has been found that there is a positive contribution of ICT to productivity growth but (historically) concentrated in the ICT-producer sector. The benefits on the adoption side depends to a large extent of more complex dynamics at the firm level, generally associated with complementary organizational practices, skills, and knowledge management. Therefore,

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9 only business possess certain capabilities can fully exploit the benefits of ICTs, which increases the dispersion of firms' productivity (Faggio, Salvanes and Van Reenen, 2009).

Economic growth, technology and productivity

In order to analyse the process of economic growth, both theoretically and empirically, we may either start directly from the production function that was central in the previous section, or develop a broader approach that is partly based on criticism of the production function approach. Both approaches will be discussed here, starting with the production function approach.

Steady state approximations

The production function was used in the growth model developed by Solow (1956), where it gave rise to a characterization of the growth path as a smooth process in which the growth rate of major economic variables, such as consumption and productivity, is constant over time. In this basic growth model, technology grows at an exogenously fixed rate, which also determines the steady state growth rate.

In the late 1980s, the literature focused on making the rate of technological progress endogenous. Three main approaches were used, each of which yielded growth paths that are

similarly smooth as the prediction from the Solow model. In the first, technology progressed as a result of learning by doing. No additional variables, such as R&D or patents needed to be incorporated in the model. This approach became known as the AK model.

In a second approach, R&D was used to endogenous technological change (Romer, 1990). In these models, profit maximizing firms invest in R&D to expand the range of a horizontally differentiated good, which is either a consumption good, or an intermediate used in production of the single consumption good. A horizontally differentiated good is a good that has quality variety, but without a hierarchical differentiation (a prime example is fruits, which is a differentiated good, but one fruit is not "better" than the other). Firms maximize the profit in creating (by R&D) and supplying a variety of the differentiated good, and this raises GDP and overall productivity. A crucial assumption in these models is that there is a strong externality in R&D: the general state of knowledge, which is increased by each invention, is the prime determinant of the productivity of R&D workers. Because of this positive

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externality, the rate of growth that results from the market is smaller than the socially optimal rate of growth, which means that there is an opportunity for R&D policy.

The third type of endogenous growth model assumed a model of vertical differentiation at the core of the growth process, i.e., production differentiation with quality improvements (Aghion and Howitt, 1992). The R&D process was modelled as a patent race, based on theoretical microeconomic work on this topic (Reinganum, 1983). In this model R&D is also profit-motivated, but in addition to the positive externality, there is also a negative externality in the form of the business stealing effect that is associated when a new inventor takes over the highest spot on the quality ladder of vertical differentiation. This negative externality may cause the market growth rate to be higher than the socially optimal rate, which would give rise to a tax on R&D, but whether this happens this depends on parameter values. Because of their reference to Schumpeter's notion of creative destruction, these models are usually called Schumpeterian growth models.

The first generation of endogenous growth models, in particular the second and third type discussed above, have strong scale economies. This is due to the way in which they model the R&D process, in particular to the role of positive externalities in the R&D process. This leads to the prediction that with a constant amount of R&D employment, the rate of growth of the economy should also be constant. However, as observed by Jones (1995), it seems to be the case that in the last decades of the 20th century, R&D employment was on the rise in most developed countries, while the growth rate showed no signs of any secular increase. This is clearly at odds with the strong predictions about scale economies of the first generation.

Jones (1995) proposed an alternative model of endogenous growth, which subsequently became known as the semi-endogenous growth model. The model resembles the second type of the first generation of endogenous growth models, but it assumes that positive externalities in the R&D process are weaker, which makes a crucial difference for the outcome of the model. The predictions of this model are consistent with observed empirical facts about R&D and growth. In the semi-endogenous growth model, growth can only occur if the population grows at a positive rate.

Evolutionary growth theory

Evolutionary growth models started with the model in Nelson and Winter (1982), in which they use to show that the basic stylized facts about total factor productivity growth that were observed in the 20th century, can be reproduced in a model without profit maximization and the associated notion of equilibrium, and with strong behavioural heterogeneity between firms. Nelson and Winter's argument was mainly about the foundations of the growth model, not so much about the outcome of R&D decisions and their impact on growth. Subsequent evolutionary growth models elaborated this theme, but also argued more extensively about the nature of the growth process. In many of these models, the growth path is far from a steady state, and instead consists of a mix of cycles, irregular trends, and regime shifts.
In these evolutionary theories, the economy is seen as a selection environment, in which firms and other economic agents try to survive by adapting their behaviour to the environment (Nelson and Winter, 2002). Innovation is a way of obtaining a competitive advantage over other firms, and the collective outcomes of innovation by all firms generate economic growth. Like in biological evolution, there are no implications that the evolutionary process optimizes anything, at least not globally. The outcome of the economic growth process will tend to a state of affairs that is locally adapted to the economic selection environment, but keeps changing as a result of innovation.

At an abstract level of interpretation, this kind of growth process is fundamentally different from the steady state models discussed before. In the steady state models, nothing about the growth process is unpredictable. Even if stochasticity may play a role in the outcome of the R&D process, the overall aggregate growth patterns that arise from these models are smooth and regular. A deviation from these growth patterns, such as the Great Depression, or the more recent global crisis of 2009, would have to explained outside the framework of growth theory, for example by business cycle theory. In evolutionary growth theory, such drastic "shocks" are part of the overall growth pattern (Silverberg and Verspagen, 1994; 2005).

This is especially true of recent models in which evolutionary growth models are combined with Keynesian macroeconomic ideas. This is usually done in the tradition of agent-based models, a tradition in which all crucial parts of the theory are modelled at the level of individual agents and their interaction (Dosi et al., 2010). This is a tradition that started in the field of so-called complexity theory, which shared a number of interests and developments with evolutionary growth theory in the 1990s. Agent-based models of evolutionary and

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Keynesian dynamics are a recent avenue of interest in the field of evolutionary growth theory.

Structural economics

A final stream of growth theory that will be discussed is rooted in the theory of Latin-American structuralist thinking. Its most central idea is different kinds of economic activities offer different opportunities for growth, both because of factors related to the supply side of the economy (such as differential potential for learning), and at the demand side of the economy (such as different elasticities of demand with respect to income). The basic idea of the Latin-American structural tradition is that the Latin-American continent has been held back in development because of its strong specialization in resources as opposed to becoming industrialized (Cimoli and Katz, 2003).

Part of the recent work in this tradition is based on the idea of a balance-of-payments restriction to growth (Cimoli and Porcile, 2014). In this approach, exports and imports need to grow at the same rate in the long run, in order to maintain balance of payments equilibrium. As both imports and exports are governed by elasticities of demand, especially income elasticities, the ratio of income elasticities of imports and exports determines whether the growth rate of a country is below or above the growth rate of the world economy.

Industrialization is seen as a way to raise the income elasticity of exports, for countries that are currently specialized in resources, and thus industrialization is a way to raise the growth rate of the economy. But the specialization in resources may show a tendency to lock in, giving rise to a low-growth trap. Breaking out of the low-growth trap depends on the resources that can be made available for innovation (Lavopa, 2014).

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