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Attila Varga
Regional Innovation and Entrepeneurship
Research Center

Regional Innovation and Entrepreneurship Research Center
Faculty of Business and Economics
University of Pécs

H-7622, Pécs Rákóczi str. 80.

Phone: +36-72-501-599/23121

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Place-based, spatially blind or both? Challenges in estimating the impacts of modern development policies: The case of the GMR policy impact modeling approach

Attila Varga
vargaa@ktk.pte.hu

Department of Economics and Regional Studies and
MTA-PTE Innovation and Economic Growth Research Group,
Faculty of Business and Economics, University of Pécs

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Abstract
Two modern approaches to development policy have recently evolved and disputed with each other, the space-neutral and the place-based approaches. Perhaps the most notable conceptual development common in these modern approaches is a strong awareness of the key role of geography in policies targeting aggregate economic growth. Thus it became clear in the new policy thinking that the impact of countries' structural policies largely depends not only on the specific instruments (e.g., human capital development, infrastructure investments, SME support) but also on the concrete patterns in which these instruments are deployed geographically. It is suggested in this paper that macroeconomic models that integrate geography could usefully help policymakers in their choice among different complex geography-instrument mixes. I survey the most important modeling challenges raised by the two modern economic development approaches. To illustrate how economic models can respond to these challenges I briefly introduce the GMR-Europe model. To complete the illustration with a practical example an impact analysis of a space-neutral – place-based policy mix implemented in regions of the European Union is presented. It is found that promoting research excellence in leading agglomerations combined with human capital development in the rest of the regions in Europe could result in a sustained positive GDP impact of EU Framework Programs at the aggregate EU level. Nevertheless, it is also important to emphasize that the aggregate impact masks marked regional differences.

Place-based, spatially blind or both? Challenges in estimating the impacts of modern development policies: The case of the GMR policy impact modeling approach

1. Introduction

Economic impact evaluation provides estimates of the aggregate effects of development policies on selected variables such as GDP, employment or wages. It thus substantially differs from micro-level evaluations that aim at assessing the immediate impacts of individual projects via cost-benefit analysis or alternative methodologies (Vanclay 2014). Input-output linkages, income multipliers and technological spillovers are the main mechanisms by which initial project level impacts propagate and affect the entire economy. Macroeconomic models are the most frequently applied instruments to estimate the economic impacts of development policies. It is argued in this paper that the different principles on which modern development policies are built necessitate the reconsideration of traditionally followed modeling approaches in policy evaluation.

Disappointment in the effectiveness of traditional economic development policies (e.g., financial transfers for physical infrastructure investments, or subsidies and tax credits to attract new firms to lagging regions) to combat interregional disparities motivates the recent emergence of a new wave of modern policy thinking. Policies suggested by the new streams focus on macroeconomic growth stimulation and treat cross-regional balancing of economic development either by separate interventions (Barca 2009) or parallel with growth enhancement (World Bank 2009). Two approaches have emerged recently: the space-neutral and the place-based approaches. The first approach grounds policy prescriptions on new economic geography models and recommends the type of interventions that reap the growth benefits of agglomeration via dominantly space-neutral instruments (World Bank 2009). Building on different principles the second approach suggests that growth potentials exist in every region and the role of mainly place-based policies is to help lagging regions realize these potentials (OECD 2009).

Perhaps the most notable conceptual development common in both approaches is the strong awareness of the key role of geography in policies targeting aggregate economic growth. It became thus clear in the new policy thinking that the impact of countries' (space-neutral or place-based) development policies largely depends not only on the specific instruments applied (such as investment in transportation infrastructure, education or R&D) but also on the geography of the country. For example the same development policy budget may in principle finance different alternative sets of projects each involving a certain combination of instruments implemented in a distinct distribution across regions. Each individual spatial and instrumental distribution of the budget might result in different impacts on aggregate (national level) growth.

I argue in this paper that specially constructed economic models could help policymakers to select a particular geographic and instrumental combination of projects that seem to utilize most efficiently the available structural policy budget according to the knowledge available at the time of the decision. Since country-level or supranational (e.g., EU-level) macroeconomic models, which are widely applied for development policy impact analysis, do not integrate geographic features of their spatial units, they have only a limited relevance in this respect. On the other hand, though regional and interregional models (e.g., computable general equilibrium models) incorporate several aspects of the geography of a country, the fact that they do not account for important macroeconomic influences on development policies (such as the monetary policy regime, the exchange rate, or taxation) also puts a limit on their effectiveness.

This paper suggests that with substantial efforts and careful, professional and enduring work it is possible to develop the kind of models that integrate geography into a macroeconomic modeling framework and as such these models can usefully support modern development policymaking. Economic theory on the one hand and empirical techniques on the other have already reached the critical intellectual mass to support such a challenging endeavor.

Increasing activity of different research groups to develop the new generation of economic impact models indicates that the problem has already been realized and the search for suitable model constructions is ongoing. These research directions include for example the MASST model (Capello 2007) and the GMR policy impact modeling approach. The GMR-approach is followed in GMR-Hungary (Varga 2007, Varga, Járosi, Sebestyén 2013), in GMR-Europe (Varga, Járosi, Sebestyén 2011), in GMR-Turkey (Varga, Járosi, Sebestyén, Baypinar 2013) and in the European Commission's RHOMOLO model (Brandsma, Ivanova, Kancs 2014). The regional innovation policy system dynamics impact model (Fratesi 2012) can also be referred to as another new generation economic policy impact model example.

The following structure is chosen for this paper. The second section situates economic impact modeling challenges in the context of recent developments in modern development policy. In the third section the most important technical issues which are reflected in new generation economic models are introduced. The fourth section is devoted to a concise non-technical description of the GMR-Europe model as an illustration of the reflection on the challenges. This section also provides a policy simulation example to show the type of capabilities that can realistically be expected from the new models at their current stage of development. Summary concludes the paper.

2 Place-based and space-neutral instruments of modern economic development policy

Starting in the postwar period the mainstream of regional policy in Europe and North America employed top-down organized redistributive systems to subsidize lagging places by means of providing funds for investments in infrastructure and public services. In the first period until about the 1970s the emphasis was on attracting new firms or retaining existing ones in particular sectors via increased physical accessibility resulting from transportation infrastructure investments as well as via subsidies, direct government investments or tax reductions. The limits of this approach led to the second wave of interventions, which started to increase its popularity in the 1980s. In this approach the emphasis moved towards building indigenous capacities of a knowledge intensive economy via education and R&D support, promotion of university-industry linkages or encouragement of regional entrepreneurial activities (Wolfe 2011).

The literature reports limited success of development policies in reducing regional disparities. For instance the contribution of EU Cohesion policy to regional convergence in the EU is only weakly positive (Hagen, Mohl 2009) despite positive impacts on national GDP (e.g., Bradley 2006, Schalk, Varga 2004, Varga, in't Veld 2010). Limited success in combatting regional inequalities might be associated with the heavy emphasis placed on transportation infrastructure investments, which can easily result in strengthening the positions of existing agglomerations (Puga 2002, with wasted resources to support declining industries in lagging regions (Barca, McCann, Rodríguez-Pose 2012), with the dominantly top-down philosophy (Barca 2009) or with little integration and coordination among different programs organized by different central government agencies (Wolfe 2011). Criticism against traditional regional development approaches caused by disappointments in policy effectiveness is further strengthened by some negative side effects of centrally administered redistributive systems such as the culture of dependency from external financial support, or rent-seeking behavior (Farole, Rodríguez-Pose, Storper 2011).

Disappointment in traditional approaches has stimulated policy thinking to reconsider the old instruments in order to suggest the kinds of interventions that are expected to enhance economic development more successfully. Two streams of modern policy thinking emerged recently. The first stream in general does not trust in regionally targeted interventions and favors space-neutral policies with universal coverage in every territory, while the second one would continue supporting region-specific interventions and argues that properly designed place-based policies are appropriate means of economic development. In both approaches the focus has moved towards policies that strengthen aggregate economic growth. Equity issues are either addressed as part of the growth package in space-neutral policies (World Bank 2009) or by means of separately designed parallel policies as suggested by the proponents of place-based interventions (Barca 2009).

The path-breaking report of the World Bank (World Bank 2009) brought the attention of policymakers irrevocably to the key role of economic geography in economic development. It draws directly from what has been learnt in the new economic geography literature over the past twenty years on the role of agglomeration in economic growth. Spatial concentration of firms is understood as a source of increasing returns, which in the end results in a higher level of growth. Centripetal forces then induce migration of firms and workers to the region that in turn further increases the scale effects of geographical concentration until positive agglomeration forces dominate. Policies should strengthen this self-reinforcing circle of agglomeration and growth and the most efficient way in this direction is economic integration of lagging places with core economic areas.

Economic integration is being reached when no major differences exist among territories in institutional development (e.g., provision of education, health care, security or regulations of land and labor) and when lagging regions are sufficiently interconnected with the agglomerated economic core by transportation linkages. Interventions thus should aim at fueling agglomeration effects in the economic core and as such have to be designed in a space-neutral way to the largest extent possible. With the exception of specific instances, such as helping urban slums or boosting regional innovation, place-based interventions targeting specific lagging areas are understood to distract resources from their more efficient agglomeration-reinforcing usage. Though the overwhelming majority of examples are cases from the developing world, some of the successful space-blind policy illustrations report experiences from developed countries such as the Appalachian Regional Commission in the US or the application of EU Structural Funds for economic development in Ireland (World Bank 2009).

Though the proponents of *place-based* development do not question the relevance of spatially blind policies or the importance of agglomeration in economic growth their main emphasis is placed on the role of region-specific policies. This is especially the case when the target is the encouragement of economic growth in lagging areas of developed countries (OECD 2009). Several arguments run into this direction. First, data of even the World Bank report (World Bank 2009) shows that the strength of agglomeration forces weakens after a certain level of economic development (i.e., the so-called Williamson-curve). Related to this issue Garcilazo, Oliveira Martins, Tompson (2014) underline that in OECD countries about one-third of total growth is produced by the top agglomerations. The authors attribute the remaining two-third of growth to the rest of the OECD regions. Second, considering the role of space-blind policies in institutional development it is argued that in developed countries variations in institutions across regions became relatively minor recently. Consequently, the growth effects that might be induced by space-neutral policies seem to be low (Barca, McCann, Rodríguez-Pose 2012). Third, the success of space-neutral policies largely depends on the mobility of labor across regions. When labor mobility is low the effects of spatially blind policies on aggregate growth will be limited since the resulting agglomeration dynamism is less effective than desired. If it is too costly to reach the required level of mobility, place-based development policies can be considered as suitable solutions (Partridge, Rikman, Olfert, Tan 2014).

Proponents of place-based development suggest territory-specific innovation policies as effective tools of growth promotion (McCann, Ortega-Argilés 2014, Tomaney 2010, Wolfe 2011). It is argued that innovation policies should be dominantly place-based because specific regional settings (commonly called regional systems of innovation) play a crucial role in the development and industrial application of new technologies. An extensive econometric literature confirms that localized resources are indeed key factors in innovation (Varga, Horváth 2014).

A whole range of instruments have been implemented in different parts of the world in the past three decades to spur innovation in the region such as direct support for human capital development, private and public R&D, promotion of industry-academy interactions, transportation, telecommunication or ICT infrastructure investments or entrepreneurship development (Coburn 1995). Despite that these instruments are widespread only a relatively minor share of regional programs became really successful. Past experiences indicate that integrated policies using multi-level governance approaches tailored to specific industries in which the regions have comparative advantage tend to be more efficient (Corona, Doutriaux, Mian 2006, McCann, Ortega-Argilés 2014, Wolfe 2011). Building on the rich information of past experiences, the EU's new Cohesion policy proposes "smart specialization" as a place-based method to support innovation-grounded regional growth (Foray, David, Hall 2009, McCann, Ortega-Argilés 2014).

This section draws attention to an important complementarity between the two modern approaches to development policy. This complementarity is present despite the heavy debates. It is correct to say that the spatially blind approach targets economic integration with mainly space-neutral instruments to reinforce agglomeration effects and the place-based approach puts emphasis on territorially specific innovation policies to stimulate growth in lagging regions. However it is also clear from the debate that the space-neutral focus does not disclose the validity of place-based policies and the place-based approach also endorses the significance of space-blind policies (World Bank 2009, OECD 2009, Farole, Rodríguez-Pose, Storper 2011).

Therefore the debate between the two modern approaches of development does not seem to be much on the set of instruments but more on the weights different instruments get in a desirable policy mix (Garcilazo, Oliveira Martins, Tompson 2014). Two examples from the main reports of each approach sufficiently support this observation. The World Bank report acknowledges the relevance of place-based innovation policies in modern economies (World Bank 2009, p. 255). A quote from the Barca report (Barca 2009), which became the conceptual base of the reformed EU place-based Cohesion policy, exemplifies that the advocates of place-specific policies also understand that in certain instances unleashing agglomeration forces might cause higher levels of growth:

"The supposed 'untapped potential' of the periphery might well turn out not to exist, as is often the case. (…) The intervention could end up constraining an efficient agglomeration process while failing to achieve results in the periphery." (Barca 2009, p. 24)

Therefore in real-world situations the choice between different mixes of place-based and space-neutral polices should be governed by the particular geography of a country. In one specific country strengthening agglomeration by space-blind or place-based policies could be more effective for aggregate growth than promoting innovation in lagging areas, while in another country the reverse might be more efficient. It is argued in this paper that empirical economic models that incorporate geography into their structures could effectively assist policymaking in the selection of suitable mixes of various place-based and space-neutral interventions. The next section reviews the key challenges of empirical geographic growth modeling.

3 The challenge of incorporating geography into development policy impact models

The short review in the preceding section demonstrates that the key feature of modern policy approaches is the emphasis on geography as a significant factor in macroeconomic growth. Agglomeration is one particular aspect of geography but local specificities such as industrial structure, the strength of research, the size of human capital or accessibility are at least as important geographic features as interregional linkages such as trade flows, labor and capital migration or knowledge transfers. Since geography is a key factor in economic growth it also significantly influences the outcomes of development policies. Thus the same development policy budget can affect national level economic growth differently depending on the alternative distributions of the resources across different regions. Also the strength and relative size of positive and negative agglomeration forces in core economic regions or the mobility of labor can significantly influence the growth effects of even the spatially blind policies. Therefore incorporating geography into macroeconomic policy impact models is crucial. However, due to the complexity of the problem this integration poses significant modeling challenges[1].

In the followings I detail the four key economic modeling challenges that need to be addressed in impact models to be used in the evaluation of modern development policies. These include modeling the effects of policies on technological progress, formulating the transmission of innovation impacts to economic variables, modeling spatiotemporal dynamics of growth and incorporating the macro dimension. I introduce these challenges in four steps of model building.

Step 1. Modeling policy impact on technological progress

The first question in model design is related to the way the impacts of policy instruments on innovation are represented in an economic model. A rich empirical literature has mapped several geographical aspects of innovation and as such collected important information for model builders (Varga, Horváth 2014). It has been demonstrated in the literature that localized knowledge flows between academic institutions and innovative firms on the one hand and among firms' R&D laboratories on the other are positively associated with innovation at the regional level (Feldman, Florida 1994). Furthermore, R&D knowledge transfers may cross regional boundaries and with a certain decay associated with physical distance tend to influence innovation of firms located in farther regions (Anselin, Varga, Acs 1997). It has also been evidenced that the association between innovation and R&D at the regional level is positively related to entrepreneurship (Acs, Varga 2005) and the agglomeration of key actors of regional innovation such as competing and related firms, business services, academic and private research laboratories and human capital (Varga 2000). The role of institutions in the knowledge generation process has also been emphasized in the literature (Boschma 2005).

The literature also suggests that the industrial dimension is an important aspect of agglomeration. Not only spatial concentration of firms belonging to the same industry but also geographical proximity of (related) industries matter for regional innovation (Glaeser, Kallal, Scheinkman, Shleifer 1992, Frenken, van Oort, Verburg 2007). More than that it has also been shown empirically that mobility of graduates from universities to firms (Faggian, McCann, Sheppard 2009) and movements of skilled individuals among firms (Breschi, Lissoni 2001) appear to be the main channels of localized as well as cross-regional knowledge transfers. Besides human capital mobility, intra- and interregional knowledge networks are also key mechanisms of innovation (Miguélez, Moreno 2013, Sebestyén, Varga 2013).

The observed positive association of innovation with research, human capital, physical proximity, agglomeration, entrepreneurship and knowledge networks at

[1] When policy demand for the evaluation of traditional development policies appeared in the 1980s macroeconomic modeling also faced with important challenges. Implementation of supply side and endogenous growth mechanisms in the then dominantly Keynesian demand-side models were the most important challenge at that time (Bradley 2006). The resulted macroeconomic models most frequently applied in EU Cohesion policy impact analysis such as the HERMIN (Bradley, Gács, Kangur, Lubenets 2005) or the QUEST (Varga, in't Veld 2010) model families managed to meet these challenges.

different spatial scales suggests that integrated policies proposed by modern development approaches aiming at stimulating R&D, education, entrepreneurial culture, transportation infrastructure investments and collaborations in research are indeed realistically expected to positively influence innovation. The question still remains though as to how these elements of innovation are integrated into a coherent empirical modeling framework. Possibilities in this respect might range from the application of geographic knowledge production function (Varga, Pontikakis, Chorafakis 2014) and regional computable general equilibrium (Hermansson et al. 2010) approaches to dynamic evolutionary modeling techniques (Fagiolo, Dosi 2003).

Step 2. Modeling the transmission of the technology impact to economic variables

The choice of how to empirically model the transmission of policy impacts on innovation to changes in economic variables such as output, employment or inflation is not an obvious one. Innovation may contribute to aggregate growth in two (not necessarily independent) ways. Technological progress either increases the production of already existing goods (a productivity impact) or results in the introduction of new products (a variety impact) (Saviotti, Pyka 2003). Modeling the productivity and variety effects in a common framework is a real challenge.

Economic growth theory offers different solutions. In the endogenous model of Romer (1990) innovation creates new varieties but differences among varieties are masked in the aggregate final goods sector and as such output growth is formulated like a productivity effect at the end. The multi-sector endogenous growth model of Aghion and Howitt (1998) allows inter-sectoral flows but the set of sectors is considered constant and as such the variety effect remains limited. Compared to neoclassical economics Schumpeterian evolutionary growth theories like the one presented in Fagiolo and Dosi (2003) and in Saviotti and Pyka (2003) seem to get closer to the right formulation of the variety effect.

Nevertheless it is a common experience for any theoretical solution that their translation to empirical models becomes indeed difficult because of the appearance of several technical issues. Among them data availability is a really serious problem especially at sub-national regional levels.

Step 3. Modeling spatiotemporal dynamics of economic growth

Innovation results in economic growth in regions subject to policy intervention if demand for new products expands (variety effect) or if the increase in demand overcompensates the decline in unit costs (productivity effect). A given national development policy budget that supports certain regions may induce growth partly by the expansion of indigenous regional resources (technology, capital, labor) and partly by inducing migration of capital and labor from other regions that could stimulate further growth by strengthened agglomeration effects.

Therefore modeling the impacts of modern development policies requires modeling the spatiotemporal dynamics of macroeconomic growth that is induced by simultaneous increase of production factors and changes in their geographical configurations. Different regional/instrumental combinations of policy support might result in different spatiotemporal growth dynamics. This complex process could be followed by a system of regional models connected by trade, migration and technology flows.

Empirical modeling of simultaneous spatial and temporal dynamics of a system of interconnected regional models is indeed a challenging task and poses several technical issues. The first issue is related to the choice of the type of regional models to be applied in impact analysis. The most widely used alternatives are partial equilibrium regional econometric models (Capello 2007) and regional computable general equilibrium (CGE) models (Donaghy 2009, Partridge and Rickman 2010). Important further differences among models are related to the way they describe markets (perfect or imperfect competition), formulate motivations for labor migration (wage versus utility disparities), or account for various agglomeration effects (pecuniary and/or technological externalities).

Another important issue is time delays considering that policies need time until they affect different economic variables. Decisions in this respect should partly be governed by concrete econometric estimations where different statistical measures (reflecting regression fit, model significance) suggest the most likely time lags in the models. In some other cases economic theory could be suggestive.

The technical challenge of modeling spatiotemporal dynamics could be addressed by modeling both policy-induced expansion of indigenous resources and their migration between regions. Consistency with the neoclassical growth framework then implies to derive saving and investment behavior from intertemporal optimization of households and firms in all locations. Development of models in this direction is slow and solutions are rare due to substantial analytical and computational difficulties involved (Bröcker, Korzhenevych 2011). Alternatives include the introduction of some ad-hoc investment and saving behavior in regional models (Ivanova et al. 2007) or separately modeling intertemporal optimization of investment and saving behavior at the macro level and migration and dynamic agglomeration effects at the regional level in an integrated model system (Varga, Járosi, Sebestyén 2011).

Step 4. Macro impact integration

The macroeconomic framework such as the exchange rate of the national currency, government deficit and debt, the monetary policy regime or the interest rate could be important factors behind the impact of development policies. In a carefully designed macroeconomic policy, economic development is indeed aligned with other macro framework conditions. Since the derivation of these conditions from the regional level is not understood theoretically (and most probably regional to macro aggregation is not even possible in this respect) integration of the macro dimension into modeling seems to be a desirable solution. This is an open area of research and examples are rare in the literature (Varga, Járosi, Sebestyén 2011).

4. An attempt to reflect the challenges in policy impact modeling: The GMR-approach

In this section we outline the GMR modeling approach as an attempt to address the four modeling challenges detailed in the preceding section. The GMR approach is an economic development policy impact-modeling framework. GMR stands for "Geographic, Macro and Regional" modeling. It is "regional" because the sub-national regional level is where many of those development policy interventions that are central in GMR modeling are implemented. It is "macro" (i.e. national or supranational) because the economic impacts of regional level interventions are influenced by policies implemented at the macro level (like fiscal and monetary policy interventions that affect taxes, interest rates, exchange rates and so on) and the impact of various macro level policy options also needs to be accounted for when the effects of regional policies are studied. Finally, it is "geographic" because different agglomeration effects, regional specificities, interregional interactions (like trade, knowledge spillovers or migration) are also accounted for in the model.

GMR models provide ex-ante and ex-post evaluation of development policies such as promotion of R&D activities, human capital advancement, private investment support or public investments in physical infrastructures. The models simulate macro- and regional economic impacts while taking into account geography effects such as regional innovation system features, agglomeration, migration and costs of transportation. The intention of the GMR research program is to develop efficient and relatively simple model structures, which fit to the generally weak quality of regional data.

The GMR-framework is rooted in different traditions of economics (Varga 2006). Knowledge generation modeling is significantly influenced by the Romerian endogenous growth theory (Romer 1990). Spatial patterns of knowledge flows and the role of agglomeration in knowledge transfers are formulated with insights and methodologies learned from the geography of innovation field (e.g. Anselin, Varga, Acs 1997, Varga 2000). Interregional trade and migration linkages and dynamic agglomeration effects are formed with an empirical general equilibrium model in the tradition of the new economic geography (Krugman 1991, Fujita, Krugman, Venables 1999). Specific macroeconomic theories are followed while modeling macro level impacts.

The first realization of the GMR approach was the EcoRET model built for the Hungarian government for ex-ante and ex-post evaluation of the impact of EU Cohesion policy in Hungary (Schalk, Varga 2004). This was followed by the GMR-Hungary model, which is currently used by the Hungarian government for Cohesion policy impact analyses (Varga 2007). GMR-Europe was built in the IAREG FP7 project (Varga, Járosi, Sebestyén 2011) and was extended (Varga, Törmä 2010) and applied for policy simulations for DG Regional Policy (LSE 2011). The most recent realization of the GMR-approach is GMR-Turkey (Varga, Járosi, Sebestyén, Baypinar 2013, Varga, Baypinar 2014).

The GMR approach reflects the four modeling challenges outlined in the previous section by structuring its system around the mutual interactions of three sub-models namely the Total Factor Productivity (TFP), the Spatial Computable General Equilibrium[2] (SCGE) and the macroeconomic (MACRO) sub-models. While the TFP sub-model embodies novel extensions in innovation modeling within the regional knowledge production function framework, already established modeling solutions are incorporated into the system with the other two blocks. Therefore the value added of the GMR approach is partly in its components and more in the solution the three

[2] Spatial Computable General Equilibrium (CGE) models consist of a system of individual regional CGE models interconnected by trade and migration linkages. To put it simply they are CGE models extended towards the spatial dimension following basically the set-up applied in Krugman (1991) that has been adopted in most new economic geography models.

model blocks are interconnected and tailored towards solving development policy impact modeling challenges.

To illustrate how the challenges involved in modeling economic impacts of modern development policies are reflected in the GMR approach first I provide a concise non-technical introduction to the structure of the GMR-Europe model[3] (section 4.1). In order to exemplify the possibilities with GMR models I then present its application in a policy impact analysis (section 4.2). Since the aim in this paper is illustration I will keep detailing technical aspects at the possible minimum, which is necessary for understanding the system. For technically oriented model explanations see Varga, Törmä (2010), Varga, Járosi, Sebestyén (2011), and Varga, Pontikakis, Chorafakis (2014).

4.1 The four modeling challenges as reflected in the structure of the GMR-Europe model

Step 1. Modeling policy impact on technological progress

Policy impact on innovation is formulated in the TFP sub-model. Following Romer (1990) and Jones (2002) development of ideas for new technologies is explained by the amount of research inputs and the stock of accumulated scientific-technological knowledge. The assumption behind this formulation is that even the same research inputs (e.g. number of researchers) can result in a larger number of new technologies if the level of knowledge already accumulated over time is higher.

In the GMR-Europe model the corresponding empirical relationship is estimated with the following regional knowledge production function:

$$\dot{A}_{i,t} = RD_{i,t-k}^{\alpha_{\dot{A}1}} A_{N,t-k}^{\alpha_{\dot{A}2}}, \tag{1}$$

where $\dot{A}$ is temporal change in new knowledge (measured by number of patents and number of publications in two separate equations), *RD* is research and development (measured by R&D expenditures), *A* is accumulated knowledge (measured by the stock of patents, and stock of publications, respectively), $\alpha_{\dot{A}1}$ and $\alpha_{\dot{A}2}$ are parameters, subscripts stand for region (i), nation (N) and time (t). Parameter $\alpha_{\dot{A}1}$ is the elasticity of new technological ideas with respect to research and as such it is taken as a measure of regional R&D productivity.

The impact of any level of research expenditures on new technological ideas is indicated by the size of $\alpha_{\dot{A}1}$, which is related to the concentration of technology

[3] GMR-Europe includes countries of the Eurozone extended with two small Central European countries, Czech Republic and Hungary. Availability of regional data on the one hand and the spatial coverage of the QUEST III macroeconomic model for the Eurozone explain the selection of countries. The model system uses data from various sources. Some of them are publicly available on the EUROSTAT web page (such as the New Cronos database for regional patents, R&D, technology employment and data for most of the macro level variables). Some of the data sources are developed for the European Commission (such as the regional FP5 and FP6 databases and the regional publication database). The model system includes 163 EU NUTS-2 regions. Estimation of the equations in the TFP sub-model is carried out in SpaceStat on the 1998-2002 data panel of EU NUTS2 regions and parameters in the SCGE sub-model are calibrated for 2002 data. The GMR-system is programmed and run in Matlab.

intensive industries[4] in the region on the one hand and the prominence of interregional research cooperation partners, measured empirically by R&D expenditures of 5th Framework Program partner regions on the other. Thus regions even with similar levels of research expenditures could generate more technological ideas if localized learning is enhanced by the agglomeration of knowledge intensive industries and outstanding R&D partners increase success in scientific publication via interregional research collaborations. R&D productivity differences induce a cumulative process of research and technology intensive industry concentration in high research productivity regions. Therefore policies supporting research in the region may result in a higher level of knowledge in the region and the strength of this impact over time is importantly influenced by research productivity. Figure 1 illustrates the regional dynamics detailed in Steps 1 and 2.

Step 2. Modeling the transmission of the technology impact to economic variables
Many of the new technological ideas become introduced in production but many of them remain unexploited. The development of concrete technologies on the basis of technological ideas is formulated in the Total Factor Productivity equation. Therefore innovation policy impact on economic variables is transmitted through an increase in TFP. Policy induced change in TFP may increase output even if capital and labor remain the same. Increased output might result from new varieties and/or from growing productivity.

TFP is modeled again following the Romerian knowledge production function. TFP depends on the region's general technological level and on its concrete capabilities (i.e. human capital) to implement technological ideas in production. However, regional impacts at any levels of technology and human capital become more intensive with the flows of knowledge among actors within the regional innovation system. Knowledge communication in the model is related partly to the concentration of economic activities in space (operationalized by total regional employment) assuming that increased employment further raises the opportunities of personal interactions and learning. Knowledge flows in the region are also related to social capital that is the willingness to collaborate on the part of the actors in the system.

The system of equations in the TFP block is estimated econometrically in Varga, Pontikakis, Chorafakis (2014) and Varga, Járosi, Sebestyén (2011). Time lags between R&D and publications, R&D and patenting, patenting and TFP as well as temporal delays in regional adjustments of research expenditures and technology employment are estimated econometrically. In order to fit the equations to data of each individual region parameters are calibrated regionally. This means that in the GMR-Europe model the TFP block consists of 163 individual regions and for each region the effects of policy variables on regional TFP are formulated in a manner depicted in Figure 1. Policy variables are R&D, interregional research networking, human capital, social capital and physical accessibility.

[4] The presence of technology intensive industries is measured by employment in knowledge intensive economic sectors. Data (employment in high and medium high technology manufacturing, high technology services, knowledge intensive market services, financial services, amenity services – health, education, recreation) are collected by EUROSTAT.

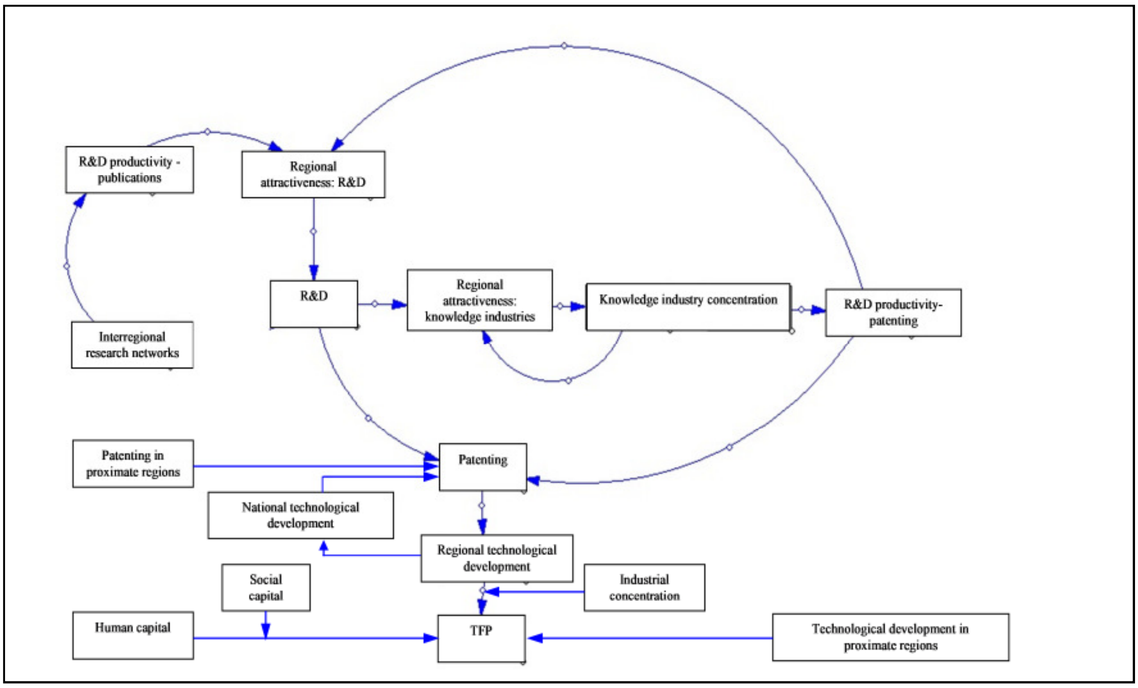

Figure 1: The estimated dynamics of innovation policies on TFP at the level of individual regions in the GMR-Europe model

<u>Steps 3 and 4. Modeling spatiotemporal dynamics of economic growth and macro impact integration</u>

A higher level of TFP resulting from innovation policy interventions may effect production partly via increased regional employment and investment and partly via labor and capital migration from other regions. Increased concentration of economic activities might strengthen dynamic positive agglomeration economies that could then initiate a cumulative process of further concentration. Therefore, increased capital and labor on the one hand and the resulting further increase in TFP sparked by agglomeration on the other drive policy-induced regional growth. In modeling spatiotemporal dynamics this complex process is separated into three steps, which at the end result in a coherent macro-regional impact via mutual alignments.

The first two steps (which are denoted as steps 3a and 3b) reflect spatial dynamics. In their design the solution frequently applied in many of the new economic geography models is followed. In the first step, the short run impact of a change in TFP on economic variables (e.g., output, capital and labor demand, prices, wages) for each region is calculated assuming that aggregate (i.e., country level) supply of capital and labor as well as their regional distribution remain constant. Following the commonly used solution in new economic geography models this process takes one period in the model, which is practically one year. In the second step, utility differences across regions motivate labor migration, which is followed by the migration of capital. This migration occurs/is realized at the end of the period. The first and second steps are modeled in the SCGE model block. So far aggregate labor and capital supply have been assumed constant. Their dynamics then is modeled in the third step with the MACRO model block. In what follows I explain spatiotemporal dynamics in more details.

<u>*Step 3a: Short run effects*</u>

At the EU NUTS 2 regional level only aggregate R&D data are available. Therefore with no information on industrial sectors or scientific fields of research activities it is not possible to relate R&D expenditures to particular industries. This explains the choice of a sectorally aggregated SCGE model for regional policy impact analysis. The applied SCGE model is a simplified version of the Dutch RAEM model adapted to the framework of the GMR system (Járosi, Koike, Thissen, Varga 2010).

Considering the *supply side* of the economy of any region production is modeled with a Cobb-Douglas function. Following the Cobb-Douglas framework profit-maximizing price, labor demand and capital demand are formulated following standard derivations in microeconomics. Turning to the *demand side* preferences of the representative household are formulated with a C-D utility function. Per capita housing is included among the goods consumed by the household. Per capita housing gets smaller with increasing concentration of employment, which has a negative effect on utility. Therefore it represents a negative agglomeration effect in the model. Utility maximization results in the usual demand function for final goods.

The increase in regional TFP resulting from innovation policy interventions decreases unit costs, which (assuming that production level does not change) affects demand for labor and capital negatively. At the same time however, decreasing prices (which are made possible by decreasing unit costs) increase demand in each territory where the region exports, which in turn raises the demand for labor and capital via increased supply. The balance between the two opposing effects determines equilibrium factor demand. In short run equilibrium, a region's production equals interregional product demand while regional labor and capital demand become equal to their respective supplies, which are taken fixed in the short run.

Step 3b: Spatial dynamics with constant aggregate K and L

Innovation policy interventions resulting in an increase of regional TFP affects prices and wages, which determine consumption. A change in consumption affects utilities as well. Utility differences across regions then influence spatial equilibrium in the country since labor migration reacts to cross-regional utility differences. Migration of labor from regions with below-average utilities targets regions with above-average utility levels.

Both positive and negative impacts of agglomeration are modeled. Labor concentration affects TFP positively (see earlier discussion in Step 2), which then runs through the system of equations influencing the values of several variables. However a larger L also means increased congestion, which affects utilities negatively. The balance between positive and negative agglomeration effects determines the extent of next-round migration, which will again change the distribution of labor initiating a cumulative causation process that affect several variables in the system of regions over time.

Step 3c: Dynamic regional and macro impacts

The applied SCGE model is static and as such it does not account for temporal changes in labor, capital and technology in an endogenous manner. What it does is that for any given aggregate level of labor, capital and technology it calculates their equilibrium spatial distributions. Dynamics caused by change in technology is modeled in the TFP model block while dynamic effects of interventions on labor and capital are simulated in the MACRO model block. In this latter block the QUEST III model, a DSGE[5] model for the Eurozone is incorporated into the system (Ratto, Roeger, int'l Veld 2009).

Changes in regional TFP as calculated in Step 3b are weighted-averaged for each time period and inputted to the MACRO model where the impacts on several macro variables (GDP, employment, investment, inflation, etc.) are calculated. Aggregate changes in K and L are then distributed across regions following the patterns of initial policy interventions. This way the indigenous change in regional K and L is simulated. To estimate the effects of agglomeration Step 3b above is initiated again. The three model blocks are interconnected and run subsequently until the aggregate regional impacts in the regional sub-models converges to the EU-level impacts estimated in the macroeconomic model. The solution to interconnect the three GMR model blocks in policy effect estimation is illustrated in Figure 2.

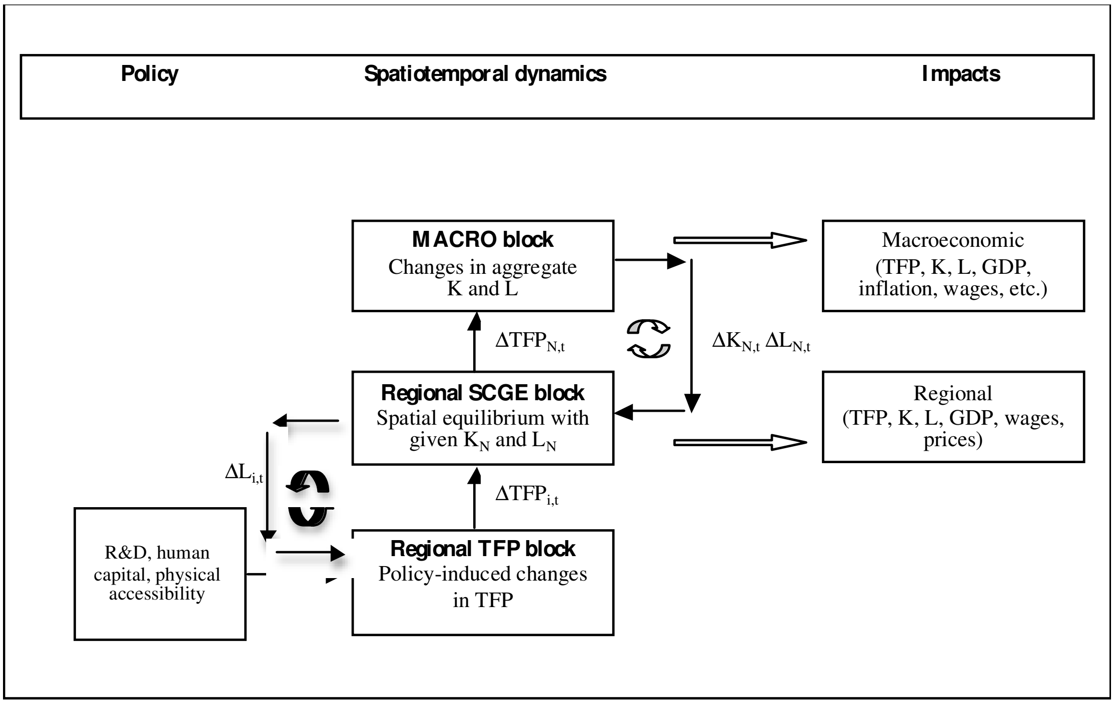

Figure 2: Regional and macro impacts of regionally implemented innovation policies in the GMR-Europe model

4.2 A policy impact analysis example: A space-neutral - place-based R&D policy mix in Europe

Some of the recently suggested development policy instruments are place-based and some of them are space-neutral. Since economic geography influences the effects of both policy instruments geography has to be incorporated in economic impact models

[5]DSGE (Dynamic Stochastic General Equilibrium) models represent the dynamic aspects of economic activity explicitly capturing the dynamic behavior of agents: they operate with forward-looking decisions of households and firms.

that are designed for the impact analysis of modern development policies. The previous sub-section described how the four policy impact modeling challenges are reflected in the GMR-Europe model. In this sub-section I provide an example for policy analysis where regional and macroeconomic impacts of a mix of space-neutral and place-based instruments are estimated with the GMR-Europe model.

According to revealed principles EU Framework Programs (which are the European Union's primary research support instruments) promote scientific excellence in the form of supporting selected consortiums located in different countries of Europe. Considering that the ultimate aim of research support is the advancement of economic growth, EU Framework Programs can be considered as a unique spatially blind economic development policy instrument. Nevertheless the growth impacts of this spatially blind instrument largely depend on economic geography. For example in regions with well-developed systems of innovation research support will most probably result in higher levels of economic growth than otherwise. Thus the actual geographic distribution of FP research subsidies is a factor behind their impact on economic growth. This necessitates the application of economic models that incorporate geography in the impact analysis of EU Framework Programs.

Figure 3 presents the estimated impacts of FP6 research subsidies on patents and GDP at the aggregate level of the Eurozone and two Central European countries (Czech Republic and Hungary)[6]. The values are in percentages and indicate the differences between the FP6 scenario and the scenario without FP6 research subsidies (i.e., the baseline). For example in 2006 patenting is about 3.5 percent higher than it would be without FP6 subsidies. Despite that FP6 R&D shocks disappear from 2008 the impact on patenting remains above zero even after 2010 when direct R&D shocks are not in effect anymore. The small and continuously declining effect on patenting indicates the presence of cumulative, longer-term positive effects of FP6 interventions on technology employment and R&D (see Figure 1 for more details on these cumulative agglomeration effects). As the observation of Figure 3 indicates, the majority of R&D impacts on patenting require three years to be realized while the enduring cumulative effects last for many more years.

GDP impacts of research subsidies follow the changes in patenting with a three-year time lag. The peak value of the GDP impact is about 0.07 percent in 2012. After 2012 the GDP impact declines to approach its lower long run value in about 2021. Of course all the (short run and longer run) impacts of the FP6 program on GDP are small which is not surprising given the relatively small amounts of FP6-provided R&D subsidies. (On average the budget of FP6 research projects is less than 2% of total public and industrial R&D expenditures.)

[6] The JRC Institute for Prospective Technological Studies of the European Commission collected the data on FP6 EU R&D contributions and provided the regional and temporal distribution of them for the period of 2003-2007.

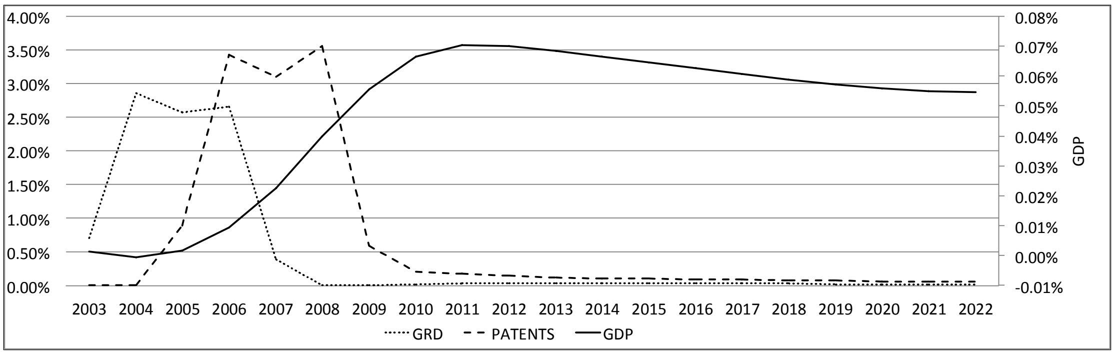

Figure 3: Scenario 1 - FP6 research subsidies: EU-level aggregate impacts on patents and GDP

Notes: The GMR-Europe model is applied for scenario calculations. FP6 research subsidies (GRD) are implemented in the period of 2003-2008. R&D subsidies and the impact on patents are measured on the left vertical axis while the impact on GDP is on the right vertical axis.

The long run impact of FP6 on GDP seems to stabilize slightly below 0.06 % after its decline from 2013 as shown in Figure 3. Would it be possible to prevent this decline of the GDP impact after the peak year (2012)? With this question in mind the original spatially blind EU Framework Program is extended with two place-based policy interventions. The results are shown in Figure 4.

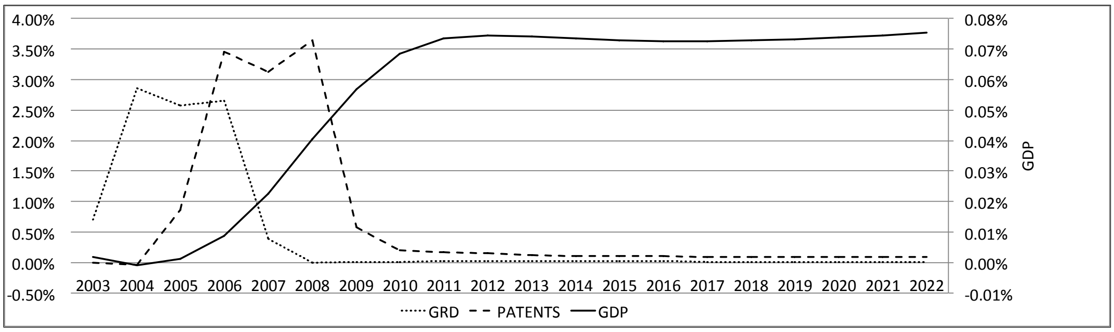

Figure 4: Scenario 2 – Quality research support and human capital compensation: EU-level aggregate impacts on patents and GDP

Notes: The GMR-Europe model is applied for scenario calculations. FP6 research subsidies (GRD) are implemented in the period of 2003-2008. R&D subsidies and the impact on patents are measured on the left vertical axis while the impact on GDP is on the right vertical axis. Scenario: a quality redistribution of 5% of national research expenditures following the geographic patterns of FP6 research support and a compensatory 0.5% annual increase of human capital over the period of 2003-2022.

The first place-based policy is called a "quality research support" intervention. Behind this scenario it is expected that resulting from strong international competition Framework Programs are more selective in research support than national funding agencies. Thus a policy is designed where 5% of all the nationally sponsored research expenditures are redistributed among regions within each country for the whole simulation period (2003-2022) in a way that the new geographic pattern of the redistributed amounts matches the regional pattern of FP6 research subsidies. Considering that the redistributed 5% almost doubles FP6 research supports in the peak years (3%) it was assumed that the quality redistribution would result in significant impacts even at the aggregate EU level. However the very small additional positive effect on patenting (which is observed by a comparison of the patenting impacts in Figures 3 and 4) indicates that the quality redistribution of national funding does not make much difference at least at the aggregate level. This suggests that (despite our expectations) national decision criteria for R&D support in most EU countries are not much different from the criteria followed in European FP6 projects.

In the second place-based scenario we combined the “quality research support” policy with a persistent, medium term human capital development intervention. In each year of the simulation period (2003-2022) we assumed that national governments are capable of increasing human capital (measured by the number of inhabitants with tertiary education) by 0.5% in those regions where knowledge intensive employment concentration is less than what is observed in leading technology agglomerations of the European Union. Though the annual increase in human capital does not seem to be dramatic the persistent policy results in a considerable 10 percent higher stock of human capital in the supported regions in 2022. Since this policy is designed for compensating those regions, which experienced a loss from the quality R&D support the scenario it is called the “human capital compensation scenario”. As the results in Figure 4 show with this policy a sustained FP6 impact on aggregate GDP can be achieved: GDP stays more than 0.07 higher than what its value would be without the combined place-based – spatially blind scenario. What this example suggests is that promoting research excellence in leading agglomerations combined with human capital development in the rest of the regions could result in a sustained GDP impact of Framework Programs at the EU level.

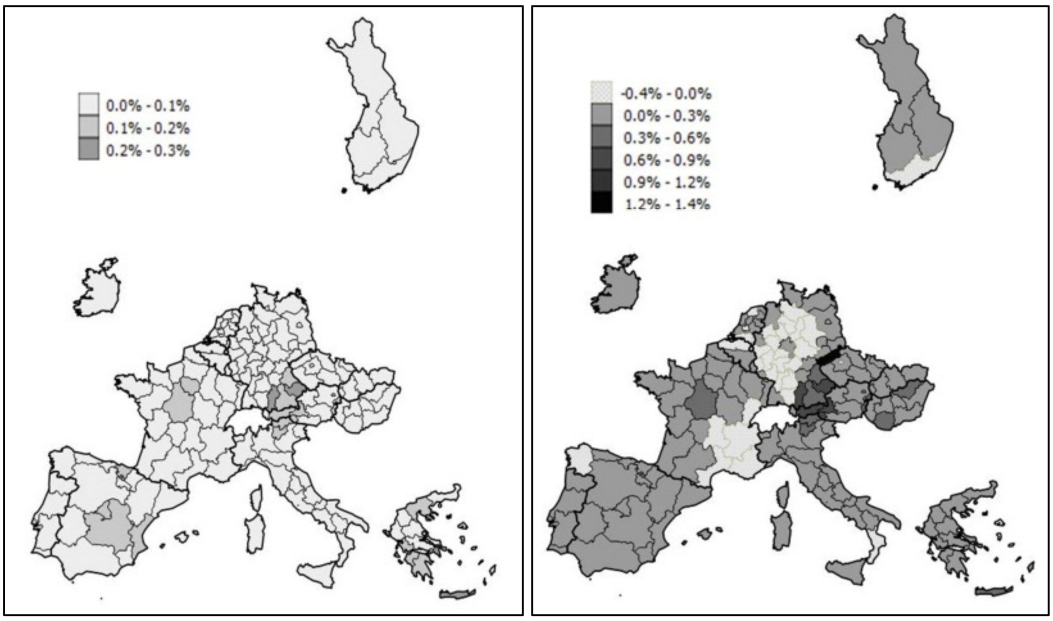

Figure 5: NUTS 2 level regional impacts of Scenarios 1 (left panel) and 2 (right panel) in the peak year of Scenario 1 (2012)

Figure 5 provides details on the GDP effects of the scenarios at the EU NUTS 2 regional level for the year 2012 (which is the year when the macro level GDP impact of FP6 research subsidies reaches the highest values). The left panel depicts the regional impacts of FP6 R&D subsidies. There is a variation across regions and this variation is partly due to differences in R&D funds among regions but also to differences in the capabilities of regions to absorb research supports and convert them to growth. The highest impact on GDP (between 0.2 and 0.3 percent) is observed in regions like Brussels and its surroundings or in Southern Germany. However, most of the regions experience GDP impacts between slightly larger than 0.0 and 0.1 percent.

The right panel of Figure 5 shows the regional impacts of the mixed place-based – space-neutral scenario. Regions that experience relatively high impacts from FP6 subsidies (i.e., regions in the second and third tiers in the left panel of the figure) managed to increase their GDP as a result of the combined scenario. These regions are those that are the beneficiaries of the quality redistribution of national R&D funds. Most of them (like the Southern German regions) can still be found among those regions where the highest GDP impacts are estimated. On the other hand, due to human capital investment compensation most of the first tier regions in the left panel experience significant increases in GDP. Many regions in Southern and Central-East Europe, Ireland, Finland, most of France and Germany belong to this category.

However, some of the regions (dominantly in France and Germany) experience lower levels of GDP than what they reach without the combined scenario. These are the regions where R&D compensation does not change research expenditures significantly. Also these are the regions that are not eligible for human capital compensation either. Since these regions experience the lowest levels of TFP changes the price levels of the goods their produce remain higher than the prices of those regions that are beneficiaries of the combined policy. Resulting from declining competitiveness these regions face with a loss of production. Additionally labor outmigration from these regions further decreases their TFP and their competiveness.

The simulation results suggest that refining the original space-neutral – place-based policy mix with a focused human capital development in those regions that experience a loss in their positions would be instrumental for improving policy outcomes both at the macro and at the regional levels of the EU. Therefore this policy extension would not only strengthen the aggregate, macroeconomic impacts on GDP but it would also work towards mitigating interregional differences in economic development in Europe.

5. Summary

Disappointment in traditional economic development approaches stimulated policy thinking to reconsider old instruments in order to design the kinds of interventions that are expected to enhance economic development more successfully. New development policy thinking reflects the understanding of the key role of economic geography in the success of policy interventions. Two approaches have been developed recently in the policy literature. The first approach favors increasing concentration of resources in the economic core with mostly spatially blind (universally applicable) polices to take advantage of strengthened agglomeration effects on growth while the other approach builds on the assumption that more growth opportunities exist in the periphery than in the core and these opportunities could be utilized with place-specific policies in the majority of the cases.

Studying the main policy documents of the two approaches makes it clear that, despite the heavy debates, the two streams of policy thinking show important complementarities. Therefore the debate is less on the set of instruments but more on the weights different instruments get in a desirable policy mix. It is argued in this paper that specially constructed economic models that integrate geography with macroeconomic modeling could be helpful both in the design as well as in the monitoring phases of complex modern development policies.

This paper draws attention to four main challenges in modern development policy impact modeling: formulating the impact of policies on technological progress, modeling the transmission of innovation impacts on economic variables, modeling spatiotemporal dynamics of growth and incorporating the macro dimension. To illustrate how economic models can respond to these challenges I briefly introduced the GMR policy modeling approach along the lines of the four challenges.

An application of the GMR-Europe model for the analysis of the economic impacts of a specific place-based – spatially blind policy mix implemented in European regions shows that spatially blind EU Framework programs affect GDP at the aggregate European level positively. The impact of the Framework Programs can be made sustainable at the aggregate EU level by combining this space-neutral instrument with place-based human capital development. However, the detailed regional analysis shows that the impacts of the combined policy vary significantly across regions. Despite that most of the regions gain from the policy mix, there are some territories where GDP becomes less than it would be without the interventions.

The GMR research program continues by incorporating new features into the system in order to develop functions that make models more valuable for ex-ante and ex-post development policy analyses. The most recent version of the GMR-Europe model will incorporate advancements of research in network analysis, entrepreneurship research and agent based modeling in order to address policies of European regions that target entrepreneurship and more intense international research collaborations. These policies will be crucial for Europe considering the heavy emphasis of the EU's novel smart specialization-based Cohesion policy on entrepreneurship, innovation and human capital development.

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