Economic Impact Estimation of Smart Specialization Policy

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Abstract
In this paper we argue that the application of economic impact models in smart specialization policy is necessary in order to come up with reliable economic impact estimations. Solutions suggested in the S3 literature for economic impact assessments cover the economic effects only partially. To estimate the impacts in the industrial, regional and national dimensions in their entirety the application of specifically designed economic models becomes necessary. We extended the GMR-Hungary policy impact model with additional features to make this model applicable for S3 economic impact estimations. In our simulations we illustrate how the application of this model can help policymakers in the prioritization process.

Economic Impact Estimation of Smart Specialization Policy

1. Introduction

Smart specialization (S3) is an innovation-based regional economic development policy (Foray 2015, McCann and Ortega-Argilés 2015). S3 targets the industrial restructuring of regions based on the support of promising new activities that are rooted in the regions' own knowledge bases. The policy is a unique mixture of bottom-up and top down elements. Entrepreneurial search as a bottom-up process results in a set of local initiatives by regional stakeholders (like entrepreneurs, public research institutions, universities) that form the basis of those activities which will get eventually selected by the government for support. The selection mechanism called prioritization is a key component of smart specialization policy. During the selection process the proposed new activities (technologies, inventions) are analyzed by the government with respect to different dimensions such as their uniqueness or their likely economic significances.

Smart specialization became integrated to the EU Cohesion Policy as a pre-requisite for the eligibility of ERDF (European Regional Development Fund) financial supports. Nevertheless, smart specialization is not exclusively a European policy. It has also been initiated and implemented in China as well as in the United States (Radosevic et al., 2017 Anastasopoulos et al., 2017).

Economic impact estimation is normally part of large-scale policies and as such it has been traditionally an essential element of EU Cohesion Policy. Understanding economic effects are important in the policy design phase (ex-ante impact assessment) as well as in the evaluation stage (ex-post impact evaluation). Economic effects of policies are usually estimated by policy impact models which calculate the regional, national or supra-national (like EU) level economic impacts of policy interventions such as investment supports or R&D subsidies. Economy-wide effects emanate from the linkages of the actors directly supported by the policy with several other actors in the economy. These impacts are most typically communicated by input-output relations with suppliers and buyers, by income multipliers or by knowledge spillovers. The impacts are usually calculated on several economic variables like the output (GDP), employment, wages, or the price level.

Since smart specialization policy targets industrial restructuring and economic growth, understanding the economic effects of S3 is crucial for policy design and evaluation. Knowing the economic impacts of each potential activity ex-ante during prioritization would help policymakers in the selection from several alternatives as understanding the effects ex-post would significantly increase the effectiveness of policy learning. Despite its key importance economic impact estimation is not yet part of the smart specialization policy framework (Varga et al., 2018).

Experiences in the implementation of smart specialization policy in many European regions suggest that knowledge about the economic effects of S3 would significantly increase policy success both in the policy design and in the policy execution phases. Capello and Kroll (2016) emphasize that many of the less advanced regions are hardly capable of selecting those priorities that are most compatible with their economic capabilities. This observation is further supported by Veugelers (2015) who points out that despite remarkable differences in innovation competencies among European regions the composition of the applied set of policies tend to be much more homogeneous. In this regard pregnant differences are observed between regions located in the North-East segments of Europe mostly characterized by matured innovation systems and regions situated in the South and East parts of Europe where the innovation and the institutional environments tend to be much less developed (Kroll et al. 2016, MacCann-Ortega-Argilés 2016, Koschatzky 2017).

Several modeling challenges explain why economic impact estimation has not find its place in the framework of smart specialization policy. The first one comes from the fact that S3 is not a sector-neutral innovation policy (Foray 2015) in contrast to sector-neutral policies usually implemented in practice. As a consequence, economic impact models most frequently applied in impact assessment estimate aggregate effects without considering the industrial aspects (e.g., Ratto et al. 2009). On the contrary, S3 targets the development of specific industrial sectors on the basis of some regional initiatives. Therefore, the economic effects of the implementation of each of the proposed activities should be estimated by the economic impact model. This is certainly a challenging task since a very micro-level change (the introduction of a new activity that can be a new technology or other inventions) at the industrial sector level needs to be incorporated in a macro (or regional) impact assessment framework. Consequently, the economic impact model should integrate the industrial dimension in its structure.

The second challenge comes from the fact that S3 is a regional development policy. Therefore, the models need to integrate several geographic dimensions that significantly determine the economic impacts of smart specialization policy. As such positive and negative agglomeration effects should be part of the model in addition to transport costs and the interregional migration of labor and capital (Krugman 1991). Spatial computable general equilibrium (SCGE) models are one option to incorporate these geographic effects (e.g., Brandsma, Kancs 2015).

The third modeling challenge is that the macroeconomic (national) dimension should also be integrated in the model framework. This is because the effects of smart specialization policy are also influenced by several changes initiated by the national government such as changes in tax rates or changes in the currency exchange rate. GMR (Geographic Macro and Regional) models developed a solution to integrate the macro and regional dimensions in economic impact assessment (Varga 2017)[1].

The fourth challenge is related to modelling the impacts of some of the policy interventions that are frequently suggested in the smart specialization literature. These include human capital development, R&D subsidies or investment support. The estimation of the economic impacts of these measures is a routine procedure in impact models. However, the estimation of the impacts of two of the suggested policy measures, namely regional entrepreneurship policy and interregional network development has not been resolved until very recently (Varga et al., 2018).

How and to what extent economic impact models can contribute to a more effective smart specialisation policy? Economic impact models can support the policy with ex-ante impact assessment (to help governments to make more informed decisions in the prioritization process). The models can also give support in monitoring (model results inform about which policy works and how the policy mix might need to be further adjusted) and in ex-post impact assessment of supporting policies.

[1] According to our knowledge the MASST (MAcroeconomic, Sectoral, Social, Territorial model) project is the other currently existing initiative that integrates regional and macroeconomic dimensions (Capello 2007). However, MASST is a forecasting and not a policy impact model.

In the prioritization process establishing a strict assessment procedure for selecting from alternative activities is crucial to minimise the costs of making mistakes (Foray 2015). Entrepreneurial discoveries are assessed along three main dimensions in the course of prioritisation: the activity's individual features, its regional spillover capacity and the new activity's economic significance. The first dimension incorporates individual characteristics of the discovery such as the degree of novelty of the activity, the extent to which it targets discovering new opportunities for the region, the existence of global demand, identification of main competitors and regional availability of key supply factors (Foray 2015).

A new activity may be highly valued according to the first dimension, but it might not be rich enough in spillover potentials to generate firm concentration. The second dimension of assessment therefore reflects the capacity of the discovery to initiate the process of firm agglomeration by means of imitative entries. Intensity of learning opportunities from the original discovery is related to domain size and the connectedness of the domain with other domains. Relevant domain size concerns the size of the sectors that could potentially benefit the most from knowledge spillovers from the original discovery (Foray et al. 2009). Furthermore, domains that are more connected with other domains provide better opportunities for learning than those that are less connected (David et al. 2009).

Even if a discovery has excellent spillover potentials the project might be too narrow in terms of its regional economic significance measured by jobs or GDP (Foray 2015). The third dimension of discovery evaluation therefore targets its likely impact on the region's economy. Economic impact evaluation of a discovery is a key aspect of prioritisation, however, the approach suggested for economic significance estimation (i.e., the new activity's demand for regional resource inputs) addresses the impacts only partially (Foray et al. 2011, Foray 2015). The application of appropriately designed economic impact models open the possibility to track down the contributions of many factors that influences the success of different industrial policies in promoting regional growth.

What are the most important economic impacts initiated by the introduction of a new activity? First, considering the local and interregional intersectoral input-output (backward and forward) linkages is crucial in determining the possible impacts of industry support. Those industries that are heavily embedded in the local economy through their input requirements and sales are expected to put the region in motion with ease in terms of economic growth. Through these direct linkages connected industries will be influenced positively, but the positive impact will flow further into the local and the national economy though the indirect linkages of other firms influenced by the targeted industry. Additionally, the introduction of a new activity might increase investment demand as a potential pull factor of local production. The resulted additional capital stock has twofold function: first, it serves as a factor of production for the selected industry, second it is assumed that the newly created capital stock will be owned by households as well thus it is a source of income generation. As an income source it will increase households' consumption budget and savings generating further additional (consumption and investment) demand.

As production increases, government tax revenues are also expected to grow which can result in higher public expenditures further boosting effects of additional demand. However when it comes to the question of total local growth it has to be emphasized that each demand component can be satisfied by the production of other regions as well (at least to a given extent) thus if local prices decrease less in case than the other buyers will substitute local and other product accordingly thus through interregional trade linkages we found another potential source /

leakage of economic growth. Apart from other domestic areas, regions are also connected to foreign markets, thus by improving local productivity (decreasing prices) foreign demand might increase as well, which can be another pull factor promoting higher growth. Lastly, the mobility of primary inputs (labor and capital) has also a key role in the growth path of each region. As a result of the positive shock additional net immigration is expected in the long run which further increases the stock of factors of production in the region. Therefore, the introduction of a new activity initiates a series of interconnected changes in the regional and national economies and the effects of these changes can be estimated by economic impact models.

Turning to monitoring and ex-post evaluation, economic models could estimate the effects of the policies that support the introduction of the new activity (e.g., human capital and investment supports, R&D subsidies, entrepreneurship and innovation network policies) at the regional, national and even at the supra national levels.

Since the introduction of smart specialization in the policy practice several remarkable advances have been made to extend the analytical toolbox of S3. Some of them are related to the support of the development of smart specialisation strategies (Fiore 2016), others address a more successful methodology to search for economic potentials (Reimers 2016) or initiate new approaches for the selection of priorities (Healy 2016). The methodologies suggested by Balland et al. (2018) and Crescenzi et al. (2018) stand the closest to impact assessment. However, Balland et al. (2018) focuses on complexity and relatedness and do not cover economic effects and Crescenzi et al. (2018) estimate firm-level but not the economy-level impacts of a smart specialisation policy.

We extended the GMR-Hungary policy impact model with additional features to make this model applicable for S3 economic impact estimations. In our simulations we illustrate how economic impact assessments with the model can help policymakers in the prioritization process. In the second section we introduce the most recent version of the GMR-Hungary model. Section three presents the illustrative simulations. Summary and conclusions close the paper.

2. The GMR-Hungary policy impact model

This section shortly describes the GMR modelling approach that we use to evaluate the economic impacts of industry support strategies. First, we discuss the general features of the model, then, a brief account of the modelling system's most important building blocks is given, including the specificities of the newly developed multisector spatial computable general equilibrium model.

2.1. The general features of GMR-Hungary

The GMR (Geographic, Macro and Regional) modelling framework was designed, and continuously improved in order to supporting development policy decisions through enabling ex-ante and ex-post scenario analyses. The framework builds on the tradition of standard macroeconomic modelling (e.g. the HERMIN model – ERSI 2002), CGE modelling (e.g. ECOMOD – Bayar 2007) or the more recently developed DSGE approach (QUEST III – Ratto et al. 2009). On the other hand, it also accounts for the geographic effects of different policy interventions (e.g., agglomeration, migration, interregional trade) allowing for the calculation of both regional and national impacts of these interventions. The inclusion of geography into impact modelling allows us to account for agglomeration externalities, knowledge spillovers, migration of production resources, trade and transportation costs as well as convergence or divergence of spatial units. For more details on this modelling framework, see Varga (2017) or

Varga et al. (2018). In this paper, we use the latest version of the GMR models for Hungary, which is the first multisector-multiregion spatial computable general equilibrium model of the framework. For an account of previous model specifications and applications see Schalk and Varga (2004), Varga (2007), Varga (2017), Varga and Baypinar (2016), Varga et al. (2018).

2.2. The structure of the modeling system

The GMR approach provides a solution to the challenges of incorporating regional, geographic and macroeconomic dimensions into the impact modelling of spatial development policies. From a methodological point of view, the structure of the system is built around three traditions in economics, each one represented by a model block: (1) a productivity (TFP) block, which incorporates relationships described in the field of the geography of innovation (e.g. Anselin et al.1997, Varga 2000, Sebestyén and Varga 2013); (2) a spatial computable general equilibrium (SCGE) block, rooted in the new economic geography (e.g. Krugman 1991, Fujita et al. 1999); (3) a macroeconomic (MACRO) block building on traditions in macroeconomic analysis. In the following sections, we briefly describe these building blocks.

2.2.1 The TFP (productivity) block

The total factor productivity (TFP) is one of the most important variables in the modelling system, accounting for the overall productivity effects of different aspects of innovation-related policy interventions (such as R&D subsidies, entrepreneurship development policies, human capital development programs). This block models the most important factors behind innovation and their interactions in influencing regional productivity levels. The TFP block is based on the knowledge production function literature (Romer, 1990), and describes the production of new knowledge as a function of utilizing knowledge production factors like R&D efforts, labour input (employment), knowledge that already exists both at the regional and national levels. In addition to these standard factors of knowledge production, a novel feature of our approach is to include two other factors of knowledge creation, which are important in smart specialization strategies. The first is the knowledge available through interregional knowledge networks (we measure this availability by the ENQ index[2]), which is assumed to enhance the effectiveness of R&D efforts in the region. The second is the role of the entrepreneurial environment (measured by the REDI index[3]) in shaping regional productivity levels, which is assumed to have strong interaction with the level of human capital in the regions, reflecting the knowledge spillover theory of entrepreneurship (Acs et al. 2009).

The TFP block is the richest component of the GMR-framework in terms of policy intervention tools, as it accounts for the direct impact of policies affecting any of the knowledge factors mentioned above. The block is capable of simulating the region-specific impacts of different policy interventions on regional productivity levels. This change in productivities is then transferred to the SCGE and MACRO blocks, which calculate the economic impacts of these productivity improvements both at the regional and aggregate levels.

Beyond its components, the TFP block is a system of empirically estimated equations describing the relationship between region-level productivity and its key determinants mentioned above. The parameters of the TFP block are estimated, using an econometric model with panel data. Further on starting with estimated parameters a calibration process is implemented to get region-specific values of some of the parameters.

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[2] For detailed description see Sebestyén and Varga (2013)

[3] For detailed description see Szerb et al. (2017)

2.2.2 The SCGE block

The TFP block calculates the expected effects of innovation-related policy efforts on regional productivity levels. These impacts serve as primary input for the spatial general equilibrium (SCGE) model block, which is designed to simulate the likely impacts of these changes on regional economic variables like output, prices, wages, employment, etc. The most important feature of this block is that it takes into account economic interactions across regions such as the trade of goods and services, the inter-industry linkages (input-output connections) and the interregional as well as inter-sectoral mobility of production factors. Furthermore, transportation costs are explicitly accounted for and (positive and negative) agglomeration effects are taken into account in this model block as well.

In the SCGE block, we distinguish short- and long-run equilibria. In the short-run, all markets clear in all regions, given the productivity levels and the stock of production factors in every region, as well as taking into account inter-sectoral linkages, transportation costs and interregional trade. However, this equilibrium does not necessarily mean that the whole interregional system is in equilibrium. In the long run, differences in interregional utility levels (depending on per capita consumption and population density) might trigger interregional migration of production factors, changing the market conditions in the next time period and leading to adjustments in the short run equilibria, further changing utility levels and so on. Through this mechanism, interregional utility differences are eliminated, leading to a spatial equilibrium in the long run.

In the following paragraphs, we describe the representation of the main economic actors in the model and the most important assumptions behind them. In the SCGE model block we represent all the important actors in a general equilibrium setting, including productive industries, households, government, investment and foreign actors as well as their interactions.

Starting with the supply side, *firms* (represented by different activities) are characterized by profit maximization and they operate in perfectly competitive markets. Profit is maximized subject to the technology of production, described by a nested production function. Firms satisfy aggregated domestic demand, which is made up of the sum of demands for households' consumption, investments, government purchases and intermediate inputs.

Regional *households* are assumed to maximize their utility. We defined two kinds of utility: 1) utility driving the choice of consumption of different goods and services, 2) interregional utility driving interregional migration. Households' income is composed of wages and capital incomes (we assume that regional capital stock is owned by households). This income is used to pay taxes, save and consume. In the case of interregional migration, households consider the interregional differences of utility levels based on regional real consumption possibilities per capita and the level of housing per capita (as an approximation of negative agglomeration externalities). Migration occurs 'between' discrete time periods, thus in each year regional economies face an exogenous amount of labor and capital supply. As a result of migration, interregional utility differences are continuously eliminating in the long run. The capital stock is assumed to be partially mobile between regions and industries with some level of friction. A portion of regional capital stock might be used by other regions' actors since households are motivated to relocate their invested capital to locations where capital is relatively scarce (thus its price is higher).

Investments are modelled in a savings-driven way, so that they are financed by savings of the households, the government and foreign actors (rest of world). Households' saving rate is exogenous, as well as the amount of foreign savings but exogenous government deficit is controlled by the MACRO block in a recursive way (discussed later). All markets clear in equilibrium, thus total saving and investment must be equal. Since savings are determined by exogenous saving rates and foreign and government savings in each discrete time period, investment must adjust to maintain equilibrium. As a result, total investment demand is driven by savings.

Although we account for the most important functions of the *government* in a general equilibrium framework, our approach can be still considered as partial. The government collects taxes and use this revenue to make purchases of goods and services. Financing health-care, education and other government-related activities are accounted for in these channels. We break down taxes into commodity and production taxes (and subsidies), with exogenously fixed ad valorem tax rates. The tax rates are calibrated on the basis of the empirical interregional input-output table, used as a background for the model. Government saving (deficit) is controlled by the MACRO block.

The *rest of world* is represented by imports and exports in the model. Since Hungary is a small and open economy, world prices are assumed to be exogenous. The price of exports and imports measured in the domestic currency is influenced by the endogenous exchange rate, which is assumed to control the balance of payment equation (the difference between the total value of imports and exports, also assumed to be exogenous). In case of imports, we sum up all foreign purchases made by industries, households, investment and the government. If imports or exports are too high/low the exchange rate will adjust accordingly to keep the balance of payment at its exogenous (calibrated) value. Since our model is not designed for international trade issues, more sophisticated aspects of international relations are ignored in the model setup.

The *domestic trade of goods* (and services) across regions is a vital part of the GMR approach, connecting all actors of the economy. Total domestic supply of products and services is assumed to be equal to total domestic demand in all time periods, however its regional structure can be varied. Firms are allowed to ship their products to any of the regions and final users can purchase products from all regions. These mechanisms are driven by interregional prices which are influenced by many factors in the model (including productivity, the availability of local inputs, dependency on foreign inputs, etc.), but most importantly by interregional transportation cost, which is assumed to follow the exogenous iceberg-type logic (Samuelson, 1952). Our approach to interregional demand of goods and services assumes that goods produced in different regions are close but not perfect substitutes for regional actors. As a result, actors make decisions about the regional source (origin) of their purchases on the basis of their preferences and the actual market prices, including transportation costs.

Such a detailed spatial CGE model requires a large amount of detailed statistical data, both at the regional and sectoral levels, which is usually not available in official databases. Particularly, interregional inter-industry transactions are not surveyed by most statistical offices, although crucial in calibrating such models. Our model is based on an estimated interregional input-output table for which we used the combination of standard regionalization methods (e.g. Jackson, 1998), and the available regional and national level data in Hungary (including the national input-output table). The resulted table represents 20 Hungarian NUTS 3 regions (19 counties and the capital Budapest) as well as 37 aggregated NACE rev. 2 industries in 2010. All equations of the SCGE model were calibrated based on our estimated interregional I-O table in a way that in the reference year (also first year of the simulations, 2010) the model equations replicate the benchmark "database".[4]

2.2.3 The MACRO block

The macroeconomic (MACRO) block of the GMR framework serves as the point, where aggregate relationships and policies can be handled (government debt, fiscal policy, etc.) and where aggregate impacts of different interventions are represented. In the present setup, one of the main roles of the MACRO block is to drive government debt and deficit on the basis of the national debt-to-GDP ratio. It is assumed, that the government will take actions in order to reach an exogenously given the target level of the debt-to-GDP ratio in the long-run. More specifically, it adjusts taxes, transfers and purchases in order to keep this ratio around its target level. In the present model, the government runs a fixed deficit rate (given in a separate time period) and this rate changes according to the debt-to-GDP ratio. The adjustment of the deficit is stronger if the growth rate or inflation is low or if the interest payment (after government debt) is relatively high. When the economy grows faster, the debt-to-GDP ratio automatically decreases without cutting back on current deficit. Similar argument can be made in case of inflation. The sensitivity of current deficit to the macroeconomic conditions is calibrated in a way that the long-run debt-to-GDP ratio is sufficiently approximated in the baseline scenario.[5] Furthermore, there is a significant overlap between the macro and the SCGE block since in the latest version of GMR-Hungary we apply a recursive dynamic SCGE model the dynamic elements (such as capital accumulation, investment decisions, etc.) are accounted for in the SCGE block.

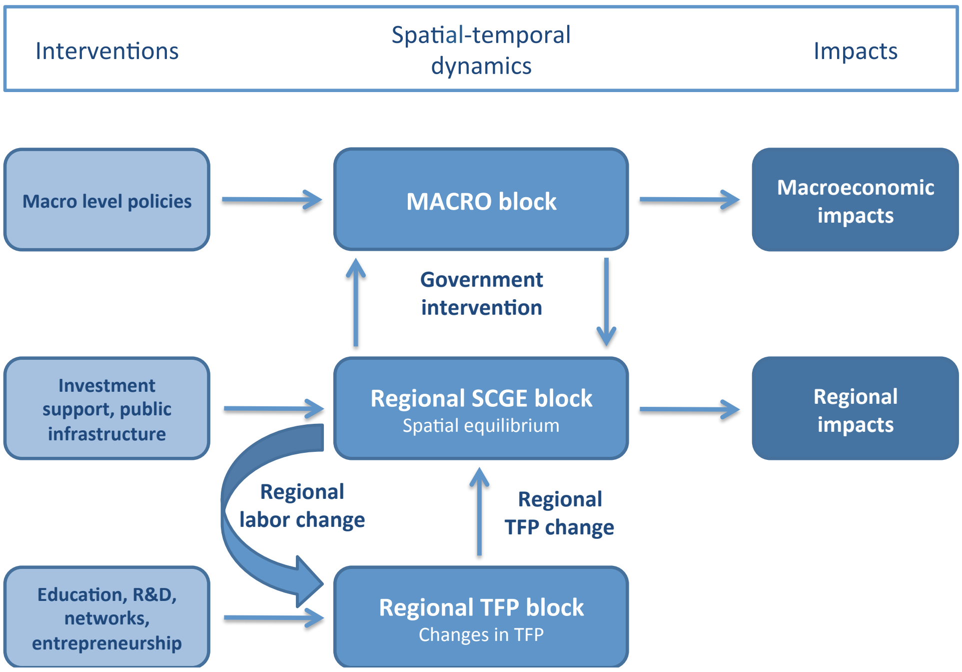

Figure 1: The interconnection of the main blocks, policy variables and impacts in the GMR-Hungary model

[4] Further details about the modelling approach, datasets and estimation can be requested from the authors.
[5] This solution represents a fiscal policy rule, targeting a public debt to GDP ratio.

2.2.4. Interactions between the sub-models

Figure 1 shows the interactions of model blocks within the mutually interconnected modelling system. As mentioned before, the TFP block controls changes in regional productivity levels, which provide the core inputs to the SCGE block. Changes in regional productivity levels then influence the allocation of production factors, production, trade, migration, etc. The SCGE block calculates how regional economic variables respond to these effects, as a result of overall market clearing within and across regions and industries. On the other hand, changes in prices, tax revenues, economic growth will have an impact on government spending in the next year calculated by the MACRO block. A change in deficit thus influences current demand of different products through public spending, but on the other hand the deficit must be financed by domestic or foreign savings. As a result, higher deficit will have a considerable investment loss, which influences long-term growth possibilities. We account for labor migration and capital accumulation between two discrete time periods. In the next time period, changes in employment (as a result of the above effects) are channeled back to the regional TFP block accounting for increased positive agglomeration effects in knowledge production . With higher level of regional employment productivity is further improved *ceteris paribus*, which is then channeled back to the SCGE block and the iteration goes on. As a result of the interactions between each block both, supra regional (national) and regional economic impacts are calculated.

As also shown in Figure 1, different policy interventions can be introduced at different levels of the model framework. Innovation-related interventions (e.g. R&D support, educational programs, network-development, entrepreneurship programs, etc.) are handled in the TFP block. Region-specific investment support, infrastructural developments are accounted for in the SCGE block, while macro level policies are simulated by the MACRO block (e.g. changes in government spending, tax rates). The direct and indirect effects of all these interventions will flow through the other model blocks and the final economic impacts are determined by the simultaneous interactions between these model components, together with the inner mechanisms of each. As a result, our policy impact simulations are able to track the likely effects of a variety of policy interventions, taking into account complex spatial and inter-industrial interaction mechanisms.

3. An illustrative policy impact assessment: Which activity to support from potential alternatives?

In general, smart specialization lacks strong empirical foundations in selecting the most promising regional industries and estimating the expecting growth of supporting those industries. In this section we illustrate the capabilities of the newly developed multisectoral GMR-Hungary impact assessment model of contributing to the prioritization process. First, we introduce our approach of selecting the most promising industries in a region based on a network centrality measure (eigenvector centrality) which estimates the spillover capacities (Foray 2015) of potential new activities that diversify the industries. If this centrality is high it means that there is a high probability of future collaboration, learning and knowledge flows between the target industry and other industries in the region since they have many intensive interactions (as buyers and suppliers). Second, we are also interested in the medium run economic impacts as well since centrality is not a guarantee of medium-run economic return of industry support policies. In order to approximate these economic impacts, we use the multisectoral GMR-Hungary model. Combining the two approaches we believe that the results can help policy makers better identifying promising domains in different regions.

3.1 Step 1: Measuring the spillover capacity of industrial sectors

Motivating centrality – spillovers

When it comes to knowledge spillovers, there is an increasing recognition that the structure of the network within which actors are embedded and through the links of which information and knowledge flows are important. These knowledge networks are shown to be important for innovation and diffusion (see e.g. Stuck et al. 2015, Grabher 2006, Glückler 2007). Some studies also emphasize that different actors can have different access to knowledge due to their differing embeddedness into these networks (Giuliani and Bell 2005, Boschma and ter Wal 2007, Sebestyén and Varga 2013). One of the most prominent aspects of this embeddedness is how central actors are within these networks (Stuck et al. 2015). There is also a wide literature emphasizing that different aspects of network position, the most prominent of which is network centrality, significantly contributes to the innovative performance of actors (see e.g. Zaheer és Bell (2005), Powell et al. 1999, or Tsai 2001).

Eigenvector centrality

There are several ways to express how central nodes are in the network. The most common approach is to simply count the number of links a given node has or summing up the weights of these links – this is called degree centrality and it is shown to be an important description of nodes' position in a network (see e.g. Barabási, 2016). A shortcoming of this simple approach is that it only considers the direct partners of a node and disregards their embeddedness in the wider network. Two commonly used alternatives are the closeness and betweenness centralities (see e.g. Wassermand and Faust, 1994), where the former shows how close a node is to others on average (measured by the number of steps required to reach one node from the other) and the latter reflects how frequently a node lies on shortest paths between others.

Another commonly used measure is the eigenvector centrality (see e.g. Bonacich, 2007), which builds on a recursive definition: a given node is assumed to be more central if its partners are more central as well. Formally, we can define

$$c_i = \frac{1}{\lambda}\sum_{j=1}^{n} a_{ij}c_j \tag{1}$$

where c_i measures centrality, a_{ij} is the general element of the adjacency matrix of the network, reflecting the existence or the strength of connection between nodes i and j, while λ is a constant. When written for all nodes i, the expression in (1) can be written in the following matrix form:

$$\lambda\mathbf{c} = \mathbf{Ac} \tag{2}$$

where c is the vector of centralities and A is the adjacency matrix of the network. Equation (2) is an eigenvalue problem and it can be shown that the eigenvector corresponding to the dominant eigenvalue of **A** provides the adequate centrality measures as defined above. The merit of this measure of centrality is that it takes into account the whole network and the embeddedness of nodes in it. The method gains special interest in our context, where

The applied method

As outlined above, we use the eigenvector centrality method to describe the spillover capacity of sectors in a region. In order to do this, we focus on the regions separately and evaluate the embeddedness of sectors within the regional economies. The proxy we use is the observed input-output linkages between sectors which correspond to two of the most important channels of knowledge spillovers namely buyers and suppliers.

Let's denote the matrix of input and output linkages by $\mathbf{R}$, where the general element $r_{pi,qj}$ represents the transaction volume between sector j in region q as the buyer and sector i in region p as the supplier. Note that this network of transactions is directed. First we render the network undirected by simply adding the two-way transaction volumes: $\bar{r}_{pi,qj} = \bar{r}_{qj,pi} = r_{pi,qj} + r_{qj,pi}$. These values are stored in matrix $\bar{\mathbf{R}}$.

In our calculations, centralities are calculated on intra-region linkages. This means that we separate diagonal blocks of matrix $\bar{\mathbf{R}}$, corresponding to regions. Technically, the intra-regional network of region r is considered as $\bar{\mathbf{R}}^r$, where the general element is $\bar{r}_{ij}^r = \bar{r}_{ri,rj}$. After setting up these undirected, intra-regional transaction matrices, the centrality measures of the sectors is region r are obtained as the elements of the eigenvector corresponding to the dominant eigenvalue of $\bar{\mathbf{R}}^r$.

We have to note two things. First, the obtained centrality scores are invariant up to a scaling constant – they reflect the relative differences of the centralities of the sectors. And second, they are not directly comparable across regions as they result from separate eigenvector calculations. In order to provide a type of comparability, we calculate the average centrality scores in every region and use these values as normalizing constants for the raw centralities:

$$\hat{c}_i^r = \frac{c_i^r}{\bar{c}^r}$$

where c_i^r are the raw centrality score of sector i in region r, $\bar{c}^r$ is the average of these scores in region r while $\hat{c}_i^r$ are the normalized centrality values, which reflect the percentage deviation of the centrality of sector i in region r from the regional average.

3.2 Step 2: Economic impacts of the selected industries

Centrality is helpful in the prioritization stage to indicate spillover capacities. On the other hand, total regional economic effects of supporting selected industries can be simulated by a comprehensive impact assessment model. In our scenario, we examine the effects of an identical, but separate investment support to every industry in every region. We set the size of the industry-specific intervention equal to 1% of the total regional capital stock. Then we distribute this investment support over 9 years between 2014 and 2023 based on the expected trend of distributing EU funds (illustrated by Figure 2) which is based on past Hungarian experiences. Then this investment support policy is applied to every industry in every region separately in order to map their regional economic impacts.

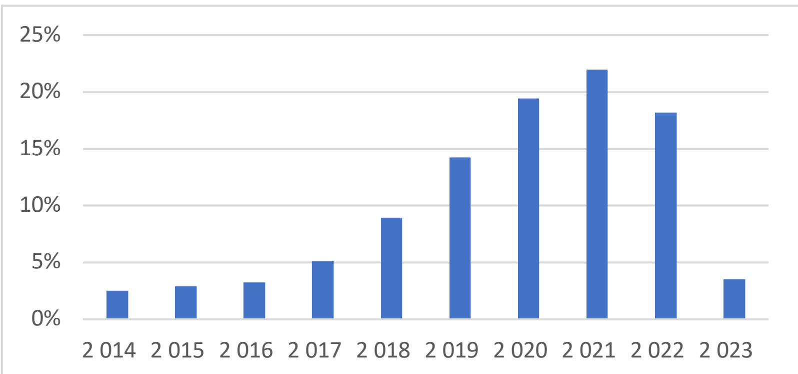

Figure 2: The distribution of investment support over time

We measure economic impact as the average annual change of total regional value added between 2014 and 2029. We emphasize that in this experiment we are interested in the total regional effects of industry support policies. Some support programs can be very effective at the industry-level but if the sector is not embedded in the local economic structure, regional impacts are expected to be lower. In this framework, we assume that industries that are central, i.e. well embedded in the region through their supplier and buyer relationships, can be an important source of knowledge flows between different actors of the regional economy, heavily contributing to long-term competitiveness and economic development of the whole region. On the other hand, there is a possibility that even a central industry is not able to generate significant short-run economic effects since many other things can influence economic impacts as detailed in the Introduction. In this section we illustrate the relationship between the measures of centrality and economic impacts in three Hungarian NUTS 3 regions (Budapest, Győr-Moson-Sopron and Baranya county) with significantly different economic potentials. For presentation purposes both measures are compared to each of their regional averages (economic impact and centrality) in the figures below.

Our first county of observation is *Budapest*, the capital city of Hungary. It has a special economic structure since it is considered to concentrate many high value-added, knowledge intensive sectors, typically business services, ICT, R&D and other services. As expected, based on their centrality values most of these activities are highly embedded in Budapest (except pharmaceutical products and publishing-editing services since they have less local inter-industry linkages) and their economic impacts are above average (telecommunication, informatics, administrative and support services, other scientific services).

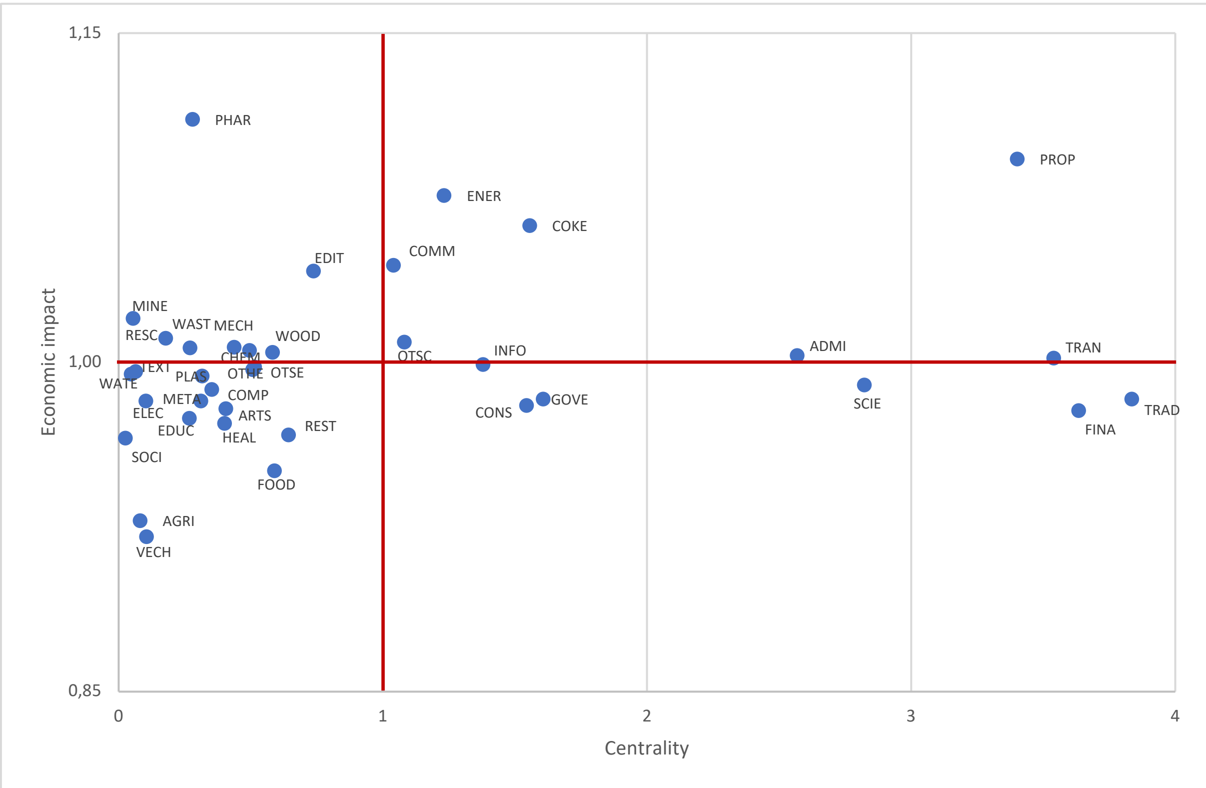

Figure 3: Economic impacts and centrality in Budapest[6]

[6] For detailed description of industries see the Appendix
Note: Red lines in the Figure indicate the level of average industrial centrality and the average growth rate of region at hand as a result of industry support intervention.

There are some sectors, however, that are central by nature: most importantly trade and transportation. These activities are highly embedded since their primary function is to connect all actors of the economy through sales and purchases (inside and outside of the region). Supporting these activities thus results in an increase in the efficiency of the economy by decreasing the production cost of other industries as well as increasing the real income of final users. Real estate services are also one of the central sectors of the economy since all actors require built infrastructure to a given extent. This is extremely important in Budapest where "land" and buildings are scarce resources which is highlighted by our results as well.

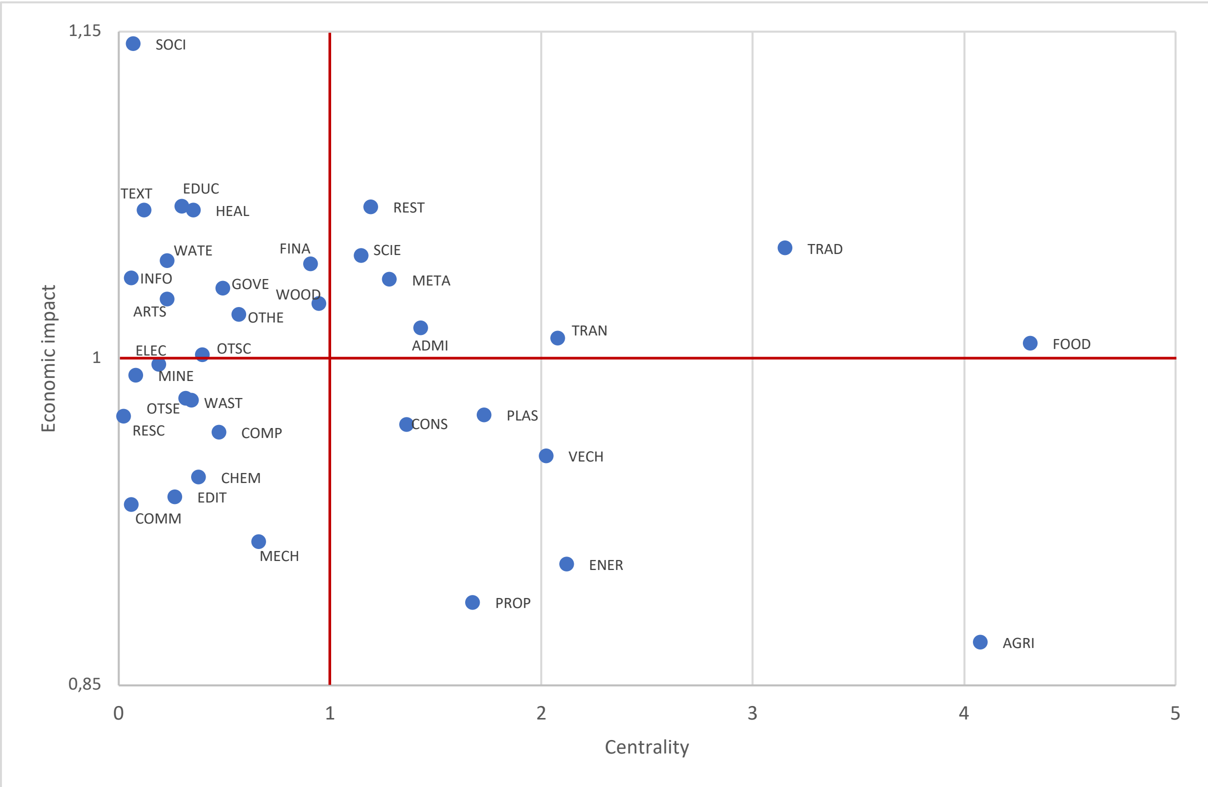

Figure 4: Economic impacts and centrality in Győr-Moson-Sopron county

However, some of the service sectors are not capable of effectively stimulating the regional GDP. In terms of economic impacts, it is surprising that financial services (FINA), and management and other business services (SCIE) were proven to be the less effective priorities. There are many factors that contribute to the total regional economic impact. The intensity of local input-output linkages, including the connection between industries and local final users is one of the most important ones. But industry support program generates additional local income thus final users are able to spend more on goods and services (and savings) which influences industries through consumption and investment. Higher spending means higher tax revenues which can increase government spending as well. On the other hand, the mobility of primary factors also contributes significantly to local growth. As, mentioned before, labor migration in our model is a function of negative agglomeration externalities as well. As a result, the effectiveness of support programs in dense areas might be weakened by these externalities. Since migration considers two factors (per capita real consumption and per capita housing) the improvement of per capita consumption is more significant in less developed regions (and this is further enhanced by the low housing per capita values) thus the positive migration effect of investment intervention (in relative terms) is weaker in Budapest which is already a huge center.

But on the other hand, the dynamic economic environment is capable of attracting more capital to the region which better supports the growth of capital-intensive industries. As a result, we experience that supporting Budapest has a tendency to enhance the spillover capacity of capital-intensive sectors (ceteris paribus) instead of labor-intensive activities. The reason for the poor performance of some sectors can be answered (at least in part) by the aforementioned processes.

Some other industries (surprisingly coke production and the energy sector) are also embedded and their economic impact is quite significant. In this case we need to be aware of the fact that the headquarter of MOL (Hungarian Oil and Gas Public Limited Company) is located in Budapest, although its activities are widespread through Hungary. However, in our database all these activities are accounted for in Budapest. Thus, we believe that the high performance of coke production (and the related energy sector) is a result of this distortion in the dataset. The distortion also affects the level of reference point (average economic impact) which is another reason for the relatively poor performance of some of the business services.

The rest of the sectors are less central and less potent in terms of economic spillover capacity. We can also see that government services, which are heavily concentrated in Budapest, are very central in the region but their economic significance is less than average which is due to the fact that their interindustry linkages are weaker than average.

On the other hand, in less developed regions (such as Győr-Moson-Sopron and especially Baranya) labor intensive industries seem to be performing better (ceteris paribus). *Győr-Moson-Sopron* county is one of the most industrialized regions in Hungary. It is characterized by significant involvement in the manufacture of automobiles and related products. Based on our centrality and economic impact measures (Figure 4) we can identify that there are three kinds of clusters of industries which are in line with our intuition: 1) agriculture and the manufacture of food and beverages, 2) automobile manufacturing and related industries (plastic and metallic products), 3) other industries that are central by nature (wholesale, retail trade, transportation, etc.).

Although motor vehicle production is one of the most dynamic sectors in the economy, the majority of the activity consists of assembling. Most of the components is imported from and the majority of the output is exported to foreign countries. However, there are significant local suppliers as well. As a result of these facts, this sector performs under average in terms of boosting the local economy. Some of its related sectors on the other hand perform better (especially the manufacture of metallic products). Apart from industrial production, the region is specialized in the agro-industry. It seems that food production, which still relies heavily on labor, has better capabilities in stimulating the local economic environment, while agriculture is less potent but still very central.

In contrast to the capital's more balanced economic structure, less developed regions experience larger variation in terms of centrality. There are some highly central activities and the rest of the sectors are characterized by relatively low centralities. On this line, we can find the lowest number of relatively central industries in Baranya. Apart from the relatively industrialized nature of Győr-Moson-Sopron, the rest of the industries does not show a significantly different picture.

The manufacture of food, beverages and agriculture are highly central in *Baranya* as well, which is in line with our expectations since this region has long traditions in these activities. Again, we experience that the food industry performs better than agriculture. Since Baranya is considered as an under-industrialized region in Hungary, we are less capable of identifying key dominant sectors (other than the agro-industry) in contrast to Győr or Budapest. Baranya lacks the productive manufacturing industrial base which could efficiently promote regional growth. Although the energy sector is quite significant in terms of centrality (since all sectors require energy inputs) it does not generate significant economic impacts which is due to the fact that this sector is characterized by high capital intensity and strong extra-regional linkages which weaken its positive local economic impacts.

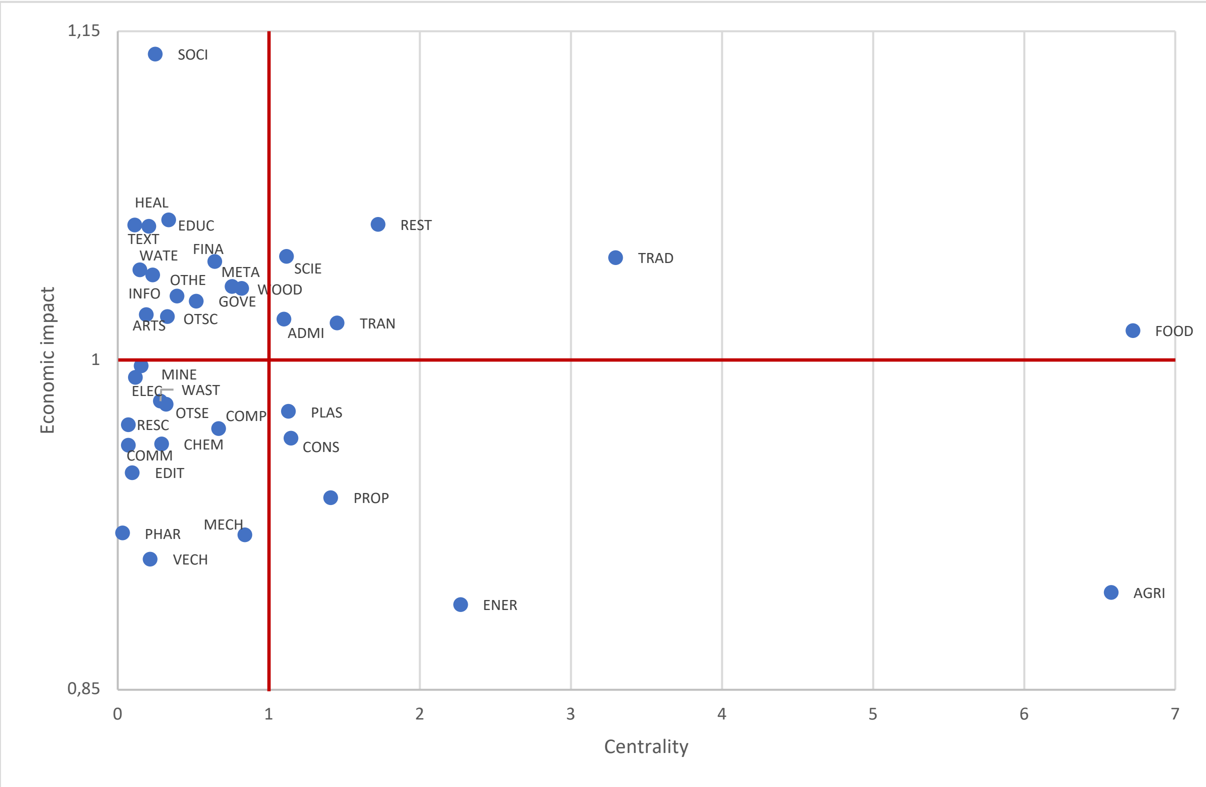

Figure 5: Economic impacts and centrality in Baranya county

Nevertheless, other competitive areas might be identified in Baranya as well since it is rich in gastronomical, cultural traditions. There could be a role of developing tourism since hotel and restaurant services are embedded in the region and they have a high economic significance. Furthermore, it seems that for less developed regions there is a more important role of generally central industries (such as trade and transportation). These regions are more dependent on the rest of the country's economy thus by enhancing the efficiency of interregional trade (providing better access to input and output markets) significant economic growth can be realized. In case of trade there is significant role for multinational retail stores which can provide learning opportunities for regional actors who have intensive connections to these foreign actors. These links are important because they can be found even in less industrialized regions, thus they could provide potential for lagging regions as well apart from the specialization in agriculture and related industries which typically characterize these areas.

4. Summary and conclusions

Smart specialization policy targets industrial restructuring and economic growth, therefore understanding the economic effects of S3 is crucial for policy design and evaluation. Despite its key importance economic impact estimation is not yet part of smart specialization policy (Varga et al., 2018). We developed a framework for economic impact estimation of smart specialization policy for the prioritization stage (ex-ante impact assessment), for monitoring and for ex-post impact evaluation. The recently developed GMR-Hungary model bears the features that make the model capable of carrying out S3 economic impact estimations.

In our illustrative policy simulations, we applied the two dimensional framework suggested by Foray (2015) for prioritization: spillover potential and economic significance. The spillover potential is proxied by the centrality of industrial sectors in the region. Centrality is considered as an important factor of long-term regional restructuring since highly central sectors have intensive connections within the regional economy though which knowledge spillovers can get enhanced. Economic significance is estimated with the latest version of the GMR-Hungary policy impact model. Our findings suggest that there is only a weak correlation between spillover potential and medium-run economic impact due to the fact that economic impacts are determined by a series of mutual interactions between various actors, markets within and between regions.

Our illustrative simulations suggest that developed regions (such as Budapest) have plenty of potentials since many high-value added and knowledge intensive services are both embedded and economically significant. On the other hand, industrial regions (such as Győr-Moson-Sopron) are dominated by a handful of manufacturing industries and not all of the centrally situated industries are capable of generating high regional growth. Finally, lagging regions (such as Baranya) are primarily dominated by agriculture and there is limited potential in developing highly embedded economically significant industries. These findings are in line with previous studies in smart specialization (Balland et al., 2018). Based on the analysis we suggest that a realistic option for Baranya is to build on the traditions in the tourism sector or to enhance the connectedness of the region through trade and transportation.

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Appendix

The list of industries

AGRI	Agriculture (A)
MINE	Mining and quarrying (B)
FOOD	Manufacture of food products, beverages and tobacco products (C 10, 11, 12)
TEXT	Manufacture of textiles, wearing apparel and leather products (C 13, 14, 15)
WOOD	Manufacture of wood and of products of wood, except furniture, paper and paper product and printing and reproduction of recorded media (C 16, 17, 18)
COKE	Manufacture of coke and refined petroleum products (C 19)
CHEM	Manufacture of chemicals and chemical products (C 20)
PHAR	Manufacture of basic pharmaceutical products and pharmaceutical preparations (C 21)
PLAS	Manufacture of rubber and plastic products and other non-metallic mineral products (C 22, 23)
META	Manufacture of basic metals and fabricated metal products (C 24, 25)
COMP	Manufacture of computer, electronic and optical products (C 26)
ELEC	Manufacture of electrical equipment (C 27)
MECH	Manufacture of machinery and equipment n.e.c. (C 28)
VEHI	Manufacture of motorvehicles and other transport equipments (C 29, 30)
OTHE	Other manufacturing, repair and installation of machinery and equipment (C 31, 32, 33)
ENER	Electricity, gas, steam and air conditioning supply (D)
WATE	Water collection, treatment and supply (E 36)
WAST	Sewerage; waste collection, treatment and disposal activities; materials recovery; remediation activities and other waste management services (E 37, 38, 39)
CONS	Construction (F)
TRAD	Wholesale and retail trade; repair of motor vehicles and motorcycles (G)
TRAN	Transportation and storage (H)
REST	Accommodation and food service activities (I)
EDIT	Publishing activities, motion picture, video and television programme production, sound recording and music publishing activities; programming and broadcasting activities (J 58, 59, 60)
COMM	Telecommunications (J 61)
INFO	Computer programming, consultancy and related activities; information service activities (J 62, 63)

FINA	Financial and insurance activities (K)
PROP	Real estate activities (L)
SCIE	Legal and accounting activities; activities of head offices; management consultancy activities and architectural and engineering activities; technical testing and analysis (M 69, 70, 71)
RESC	Scientific research and development (M 72)
OTSC	Advertising and market research and other professional, scientific activities (M 73, 74, 75)
ADMI	Administrative and support service activities (N)
GOVE	Public administration and defense; compulsory social security (O)
EDUC	Education (P)
HEAL	Human health activities (Q 86)
SOCI	Social work activities (Q 87,88)
ARTS	Arts, entertainment and recreation (R)
OTSE	Other services activities (S)