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*Title: Methodological description of the extended GMR-Europe model for the S3 policy evaluation in Centro region, Portugal*

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# Introduction

This report aims to introduce the recent multi-sector expansion of the GMR-Europe impact model which is used for the analysis of S3 interventions in Centro region in Portugal. To prepare the multi-sector sub-model, a regional input-output table is first estimated using the available regional data and national input-output table (IOT). The variables and parameters of the multi-sector model can be initialized and calibrated based on this regional IOT. Next, based on the regional I-O table the one-sector SCGE block of the model is developed into a multi-sectoral model for the selected region. Since many S3 related industry-specific policies affect regional productivity, it is necessary to modify the productivity (TFP) block also.

The structure of the study is as follows. In the second section the estimation of the I-O table is described, then the theoretical framework of the multi-sector sub-model is presented. The fourth section provides the details of the initialization and calibration of variables and parameters. The fifth section explains the multisectoral extension of the TFP block and the methodology of human capital modeling.

# The estimation of the regional I-O table

The regional input-output table is the most important data source which serves as the basis of the calibration of the multisectoral sub-model. However, it had to be estimated since there are no regional IOTs available in the database of the Portuguese statistical office. The estimation of the regional table is not straightforward within the framework of the GMR model. Since the original GMR-Europe is a one-sector model which does not account for interindustry linkages, regional production (value added) is consumed by final users in regions. Thus, interregional trade only consists of final goods. However, in a multisectoral setting trade would consist of both final and intermediate goods which is not consistent with the setup of the GMR model. To overcome this issue, we only accounted for final use part of interregional trade. For this purpose, we used the trade data available in the GMR model for Centro region as a constraint.

The estimation of the regional IOT itself can be divided into two steps. First, the compilation of the initial table, and second, the balancing of the initial table to eliminate any inconsistencies between rows and columns. In the first step the national IOT is usually used to be regionalized using various methods and available regional data. However, for 2012, the base-year of the GMR-Hungary model, there is no available national IOT at the Portuguese Statistical Office, thus we use instead the one from the WIOD database[[1]](#footnote-1). This national IOT is then regionalized using available regional industry level proxy data.

For Centro region, we obtained industry-specific employment and value added data for 36 aggregated sectors[[2]](#footnote-2). The technology of industries is assumed to be identical to the national level technology, thus input coefficients are not changed in the initial table at first. The regional transaction table is calculated by using national coefficients and regional gross output data:

 (1)

Where is the regional transaction table, stands for the national input-output coefficients and is the regional gross output.

For any element that is not known at the regional level in the required industry structure the national variable is regionalized by the ratio of the regional and national sectoral value added:

 (2)

Where is the regionalizing factor, and are the regional and national level industry-specific value added data.

In the case of foreign imports, it is assumed that regional industries have the same import-propensity as national industries.

The aggregated size of interregional trade (both on the import and export side) is given by the data in the GMR model. This is important since the table has to be consistent with the data already stored in the model. The internal sectoral structure of interregional imports was distributed proportionally based on the sectoral value added of the sector and the total demand of end users. Similarly, the structure of interregional export was divided according to the sectoral value added shares. Initially, export and import in each region are set to values that ensure zero trade balance, thus total export and import is identical. We followed the same logic in the regionalization of industry-specific taxes.

Besides sectoral value added, we also obtained data on the components of value added: the sectoral labor and capital expenditures in Centro region. However, these values are not consistent with the partially estimated GMR data, thus based on the data we calculated the industry-shares of compensation of employees, and gross operating surplus to distribute the aggregated values given by the GMR model into industries. However, this distribution scheme does not guarantee consistency with the sectoral GVA values, thus we used a matrix balancing technique (RAS – Stone, 1961) to balance this initial value added matrix which eliminates any inconsistencies to the sectoral GVA values and the total regional labor and capital cost values.

In the case of final users, we regionalized the final consumption of households using per capita consumption values ​​and population assuming that the structure of consumption is identical to the national level structure. In the case of investments, we used the total regional investment data. Since no relevant data is available for the government, in this case we regionalized based on the ratio of total regional value added. In the case of exports, we proceeded similarly, but assumed that the amount of interregional (GMR within Europe) exports was also given by the model in the base year.

Using these data, we compiled an initial regional input-output table (RIOT), which is not consistent with the available column and row totals, thus it needs to be balanced. For this, again, we used the RAS method, which adjusts the table to the predefined margins (sectoral gross output, total consumption, etc.), but the structure of the table created in this way remains as close as possible to the structure of the initial table. This balancing method is only applied to the transaction table and the matrix of final consumption, since the lower segment of the table (resource expenditures) is already balanced.

In the end, we constructed a regional IOT that is consistent to the regional data of the GMR-EU model, as well as the available regional-sectoral statistical data in Portugal. However, this RIOT must be further modified, as the logic of the model outlined later requires this. In the model, the final consumption is taken into account in a net way, so the amount of (foreign and interregional) imports and collected taxes must be deducted from the amount of total regional use (consumption + investment + government consumption + /foreign and interregional/ exports). Thus, this aggregated RIOT with the net approach serves as the basis of the model described below.

# The multisectoral extension of the SCGE block

## The methodology of the extension of the SCGE block

The SCGE block of the GMR-Europe impact assessment model is an aggregated one-sector model which means that all activities are compressed into an aggregated sector. As a result, output is accounted for in a net manner, meaning that inter-industry transactions are not accounted for, and regions export and import one composite products from/to other regions. To account for the sector-specific characteristic of S3 we need to go beyond the one-sector approach. However, redesigning the whole GMR-Europe model is a difficult and resource-intensive process, thus we decided to disaggregate only Centro region into a multisectoral spatial unit to account for industries and interindustry linkages in the model. Apart from that, the overall structure of the GMR SCGE model block is not changed, however the regional variables of the Centro region are broken down into sectoral variables. In this section, we briefly discuss how this sectoral breakdown was carried out. The original model description of the one-sector GMR model can be found in Varga et al. (2018).

**Figure 1:** the schematic structure of the SCGE block of GMR with the multi-sectoral sub-model extension



Source: authors’ own elaboration

In Figure 1 we can see the schematic structure of the SCGE block of the GMR model. On the left-hand side, it can be seen how a ‘normal’ one-sector region is modelled in the block. Regional labor () and capital () are combined into value added () which is the output of regional production. Through interregional trade () this output is then demanded by consumers in many regions where consumption () is financed by regional labor and capital income. Wages and capital prices are set in the regional markets where labor and capital supply (, ) are fixed in the short run (but may be changed over time through migration and capital accumulation).

On the right-hand side we can see the different layout of the multisectoral sub-model. Now labor and capital demand are broken down to industries (, ) in region ‘q’. These factors of production are then combined into sectoral value-added output () which is then combined with interindustry inputs into gross output (). Gross industrial output is then demanded by two users. First, products can be purchased by other industries as intermediate inputs (), and second, by consumers (). This industry-level consumption demand is aggregated into total regional (both local and interregional) demand () according to a Cobb-Douglass function. This total demand expresses the demand of local and all extra-regional actors for the locally produced goods. It must be noted that this intermediate demand remains local, and it does not enter interregional trade since the rest of the one-sector SCGE block cannot account for intermediate use, thus interregional trade consists of only final demand.

The total (local and interregional) demand by consumers located in region ‘q’ () is financed by local labor and capital income, however, in the multisectoral sub-model households can decide in which industries they would like to use their labor and capital supply. The industry specific supply of factors of production is controlled by CET functions.

The SCGE block of the GMR model is then extended by this multisectoral sub-model in the case of Centro region in Portugal, all the other 180 regions remain in the same one-sector model specification. The multisectoral model’s calibration is based on the estimated regional input-output table for the Centro region. The calibration procedure is described in section 4.

## The equations of the sub-model for the Centro region

According to the logic introduced in the previous sub-section, we modify the equations of the original one-sector SCGE block of the GMR model for the Centro region. In this section, we describe the modified equations within the multisectoral sub-model. All other components of the SCGE block remain unchanged.

### The supply side

Companies create their value added using sectoral capital and labor input with Cobb-Douglas technology:

 (3)

Where *YCi* represents sectoral value added, A*Ci* is the sectoral total factor productivity calculated with consideration of economies of scale, *LDemCi* and *KDemCi* denote the size of labor and capital utilization within the sector, respectively. Additionally, and are parameters indicating the calibrated supply elasticities of the production function. From the production function, the equations for sectoral labor and capital demand can be derived:

 (4)

 (5)

Where *wCi* and *rCi* represent the prices of production factors (labor and capital), which are assumed to flow frictionlessly between sectors. Due to the assumption of perfect competition, the zero-profit condition closes the production of value added:

 (6)

Where *PYCi* is the price index of sectoral value added. At the next level of the nested production function, we characterize domestic output using a Leontief-type production function, which takes as inputs the sectoral value added and the demand for intermediate products:

 (7)

Where denotes the total demand of sector for intermediate products. While *aYCi* and *ai,j* are calibrated coefficients expressing the quantity of value added and intermediate products required for one unit of output. From the production function, we derive the equations for value added:

 (8)

Where *XCi* represents domestic output (before using imported inputs). Finally, the zero-profit condition ensures equality between revenues and costs.

 (9)

Where denotes the price of the sectoral output.

### Income

In the sub-model, the amount available for final consumption is determined by income, which is defined by wages and capital income received for labor and capital:

 (10)

Where *YH* is the regional income.

### Utility

The regional utility function takes the following form:

 (11)

Where denotes the regional average utility per capita, represents the regional aggregate demand, is regional housing, is the regional population, and are the share parameters of consumption and housing respectively.

The regional aggregate demand can be calculated as the ratio of incomes and the perceived (considering transportation costs) price () in the region.

 (12)

### The demand side

For simplicity within the current model framework, we treat the elements of final demand (consumption, investment, government consumption) collectively. However, these can be relatively easily disaggregated into their components. Fundamentally, the aggregate final demand would consist of two components: imported and local products. In the GMR model, though, we account for final demand in a net manner, subtracting the region's imports from the total gross final demand value. This logic is in line with the original single-sector GMR model. By following this principle, we ensure that the value of final demand corresponds to the region's income (value added). We utilize this property in the generated table, assuming that in the base year, the total interregional demand for the region's products matches the final demand derived in this manner.

 (13)

Where is the industry level final demand for products that are produced in Centro region (from inside and outside of the region), and YPT16 denotes the total interregional demand for the region's products. FOB price takes the following form:

 (14)

### GDP consistency

As previous adjustments were conducted on an aggregated regional level, due to the multi-sectoralization, the macro consistency of GDP cannot be assured as before. As capital and labor flow between sectors, the structure and volume of output also change. Even if we adjust the values of variables on a regional level, due to the rearrangement of sectoral structure, we cannot guarantee the consistency of GDP. Hence, we introduce an additional condition:

 (15)

Therefore, this equation prescribes that the aggregated sectoral GDP (on the left-hand side of the equation), calculated at appropriate prices, should match the value of the regional GDP, which is corrected to the GDP calculated by the macro block (on the rights-hand side of the equation).

### Intersectoral factor mobility

Due to intersectoral linkages and the integration into the broader GMR framework, it is necessary to allow for the migration of primary resources between sectors in the model. However, we consider it a more realistic assumption that this mobility is not perfect and comes with some friction. Thus, the wage and capital price differences arising between sectors lead to only moderate migration. We implemented this using CET functions for both labor and capital:

 (16)

Where represents the regional total capital stock, denotes the sectoral capital supply, is the shift parameter of the CET function, is the share parameter, and is the elasticity of transformation parameter. The supply function derived from the CET function takes the following form:

 (17)

Where represents the sectoral capital price, is the regional average capital price, and is the elasticity of transformation. The capital supply is closed by an equation that prescribes the equality of the value of the regional capital stock and the aggregated sectoral capital value:

 (18)

The CET function describing the flow of labor between sectors takes the following form:

 (19)

Where represents the regional total labor force, denotes the sectoral labor supply, is the shift parameter of the CET function, is the share parameter, and is the elasticity of transformation parameter. The supply function derived from the CET function takes the following form:

 (20)

Where represents the sectoral wage, is the regional average wage, and is the elasticity of transformation. The labor supply is closed by an equation that prescribes the equality of the values of the regional labor force and the aggregated sectoral labor:

 (21)

### Equilibrium conditions

In the model closure, it is necessary to prescribe the equality of demand and supply in the markets of products and primary resources. For products, this implies that local product supply must cover local final and intermediate demand:

 (22)

In the case of the labor and capital markets, by aggregating sectoral demands, we obtain the regional demand magnitudes, which are closed by the SCGE block through the short-run fixed labor and capital supply.

 (23)

 (24)

Where the sectoral supply of labor and capital is treated as an exogenous condition within a given period. However, optionally between periods, we can allow for more/less capital to flow to the individual sectors compared to the previous periods due to the effects of sectoral wage and capital price changes.

# Calibration principles

In this section, on the one hand, we provide a detailed description of the way variables are initialized based on the regionalized I-O table, additional data and the model equations. On the other hand, we account for the detailed description of the calibration method used to calculate the different model parameters.

## Value added

With the initialization of variables, we follow the same model structure as in Section 2. First, we start with the production factors of production, value added and their respective prices. Using the compensation of employees and the number of employees we initialize the sectoral wage in the region:

 (25)

Where is the sectoral wage rate, is the sectoral compensation of employees, is the official number of employees by industries.

Since we do not have sectoral information on the capital stock in the region, we decided to assume that in the initial state sectoral capital prices are equal to the aggregated regional price of capital which is given by the original GMR model. Then, using this price and the gross operating surplus data from the I-O table, we calculated the estimated capital stock in industries as follows:

 (26)

Where is the sectoral price of capital, is the sectoral gross operating surplus, is the estimated sectoral capital stock.

Using factor quantities and prices, the initial value of sectoral value added is given by the zero-profit condition (Equation 4):

 (27)

Where is the sectoral value added, is the initial price index which is normalized to unity.

The sectoral share parameters of the production function () are calculated similarly to the ones in the original GMR model where in the case of labour parameters, economies of scale[[3]](#footnote-3) is also taken into account () in a sector-neutral way.

 (28)

 (29)

As a result, the sum of share parameters is larger than unity. We, then use these parameters to initialize the sectoral total factor productivity ():

 (30)

However, at this point, the share parameters, sectoral wages, capital prices, and the VA price indices are not consistent due to the introduction of economies of scale (Lγ). Therefore, during the calibration, using equations (1), (2) and (3), we recalibrate the values of the sectoral wage and capital prices in such a way that all three equations are satisfied with the initialized sectoral value added, labor and capital, and output price. The determination of these values is carried out by the solver of the Gams software, and then later these factor prices (wC1 and rC1) will be used in calculations.

## Gross output

The initial value of sectoral gross output can be calculated using the zero-profit condition of equation (5) and data of intermediate use from the I-O table as follows:

 (31)

Where and are the sectoral gross output values and their respective price indices (initially normalized to unity), and is the intersectoral use of products.

The coefficients of the Leontief production function were calculated based on these initial values as follows:

 (32)

 (33)

Where and are the coefficients of the composite resource (value added) and intermediate inputs respectively.

## Sectoral consumption

Initial values of consumption demand () is derived from the data in the I-O table:

 (34)

Where is the nominal value of final demand in the region by industries.

Using equation (24), share parameters () of the CES demand function can be calibrated as follows:

 (35)

Where is the total interregional demand (from inside and outside the region) towards products produced in Centro region (composite output), and is the price index of this demand (both are originated from the original GMR-EU model). In this formulation aggregated regional demand is broken down to the sectoral level via a CES function.

Then, the shift parameter () can be also determined:

 (36)

Where is the elasticity of substitution, while is the elasticity parameter.

## Income

The total income of final users is given by equation (8) as follows:

 (37)

## Intersectoral factor mobility

Based on the sectoral labour supply function (equation 17) the share parameters of sectoral labour supply can be calibrated as follows:

 (38)

Using the CET function the share parameter can also be determined:

 (39)

Similarly, in the case of capital, based on the sectoral capital supply function (equation 19) the share parameters of sectoral capital supply can be calibrated as follows:

 (40)

Using the CET function the share parameter can also be determined:

 (41)

# Changes in the TFP block

## The multi-sector extension of the TFP block

In order to account for industry-specific economic and productivity effects of industry-specific policy intervention the productivity block must be extended as well. In this case, however, the original model structure is preserved, and it is applied to each industry. This procedure is done in three steps:

1. We run the TFP model separately for each and every industry-specific shock to estimate the regional productivity effect of each industry-specific intervention. This way for each policy instrument we define 36 industry-specific regional TFP timeseries.
2. We calculate 36 GDP time series using the base-year labor, capital data and the baseline and the scenario (1. step) TFP timeseries. This GDP timeseries describes how regional GDP might change due to productivity changes only.
3. We adjust industry-specific TFP values separately until the aggregated industry-level GDP (using the base-year industry-level labor and capital inputs) matches the regional GDP value calculated in step 2. If there is difference between the 2 GDP measures, industry-level TFPs are changed in proportion to the initial size of TFP effects (step 1) until the difference is eliminated.

## The methodology behind modeling human capital accumulation

The modelling of the potential effects of funding on human capital follows the approach used by Jones (2002). Human capital is accounted for as the efficiency of trained individuals in the economy. Training and education over time has a delayed positive impact of efficiency which remains (and decays without further educational efforts) over time. In the original model Jones (2002) defined different types of labor (s) and education and training support affected different groups differently. However, the GMR model does not differentiate skill-specific labor types, and we have only limited information on the exact use of education funds, thus we employed a simplified model with only one aggregated human capital type.

In this framework, the efficiency of human capital is defined as follows:

 (42)

where and are the efficiency of human capital in period t and in the base year, is the average years of schooling in period t and ψ is a return to schooling parameter, which shows how one unit improvement in the years of schooling improves human capital efficiency. Its value is set to 0.07 based on Jones (2002).

By assumption, education and training support increases the years of schooling according to the equation below:

 (43)

Where is the base-year years of schooling, and is the average time spent in traning as a result of education support. Where is the year equivalent of the average time spent in training in period t which is determined by the following formula:

 (44)

Where is the exit-rate of working age population (~3.7%), and is the average year-equivalent of training funded in period t, which is the main policy variable of this model which connects the funding data to human capital modelling. The year-equivalent of training is given by the formula below:

 (45)

Where shows how many students can participate in education and training for one year due to the funding provided. This can be interpreted as the absolute change of training participation (how many additional years are spent in education by all the students). To calculate the change of the average year-equivalent of training, we need to divide this absolute change by the number of individuals in the job market (*empt*), which gives us the average increase in the time spent in education and training for all the job market participants.

With no intervention the average time spent in training is set to zero, thus there is no change in the years of schooling, thus human capital efficiency remains unchanged over time (*ht=1*). However even a single-year support to education will have a permanent effect on time spent in education (which decreases over time by the exit-rate). The permanent change in time spent in training will increase years of schooling and indirectly human capital efficiency. Without further educational stimulus efficiency gains slowly decay over time (and get back to the initial level eventually).

# References

Jones, C. I. (2002). Source of U.S. economic growth in a world of ideas. American Economic Review, 92(1):220-239.

Stone, R. (1961): Input-Output and National Accounts. Paris: Organization for Economic Cooperation and Development.

Varga, A. – Sebestyén, T. – Szabó, N. – Szerb, L. (2018): Economic Impact assessment of Entrepreneurship policies with the GMR-Europe Model. FIRES research report. Deliverable 4.6.

1. Since the GMR model is calibrated on 2012 PPS data first we converted the original USD WIOD IO table to the consistent unit. [↑](#footnote-ref-1)
2. In the case of missing sectoral data, we used proportional distribution. [↑](#footnote-ref-2)
3. For modelling details see Varga et al. (2018). [↑](#footnote-ref-3)