Application of MRIO model on a small economy: case study of the Czech Republic

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Introduction

Examination of inter-sector relations in national Input-Output tables is very important and popular. It helps us to predict and model changes in the economy when particular "shock" occurs. This analysis is useful not only for the whole nation and the neighbouring states, but also for the interregional level. Generally, we can distinguish two main types of the regional input-output models – interregional (IRIO) and multiregional (MRIO). According to theory (see e.g. Miller and Blair, 2009) the IRIO models are much more data demanding, therefore, more attempts to construct regional input-output models can be found of MRIO type. Popularity and importance of this topic was proved by the fact that the whole special issue of *Economic Systems Research* Journal (**25**:1, March 2013) was dedicated to the MRIO models. However, it is always necessary to define the "level" of regions. In the Special Issue these were mostly the world states (e.g. EORA, EXIOBASE, GTAP, IDE-JETRO or WIOD). We are in this paper focusing at the "real" regional level, i.e. sub-national parts of one state, namely 14 NUTS 3 regions of the Czech Republic. The aim of this paper is to present the main findings when applying the MRIO model on a small and open economy, namely 14 NUTS 3 regions in the Czech Republic.

The paper is divided into several sections. Section 1 brings an insight into the topic and describes the first necessary steps in construction of the model and some preconditions which were essential to decide about at the very beginning.Section 2 depicts decisions connected with regional structure of the Czech Republic and specifics of its regions. Section 3 briefly discusses the most difficult part – estimation methods of interregional trade and section 4 introduces method that we used for the first estimate. Section 5 contains the results and discussion of them. Last section concludes.

1 Theoretical background

1.1 SIOT tables in the Czech Republic and regional IO models

At this time input-output tables are regularly published in the Czech Republic by the Czech Statistical Office only at national level. Supply and use tables (SUT) are available every year, symmetric input-output tables (SIOT) every five years (plus additionally the year 2009) in the form of product-by-product, industry-by-industry and product-by-product based on the Almon procedure. SIOTs are officially published in the Czech Republic for 82 products in classification CZ-CPA, however they can be computed for 88 or 110 products as well.Figure 1 shows structure of Czech SIOT table.

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Figure 1 – Czech SIOT table

Symmetric Input-Output table
product x product
2010

Current basic prices
CZK million

CZ-CPA products	Name	CZ-CPA products INTERMEDIATE CONSUMPTION					Final Consumption Expenditure			Gross fixed capital formation incl. valuables	Changes in inventories	Exports (FOB)	Final use total	Used resources total	CZ-CPA products
		Products of agriculture, hunting and related services	Products of forestry, logging and related services	...	Other personal services; undifferentiated goods and services produced by private households for own use; services provided by	Total	Households	Governments	NPISH						
		01	02		96+97+98+99		P.3			P.51+P.53	P.52	P.6			
01	Products of agriculture, hunting and related services														01
02	Products of forestry, logging and related services														02
...															...
96+97+98+99	Other personal services; undifferentiated goods and services produced by private households for own use; services provided by extraterritorial organisations and bodies														96+97+98+99
P.2	**Intermediate consumption (basic p.)**														TOTAL
D.21-D.31	Net taxes on products														
P.2	**Intermediate consumption (purchasers' p.)**														
D.1	Compensations of employees														
D.29-D.39	Other net taxes on production														
K.1	Consumption of fixed capital														
B.2n+B.3n	Operating surplus, Mixed income, net														
B.1g	**Value added, gross**														
P.1	**Output (basic p.)**														
P.7	**Import**														
	Resources														

Source: CZSO, 2014, authors' adaption

This paper is aimed at the construction of a multiregional input-output (MRIO) model in terms of a small and very open economy. If we consider general equation (1) of IO tables (see Miller and Blair, 2009, for details), where **x** stands for total gross output, **f** for final demand and **L** for Leontief inverse matrix[3],

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{f} = \mathbf{L}\mathbf{f} \quad , \quad (1)$$

the main difference among interregional and multiregional models lies in the computation of technical coefficients matrix **A** (in case or RIOT defined as $\mathbf{A^r}$ or $\mathbf{A^{rr}}$). Whereas in case of the IRIO model, we take into account the region of origin as well as region of destination, in case of the MRIO model the region of origin is neglected. This leads to computations of technical coefficients (elements of matrix **A**) according to equation (2) for case of the MRIO model

$$a_{ij}^{r} = \frac{z_{ij}^{\cdot r}}{x_j^r} \quad , \quad (2)$$

and according to equation (3) for case of the IRIO model

$$a_{ij}^{rr} = \frac{z_{ij}^{rr}}{x_j^r} \quad , \quad (3)$$

where $z^{rr}{}_{ij}$ stands for crown flow of a good in sector *i* from region *r* to sector *j* in region *r*, and $z^{\cdot r}{}_{ij}$ shows neglecting of region of origin; $x^r{}_j$ stands for total output of sector j in region r.

Regional input-output models provide a set of economic multipliers that can be used to monitor the effects of changes in the demand for economic activity in a given region, mostly individual changes in final demand through the economy in a short-time period. We call such models as impact or multiplier models. The issue of regional multipliers that uses a more general concept including multipliers in the field of employment, income, households but also government revenue, is often used for the impact analysis at a regional level.

1.2 Regional input-output multipliers[4]

In the input-output model for one region *r* is one way of capturing regional relationships among sectors given by a matrix $\mathbf{A}^{\mathrm{r}}$ obtained by multiplying the vector of inputs' proportions required by individual sectors and matrix of technical coefficients **A**. If we consider the estimates of households' inputs (household consumption and income produced in the region), the model can be closed with respect to households with the fact that it allows us the calculation of regional multipliers of total income.Regional multiplier for *j*-th sector is obtained as a sum of *j*-th column of Leontief inverse matrix. We consider matrix of technical coefficients for a two-region interregional model

$$\mathbf{A} = \begin{bmatrix} \mathbf{A^{rr}} & \mathbf{A^{rs}} \\ \mathbf{A^{sr}} & \mathbf{A^{ss}} \end{bmatrix} \quad (4)$$

and Leontief inverse matrix

[3]Leontief inverse matrix is defined as $\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1}$.

[4]For more in-depth analysis of regional input-output multipliers see Miller and Blair (2009).

$$\mathbf{L} = \begin{bmatrix} \mathbf{L_{11}} & \mathbf{L_{12}} \\ \mathbf{L_{21}} & \mathbf{L_{22}} \end{bmatrix} \quad . \qquad (5)$$

The basis of the IRIO and MRIO models lies in the fact that they include impacts in one region (*r*) caused by changes in another region (*s*), often referred to as interregional spill-over effects captured by sub-matrices $\boldsymbol{L_{12}}$ and $\boldsymbol{L_{21}}$. Using theIRIO model, three multiplier effects can be found. One group is formed by intraregional effects. If we consider two regions *r* and *s*, then we obtain a multiplier for region *r* by multiplying unit vector and sub-matrix $\boldsymbol{L_{11}}$ and analogously a multiplier for region *s* by multiplying unit vector and sub-matrix $\boldsymbol{L_{22}}$. Another group is formed by interregional effects. Interregional input-output models include impacts in one region caused by changes in another region (so-called interregional spill-over effects) and these impacts are captured by sub-matrices $\boldsymbol{L_{12}}$ and $\boldsymbol{L_{21}}$. And finally, the third group includes national effects. If we consider the existence of exogenous growth rates in the final demands for goods of region *r*, then the national effects in the sectors' outputs of region *r* are represented by the column totals of sub-matrices $\boldsymbol{L_{11}}$ and $\boldsymbol{L_{21}}$. For region *s* national effects are represented by the column totals of sub-matrices $\boldsymbol{L_{12}}$ and $\boldsymbol{L_{22}}$.

All multipliers in the IRIO model have its counterparts in the MRIO model. Each of the components of interregional case has its estimated counterpart in multiregional case. The multiregional model can be written by equation (6), compare with equation (1)

$$\mathbf{x} = (\mathbf{I} - \mathbf{CA})^{-1}\mathbf{Cf} \quad . \qquad (6)$$

An important fact is that exogenous sectors in the IRIO model represent final demands for goods produced in a particular region, whether they are allocated anywhere. In the MRIO model vectors **f** represent demands for goods performed by exogenous sectors allocated in a given region, whether it was manufactured anywhere. The matrix **C** distributes final demands through supplying regions in accordance with the proportions contained in components of matrix **C**. Finding of intraregional, interregional and national effects is based on the same principles as for the interregional input-output multipliers.

1.3 Steps done so far

Our aim is to construct regional input-output tables (RIOT) for 88 products and subsequently the MRIO model for further analyses. Creation of our model consists of several phases.The first step was definitely the regionalisation of components of expenditure approach to GDP to 14 NUTS 3 regions (Final households' consumption expenditures, Final government consumption expenditures, Final NPISH consumption expenditures and Gross Fixed Capital Formation). The previously estimated regional price levels (see e.g. Cadil et al., 2014) were included into computations. Then the commodity breakdown needed to have been estimated and balance for each product in each region was found. For details see section 4. The next steps are estimation of foreign trade (see in the next sections) and the matrix of intermediate consumption.

There have so far been no attempts to construct regional input-output tables as there are several obstacles.One of them is definitely the missing compilation of regional GDP using consumption approach (for comparison of all three compilation approaches in the Czech Republic environment see Kahoun and Sixta, 2013). However, first experimental estimates are already available (Kramulová and Musil, 2013). The second, even more complicated, is the problem with estimation

of foreign trade at the regional level (see e.g. Bracalente and Perugini, 2010, Chlad and Kahoun, 2011 or Harris and Liu, 1998). Apart from international trade, it is necessary to take into account also the interregional trade. And data sources at the regional level are really very scarce. We will discuss in section 3 possible approaches to estimate the trade as this is the main task standing in front of us at the moment.

2 Regional structure of the Czech Republic

We have already mentioned that Czech Republic is a small and open economy. Let us introduce these two characteristics more closely. In the whole Czech Republic there live around 10.5 million inhabitants and it is divided into 14 NUTS 3 regions ranging from approximately 300,000 inhabitants in case of Karlovarsky kraj up to slightly less than 1.3 million inhabitants in case of Stredocesky kraj and Praha (Prague). The regional distribution is shown in Figure 2.

Figure 2 - NUTS 3 regions in the Czech Republic

Source: Ministry of Transport, 2005, authors' adaption

This means that regions are really quite small and moreover interrelated. It occurs quite often that people living in one region work in (and every day commute to) another, not necessarily neighbouring, region. This phenomenon is mostly significant in surrounding regions of big cities, which offer better opportunities of work. This openness of regions brings some other important consequences. It is clear that shares of interregional and international transactions on total transactions in the regions are highly significant. These regions vary quite a lot, especially from the point of view of economic performance or sector specialization. For example he capital city of

Prague forms a separate region (actually a city region) and it is obvious that its economy substantially differs from the surrounding region, which has more or less the function of its suburb, or some other more rural regions.

3 Methods for estimation of trade

As it was already stated, interregional trade is the most difficult to estimate. The main problems consist in so-called cross-hauling (i.e. cross-border trade among regions) and missing data on commodity flow among regions. There are generally more approaches that may be used for estimate of the trade. Each of them has advantages and disadvantages. The main disadvantages are usually strong preconditions of the methods.

Very frequently used are different types of location quotients (see e.g. Tohmo, 2004). They were experimentally computed also in the Czech Republic, at least for two regions – Moravskoslezsky kraj (Skokan, 2004) and Jihocesky kraj (Bednářová, 2007). However, these computations served predominantly for the identification of clusters. However, e.g. the precondition that there exists no trade with the same product is very strict. Riddington et al. (2006, p. 1069) confirm that using "location quotient approaches may produce misleading results". Among other approaches we can mention e.g. gravity models (Riddington et al., 2006 or Casini Benvenuti et al., 1996). Next section will introduce our approach that we used for the first estimate of the trade.

4 Our approach to trade estimate

It was introduced earlier, that the Czech Statistical Office does not publish data on expenditure approach in regional breakdown. Firstly, final consumption expenditures and gross capital formation were estimated. Final households consumption expenditures (FHCE) form the biggest expenditure component (about 50 % at the national level), but this share varies at the regional level (Kramulová and Musil, 2013). FHCE in regional breakdown were estimated using many regionalisation keys; calculations were done in COICOP classification in which national data and regionalisation keys are available. National transition key (COICOP x CPA) was used for transformation of the data into product classification CPA. Final government consumption expenditures consist of two components: non-market output and social benefit in kind. Non-market output was regionalised by compensation of employees in industrial division. The main part of social benefit in kind forms health services that were regionalised by revenues of hospitals from health insurance companies. Other social benefit in kind was allocated to regions by Mid-Year Population. Final consumption expenditures of non-profit institutions serving households were estimated similarly. Gross fixed capital formation is estimated regionally and published by the Czech Statistical Office. Changes in inventories were estimated by gross value added of industries in which inventories can occur. Net acquisition of valuables, which is a negligible item, was regionalised by structure of gross fixed capital formation. In the first step all macro-aggregates were estimated in purchasers' prices. In order to obtain macro-aggregates in basic prices all valuation sets had to be estimated. There are no special regional taxes and subsidies on products in the Czech Republic, therefore taxes and subsidies were allocated to regions proportionally to uses at purchasers' prices. The same approach was applied to transport and trade margins, though luxury

products with higher rate of trade margin are sold mainly in Prague. Authors are convinced that a share of these products is quite small and it does not influence the results.

The difference between output approach and above mentioned components of expenditure approach is caused by net export that consists of interregional and international trade. There is no data source for estimation of export and import of regions. Therefore, we have developed a model for estimating export and import of regions that is suitable for small countries. International export and import was divided into three parts: export/import of goods, purchases of non-residents abroad; purchases of residents abroad respectively and export/import of other services. We suppose that export capability of all regions is the same i.e. a share of export of product on its output is the same. This approach is applied on export of goods and export of other services. Tourism Satellite Account (namely the indicator "Number of overnight stays in collective accommodation establishment") was used for regionalisation of purchases of non-residents. Tourists spend most nights in Prague (about 60%) and in Karlovarskykraj (about 17%). Later, the data are transferred from purchasers' prices to basic prices as described above. We suppose the same valuation on goods on the border of the country as on the border of the region. This is in line with current practice of the Czech Statistical Office, because the value of export of goods at basic prices and in FOB (free on board concept) is the same.

International import of goods was allocated into regions by domestic uses at basic prices. As non-market output cannot be internationally traded, social benefit in kind is only taken into calculation for government and NPISH consumption expenditures. Purchases of non-residents at basic prices are taken into accounts because also non-residents can buy imported goods (e.g. whiskey). Import of other services was regionalised by intermediate consumption at basic prices as we expect no final use of these services. Purchases of residents abroad were allocated to regions by final household consumption expenditures. An assumption of the same share of purchases of residents abroad on FHCE in all regions is quite strong and the share can vary because of different regional standard of living. On the other hand, the share of purchases of residents abroad on total import or on final household consumption expenditures is small.

5 Results and discussion

Estimated international export and import are shown in the Table 1. The highest surplus of foreign trade is observed in Středočeský kraj. This region is quite export-oriented with two huge car factories (Škoda Auto and Toyota Peugeot Citroën Automobile) that export significant part of their output. Balance of international trade is in deficit in the capital city Praha. There is a very small production of goods that have to be imported, e.g. cars. Net export of goods is about -170 000 mil CZK which is partly compensated by net export of services. Total balance of foreign trade (international and interregional) has significant surplus, about 150 000 mil CZK (Kramulová and Musil, 2013). It means that balance of interregional trade is in surplus that is caused by several reasons. Commuting from Středočeský kraj to Praha is usual because Praha offers more job opportunities than any other region in the Czech Republic. Commuters spend a part of their expenditures in Praha that are recorded as export of services in Praha and import of services in Středočeský kraj. Moreover, many people from other regions live temporarily in Praha. Another

reason is export of services such as marketing or IT services of headquarters of companies in Praha to branches or factories in other regions.

Table1: International export and import, 2011, mil CZK

Region	International export	International import	Balance
Praha	371 137	419 271	-48 134
Středočeský kraj	457 064	390 354	66 710
Jihočeský kraj	122 601	124 576	-1 975
Plzeňský kraj	149 409	134 671	14 738
Karlovarský kraj	58 580	45 751	12 829
Ústecký kraj	199 237	225 625	-26 388
Liberecký kraj	108 288	90 320	17 968
Královéhradecký kraj	150 000	125 359	24 641
Pardubický kraj	198 399	172 843	25 556
Vysočina	117 171	108 921	8 250
Jihomoravský kraj	240 933	246 323	-5 390
Olomoucký kraj	115 919	112 121	3 798
Zlínský kraj	154 011	139 587	14 424
Moravskoslezský kraj	376 154	324 599	51 555
Czech Republic	2 818 903	2 660 321	158 582

Conclusion

The paper describes benefits and difficulties connected with the MRIO model specification for very small regions of one country. The main obstacles are limited data sources and strong regional relations. Our model improves current regional analyses that are based on national Input-Output tables and fully ignore differences in the structure of regional economies.

We did not find locationquotients as appropriate method for the conditions of the Czech Republic and developed methodology that enables to estimate international export and import in product breakdown that is necessary for regional analysis based on Input-Output tables. On the other hand, interregional trade can be expressed as a balance only. As the Czech Republic is a small country, relations among regions are strong which can be observed in Praha.

This approach serves as a first estimate that will be further adjusted using more sophisticated methods that may verify or falsify these first results. After successful solving of previous obstacles (estimate of components of expenditure approach in regional breakdown, transformation from COICOP classification to CPA or shift from purchasers' prices to basic prices), a good estimate of international and interregional trade is now a necessary condition for further steps in developing the MRIO model for Czech NUTS 3 regions.

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References

Bednářová, D. (2007).*Inovace a klastry v rozvoji regionů – Jihočeský kraj a Rakousko*.České Budějovice: Jihočeská univerzita v Českých Budějovicích.

Bracalente, B. and Perugini, C. (2010). The components of regional disparities in Europe. *Annals of Regional Science*. Vol. 44, No. 3, pp. 621–645.

Cadil, J., Mazouch, P., Musil., P. and Kramulova, J. (2014, in print). True regional purchasing power: evidence from the Czech Republic. *Post-Communist Economies*. Vol. 26, No. 2, pp. 241–256.

Casini Benvenuti, S., Martellato, D. and Raffaelli, C. (1995). INTEREG: A Twenty-Region Input-Output Model for Italy. *Economic Systems Research*.Vol. 7, No. 2, pp. 101–116.

Chlad, M. and Kahoun, J. (2011). Factors Influencing the Rating of Regional Economic Performance or Reasons why Prague has Become the 6th Best Economically Performing Region of the EU. *Statistika, Economy and Statistics Journal*. Vol. 48, No. 2, pp. 4–23.

Harris, R. I. D. and Liu, A. (1998). Input-output modelling of the urban and regional economy: The importance of external trade.*Regional Studies*. Vol. 32, No. 9, pp. 851–862.

Kahoun, Jaroslav and Sixta, Jaroslav. (2013). Regional GDP Compilation: Production, Income and Expenditure Approach. *Statistika, Economy and Statistics Journal*. Vol. 93, No. 4, pp. 24–36.

Kramulová, J. and Musil, P. (2013). Experimentální odhad složek výdajové metody regionálního HDP v ČR. *Politická ekonomie*.Vol. 61, No. 6, pp. 814–833.

Miller, R. E. and Blair, P. D. (2009). *Input-output analysis: foundations and extensions*. 2nd ed. Cambridge: Cambridge University Press.

Ministry of Transport (2005). *Transport Yearbook Czech Republic 2004*. Praha: Ministry of Transport.

Riddington, G., Gibson, H. and Anderson, J.(2006). Comparison of Gravity Model, Survey and Location Quotient-based Local Area Tables and Multipliers.*Regional Studies*. Vol. 40, No. 9, pp. 1069–1081.

Skokan, K.(2004). *Konkurenceschopnost, inovace a klastry v regionálním rozvoji*. Ostrava: Repronis.

Tohmo, T. (2004). New Developments in the Use of Location Quotients to Estimate Regional Input-Output Coefficients and Multipliers.*Regional Studies*. Vol. 38, No. 1, pp. 43–54.

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