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Multi-Regional Input–Output Tables for Macroeconomic Simulations in Poland's Regions

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Abstract: The capacity of multi-regional input–output tables (MRIOTs) to investigate linkages across structures and subnational regions within a country makes them a useful and solid tool of various types of simulations. This study develops MRIOTs for the Polish regions that can be subsequently employed to macroeconomic simulations, including assessing internal policy impulse responses or testing the regional economic resilience to external shocks. For this purpose, we build three macro-regions, discuss how their structural features validate their use to study differentials in economic policy effects or regional economic resilience, and finally, describe the process of constructing the MRIOTs.

Keywords: multi-regional I–O tables; CHARM method; CGE

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1. Introduction

The spatial allocation of economic activities and regional performance have gained momentum in regional policy implementation and analysis. Hence, the regional economic structure, productive capacities, technologies, localisation factors, and regional behaviour of economic agents are essential in the implementation of any policy. More recently, these issues gained even more importance, as they critically affect regional resilience to external shocks, understood as both resistance to shocks and the subsequent recoverability (Martin and Sunley 2015).

One tool widely used in regional policy analysis is the regional computable general equilibrium (CGE) model. In order to estimate a regional CGE model, multi-regional input–output tables (MRIOTs) are necessary. Hence, MRIOTs have become an important tool for "studying the interrelations of different economic structures and trade, as well as their implicationzs for a broad range of societal, economic and ecological issues" (Többen and Kronenberg 2015, p. 1). There is little doubt that with the broadening pool of national MRIOT sets, our understanding of the regional dynamic processes modelled deepens. Examples of existing studies that develop subnational MRIOTs and apply them in various fields include: Eding et al. (1999) for The Netherlands), Liang et al. (2007, for China), Yi et al. (2007, for Japan), Cazcarro et al. (2013, for Spain), Gallego and Lenzen (2009) and Malik et al. (2014, for Australia), Radvanski and Lichner (2018, for Czechia), Alikaj and Alexopoulos (2014, for Greece), Sila and Juvančič (2005, for Slovenia), Golemanova (2018, for Bulgaria) or Kronenberg and Többen (2011) and Többen (2014, for Germany).

Given its spatial heterogeneity, marked by the uneven distribution of economic activity, divergent industrial structures and sharp rural–urban divide, Poland makes a very interesting case study to track regional differences in responses to both uniform and targeted impulses, as well as regional spillovers of these responses.

Each region's table is divided into several areas' I–O tables containing 11 industry sectors. Aggregation of sectors in the original I–O table was carried out with regard to the regional structure of economic activities. The size of the region, its significance in national

economic terms and diversified industry mix were the main reasons behind the decision to analyse a relatively broad set of 11 sectors. We believe that the construction of our MRIOTs opens up a new research avenue for macroeconomic and regional policy analysis, accounting for specific features of a spatially heterogeneous emerging economy, based on static and dynamic regional CGE models.

2. MRIOTs in Policy Analysis—A Comparative Perspective

Theoretical foundations for developing interregional I–O models at the subnational level were laid down by Isard (1951), although the appreciation of regional I–O analysis varies across countries. A country which has had a long tradition in studying and monitoring economic performance is the Netherlands. For instance, Eding et al. (1999) presented a five-step structured approach to construct rectangular regional I–O accounts. Their method wassubsequently widely employed for modelling regional environmental issues (e.g., Oosterhaven et al. 2008).

Generally, regional I–O analysis is relevant in larger and more heterogenous countries, where it can provide valuable insights into regional economic development and well-informed advice to regional policymakers. One such example is Germany, where important economic policy decisions are made at the federal state government level. Kronenberg and Többen (2011) describe the process of constructing a regional I–O table (RIOT) for the largest federal state (North Rhine-Westphalia), applying the cross-hauling adjusted regionalisation method (CHARM) to the NIOT combining regional and national employment data with auxiliary information, while demonstrating that the limited information resource problem can be overcome by the efficient use of the remaining, available data. Using their methodology, Többen (2014) shows the construction procedure of German MRIOTs for the purpose of investigating the impact of energy policy actions on spatio-structural changes, as well as the associated social welfare redistribution. From a methodological standpoint, an interesting aspect of this study lies in simplifying and enhancing the integration of initial estimates and excessive data amounts.

RIOTs were also constructed for smaller countries and areas. For instance, Sila and Juvančič (2005) develop a RIOT for eastern Slovenia, as a quantitative basis for simulating exogenous shocks (e.g., related to EU policies) to the regional economy. A similar approach was adopted by Golemanova (2018), who focused on the south-eastern region of Bulgaria.

Other small European countries for which regional I–O tables were constructed are Greece and Czechia. Alikaj and Alexopoulos (2014) study the economy of western Greece by constructing a regional social accounting matrix (R-SAM), which is subsequently used to derive regional income, output, and employment multipliers. In a more recent paper, Radvanski and Lichner (2018) apply estimation by the CHARM for constructing the Czech Republic's MRIOTs at the NUTS-2 level using the NIOT and national supply and use tables, along with regional labour market, regional national accounts, and foreign trade data.

This empirical body of research is not limited to European countries. For example, Gallego and Lenzen (2009) assemble a detailed MRIOT framework for Australia, covering 344 sectors across 8 regions. They supplement it with a variety of environment-related data and obtain a tool for analysing environmental policy effects. Additionally, focusing on Australia, Malik et al. (2014) developed and tested an analytical and numerical approach that allows the rebalancing of an (unbalanced by augmentation) I–O or supply–use table and plug this framework to investigate the effects of introducing a new (biofuel) industry on total output and employment.

Although MRIOTs were developed and used for policy effect simulations in numerous large- and medium-sized spatially heterogeneous economies, the lack of these tables remains an obstacle for multi-regional I–O analysis and estimating regional CGE models in many other countries. For Poland, a MRIOT is not compiled yet, although the country's

structural characteristics and developments over the past two decades makes it a country where such a tool could be efficiently used for supporting economic policy decisions.

This paper fills this gap and develops MRIOTs for three macro-regions, namely the eastern, rural parts of the country (East), more urbanized western areas with easier access to the EU markets (West), and the residual central belt (Central).

3. Regional Decomposition of the Polish Regions (Voivodships)

The primary data used in this study are single-country static I–O tables for Poland, based on the 2015 NIOT (released on 28 June 2019). The regionalisation is based on non-survey methods using available regional statistical data from the Eurostat and the Polish Statistical Office (GUS). First, the NIOTs are aggregated from 77 to 11 sectors, (see Table 1).

Table 1. Definition of aggregate sectors.

No.	Abbreviation	Name	CPA
1	Agr	Agriculture	A
2	Ind	Industry (Except Construction)	B+D+E
3	Man	Manufacturing	C
4	Constr	Construction	F
5	WTAF	Wholesale Trade Services Land Transport Services Accommodation and Food Services	G+H+I
6	PIS	Publishing and Information Services	J
7	FIS	Financial and Insurance Services	K
8	RES	Real Estate Services	L
9	BusS	Business Services	M+N
10	PubS	Public Services	O+P+Q
11	OthS	Other Services + Personal Services	R-U

Source: GUS (2019); authors' calculations.

Regional economic research on Poland usually acknowledges the importance of structural differences, which in turn triggers diverse regional economic dynamics (Cieślik 2005; Chidlow et al. 2009; Gajewski 2015, 2016). Indeed, regional disparities in Poland are amongst the starkest in all EU member states. Sharp structural differences are observed especially between Western and Eastern Poland to the extent that the terms "Poland A" and "Poland B" were coined and settled to label these two geographical areas. The differences are most striking in the role (and the extent of backwardness) of the agricultural sector, state of infrastructure, business sector structure (e.g., importance of family-run businesses, intensity of competition) and the urbanization rate, the latter being substantially higher in the west.

Most of these multilayered differences have deep historical roots dating back to the period of partitions, between 1792 and 1918, when the country was divided between Russia, Prussia, and Habsburg Austria, and was shaped by three distinct social and economic systems and policies (Gajewski and Tchorek 2017).

Therefore, before the regionalisation process, the 16 Polish NUTS-2 regions (voivodships) are grouped into the East, West, and Central macro-regions, based on their socio-economic characteristics. Here we adopt the classification developed by Gajewski and Tchorek (2017), which leads us to the following three macro-regions (Figure 1):

- East, which is predominantly rural, with a historical legacy of being backward and based on subsistence farming, with underdeveloped infrastructure and unfavourable business sector indices, translating into relatively low-income levels.
- West, encompassing highly urbanized areas, with relatively dense transport networks and easier access to EU markets, while the industrial structure is dominated by services.
- Central, composed of the remaining four voivodships and separating the West from the East.
- Macro-regions interact with each other through the movement of goods and services, capital and labour.

Figure 1. Composition of the East (grey), West (black), and Central (white).

4. Key Features of the Three Macro-regions Used to Build the MRIOTs

As the three identified macro-regions (East, West, and Central) constitute the building blocks of our MRIOTs, we further discuss their main features and the usefulness of this disaggregation for macroeconomic policy analyses.

The fiscal and monetary policy transmission mechanisms are largely influenced by economic structures (proxied by the industry mix), the nature of business sectors and their dynamics, income levels, and the level of development among others (Anagnostou and Gajewski 2019). According to recent studies, regional resilience tends to be affected by similar variables (Hudson 2010).

Table 2 shows the main macroeconomic variables that define the economic profiles of the three macro-regions. West is the largest in terms of population, production, and capital formation. It comprises relatively industrialized areas, with dense transport networks, thus attracting foreign investment in manufacturing. It is also relatively well urbanised, with several large dynamic urban centres, including Wroclaw, Poznan, Silesian conurbation, and Tricity (Gdansk, Gdynia, and Sopot). Its proximity to the German and Czech borders, as well as access to Baltic seaports, induces the movement of goods. East is much smaller in terms of GDP, population, and employment and has a more rural

profile. The business sector here is dominated by family-run businesses rather than foreign enterprises (see Gajewski and Tchorek 2017). East's lower attractiveness for foreign investment results mainly from its infrastructural deficiencies (i.e., sparse road and rail networks), but also the relatively low-income levels and purchasing power. Central is a residual region and as such the most heterogenous one. It dominates other macro-regions in terms of per capita GDP, while also coming close to West in terms of total capital formation. The profile of this macroregion is strongly influenced by the capital city of Warsaw and, to some extent, Krakow and Lodz. Apart from the largest cities in Poland, Central encompasses vast underdeveloped areas, structurally more similar to East.

Table 2. Economic indicators for the three macro-regions, 2015.

Region	GDP	GDP per Capita (Gdpcap)	Gross Value Added (GVA)	Intermediate Consumption (Cons)	Gross Fixed Capital Formation (Gfcf)	Employment (Empl)	Population (POP)
			Million PLN			*Million persons*	
Poland	*1,800,227*	*48,496*	*1,597,202*	*2,022,431*	*361,490*	*16,100*	*38,005,614*
East	240,481	35,679	213,360	256,267	50,550	2767	6,920,567
West	829,275	45,279	735,751	966,286	163,174	7512	17,895,000
Central	730,471	55,164	648,090	799,878	147,766	5821	13,190,047
				% of national total			
East	13.36%	73.57%	13.36%	12.67%	13.98%	17.18%	18.21%
West	46.07%	93.37%	46.06%	47.78%	45.14%	46.66%	47.09%
Central	40.58%	113.76%	40.58%	39.55%	40.88%	36.16%	34.71%

Source: Eurostat; authors' calculations.

Table 3 provides more insights into the structures of these macro-regions. For example, East contributes 13.4% to the total value added, but as much as 22.9% to agriculture, while only 10.2% to industry and even less to market services. Its share in total employment is 17.2%, surpassing the macroregion's share of value added, capital formation, or compensation. This shows its relative disadvantage in productivity, investment activity, and purchasing power, respectively. Table 3 also shows that the highest concentration of market services occurs in the Central region, while the West region dominates in manufacturing, industry, and construction.

Table 3. Sectoral economic indicators by sector 2015 (% of the national total).

	Region	Total	Agr	Man	Ind	Constr	WTAF	PIS	FIS	RES	BusS	PubS	OthS
							%						
GVA	EAST	13.38	22.87	16.12	10.20	12.56	11.70	4.10	7.63	10.75	6.12	16.97	14.00
	WEST	46.46	48.56	52.31	64.49	47.10	44.76	31.73	35.51	45.55	37.90	45.32	44.14
	CENTRAL	40.16	28.56	31.57	25.30	40.34	43.54	64.16	56.85	43.69	55.98	37.71	41.86
GFCF	EAST	13.98	23.92	14.96	11.47	8.59	15.23	5.85	5.17	14.11	7.43	16.16	17.28
	WEST	45.14	46.72	51.63	54.87	48.05	39.71	26.29	27.51	43.48	32.90	45.80	50.28
	CENTRAL	40.88	29.36	33.41	33.67	43.37	45.06	67.85	67.32	42.41	59.67	38.04	32.44
Employment	EAST	17.18	24.43	17.82	11.61	16.01	16.37	7.05	11.07	13.42	12.28	18.69	17.31
	WEST	46.66	36.01	50.28	62.52	47.34	48.30	39.43	43.75	49.82	46.09	44.91	46.54
	CENTRAL	36.16	39.56	31.90	25.87	36.66	35.34	53.52	45.17	36.76	41.63	36.40	36.15
Compensation	EAST	13.38	22.87	16.12	10.20	12.56	11.70	4.10	7.63	10.75	6.12	16.97	14.00
	WEST	46.46	48.56	52.31	64.49	47.10	44.76	31.73	35.51	45.55	37.90	45.32	44.14
	CENTRAL	40.16	28.56	31.57	25.30	40.34	43.54	64.16	56.85	43.69	55.98	37.71	41.86

Source: EUROSTAT data (2015); authors' calculations.

In sum, the economic structures and level of development of these macro-regions are coherently distinctive, which allows exploring the differences in their macroeconomic policy effects (i.e., endogenous shocks), as well as their resilience to exogenous shocks. In the following sections, we present the regionalisation process of developing the supply–use framework, on which the Polish MRIOTs are based on. More specifically, data on employment at the national and regional level with the structure of activities identical to the

national input–output table and some additional socio-economic indicators, such as the income tax base and percentage of the national value added produced within the region were employed. Interregional and foreign trade is estimated with the modified version of the cross-hauling adjusted regionalization method (CHARM), proposed by Kronenberg (2009).

The construction process, described below, consists of the following steps. First, we estimate regional output by branch, using data on employment by industry to construct a regional supply table. Second, we estimate primary inputs and intermediate use of commodities by invoking the equal technology assumption and adjusting the estimates based on regional superior information. Third, we estimate the final use of commodities, drawing upon a household survey of consumption expenditure. Finally, we estimate regional imports and exports using the modified version of CHARM.

5. Construction of the Polish MRIOTs

5.1. General I–O Table Definitions and Identities

The MRIOTs for the Polish regions are constructed using the same layout as the corresponding NIOT (see Table 4) and following the methodology outlined by Kronenberg and Többen (2011).

The NIOT for Poland distinguishes between 77 homogeneous sectors. Three symmetric, sector-product tables in current basic prices were used, where total, domestic, and imported flows are available at the national level. Table 4 shows a version with m products and n homogeneous sectors. The core of the I–O tables is the inter-industry transaction matrix (Z), where $z_{1,1}^{N}$ represents the value of product 1 used by sector 1, regardless of the origin of the product. The columns of this table indicate the demand of intermediate goods and the rows indicate the use of these commodities by industry. The row sums, $Z_{m,1}^{U.N} \ldots Z_{m,n}^{N}$, of this matrix denote the total intermediate consumption of inputs of the n sectors, with taxes less subsidies on products, $tax_1^N \ldots tax_n^N$; as such, we obtain the total intermediate consumption/final uses, $fu_1^N \ldots fu_n^N$ for the n sectors. Further, the value added is determined as the sum of the compensation of employees ($comp^N$), net operating surplus (nos^N), depreciation of fixed capital (cap^N), and net taxes on production ($othtax^N$). Adding the gross value added (primary inputs) (v^N) with the total intermediate consumption/final uses (fu^N) gives us the total output (x^N). Finally, by summing up the total output (x^N) with the imports (imp^N), we obtain the total supply (s^N).

Each row illustrates the way in which products of a sector are used. The row sums of the $\boldsymbol{Z}$ matrix, $Z_{1,n}^{D.N} \ldots Z_{m,n}^{D.N}$, represent the total use of each product for intermediate consumption by each sector at the national level. Further to the right, we can see final domestic consumption expenditure by households hhc^N, non-profit institutions serving households ($npish^N$), and by the general government (gov^N), as well as the gross capital formation ($gfcf^N$), changes in inventories, and changes in valuables (civ^N) and exports (exp^N). The total intermediate consumption ($Z^{D.N}$) and the total final demand (fd^N) add up to the total use (u^N). Based on the above table components, one fundamental identity that must always hold is that the total supply (s^N) is equal to the total use (u^N) for each sector.

Given the above definitions and considering the NIOTs and the regional data available, we regionalize the data and construct the MRIOTs.

The layout of our MRIOTs is illustrated in Table 5. Their construction procedure consists of estimating several regional components, namely (a) regional intermediate demand, (b) regional value added and regional primary inputs, (c) regional final domestic use, and (d) intra-regional trade flows and regional trade flows with the rest of the world.

Table 4. Layout of the Polish NIOT.

Supply \ Use		Intermediate Consumption: Sectors **1**	...	***j***	...	***n***	Total Intermediate Consumption ($Z^{D.N}$)	Final Domestic Use (fdu^N): hhc^N	gov^N	$npish^N$	$gfcf^N$	civ^N	Exports: exp^N	Total Final Demand (fd^N)	Total Use (u^N)
Products	1	$z^N_{1,1}$	…	$z^N_{1,j}$	…	$z^N_{1,n}$	$Z^{D.N}_{1,n}$	hhc^N_1	gov^N_1	$npish^N_1$	$gfcf^N_1$	civ^N_1	exp^N_1	$fd^N_{1,n}$	u^N_1
	...	…	…	⋮		…	…	...	...	...	...	...	…	…	…
	i	$z^N_{i,1}$	…	$z^N_{i,j}$	…	$z^N_{i,n}$	$Z^{D.N}_{i,n}$	hhc^N_n	gov^N_n	$npish^N_n$	$gfcf^N_n$	civ^N_n	exp^N_i	$fd^N_{i,n}$	u^N_i
	...	…	…	…	…	…	…	...	...	...	...	...	…	…	…
	m	$z^N_{m,1}$	…	$z^N_{m,j}$	…	$z^N_{m,n}$	$Z^{D.N}_{m,n}$	hhc^N_m	gov^N_m	$npishc^N_m$	$gfcf^N_m$	civ^N_m	exp^N_m	$fd^N_{m,n}$	u^N_m
Total Intermediate Inputs (tii^N)		$Z^{U.N}_{m,1}$	…	$Z^{U.N}_{m,j}$	…	$Z^{U.N}_{m,n}$									
Taxes less subsidies on products (tax^N)		tax^N_1	…	tax^N_j	…	tax^N_n									
Total intermediate consumption/final uses (fu^N)		fu^N_1	…	fu^N_j	…	fu^N_n									
Compensation of employees ($comp^N$)		$comp^N_1$	…	$comp^N_j$	…	$comp^N_n$									
Other taxes less subsidies on production ($othtax^N$)		$othtax^N_1$	…	$othtax^N_j$	…	$othtax^N_n$									
Consumption of fixed capital (cap^N)		cap^N_1	…	cap^N_j	…	cap^N_n									
Operating surplus and mixed income, net (nos^N)		nos^N_1	…	nos^N_j	…	nos^N_n									
Operating surplus and mixed income, gross (gos^N)		gos^N_1	…	gos^N_j	…	gos^N_n									
Gross value added at basic prices (Primary Inputs) (v^N)		v^N_1	…	v^N_j	…	v^N_n									
Total output at basic prices (x^N)		x^N_1	…	x^N_j	…	x^N_n									
Imports CIF (imp^N)		imp^N_1	…	imp^N_j	…	imp^N_n									
Total Supply (s^N)		s^N_1	…	s^N_j	…	s^N_n									

Source: GUS (2019); authors' calculations. Note: Final Demand (fd^N) = final consumption expenditure by households (hhc^N) + final consumption expenditure by non-profit organizations serving households ($npish^N$) + final consumption expenditure by government (gov^N) + gross fixed capital formation ($gfcf^N$) + changes in inventories and valuables (civ^N) + exports (exp^N).

Table 5. Layout of a MRIOT.

Supply \ **Use**			**Intermediate Consumption**									**Total Intermediate Consumption (tic^R)**	**Final Domestic Use (fdu^R)**	**Exports (ex^R)**			**Total Exports (Row)**	**Total Exports ($e^R = ex^R + exp^R$)**	**Total Final Demand ($fd^R = fdu^R + exp^R$)**	**Total Use (u^R**
			Sectors																	
			Region r			**Region q**			**Region s**					**Region r**	**Region q**	**Region s**				
			1	**…**	**n**	**1**	**…**	**n**	**1**	**…**	**n**									
Products	Region r	1	$z^r_{1,1}$	…	$z^r_{1,n}$							Z^r_1	fdu^r_1	0	ex^{rq}_1	ex^{rs}_1	exp^r_1	e^r_1	fd^r_1	u^r_1
		…	…	…	…							…	…	…	…	…	…	…	…	…
		m	$z^r_{m,1}$	…	$z^r_{m,n}$					…		Z^r_m	fdu^r_m	0	ex^{rq}_m	ex^{rs}_m	exp^r_m	e^r_m	fd^r_m	u^r_m
	Region q	1				$z^q_{1,1}$	…	$z^q_{1,n}$		…		Z^q_1	fdu^q_1	ex^{qr}_1	0	ex^{qs}_1	exp^q_1	e^q_1	fd^q_1	u^q_1
		…				…	…	…		…		…	…	…	…	…	…	…	…	…
		m				$z^q_{m,1}$	…	$z^q_{m,n}$		…		Z^q_m	fdu^q_m	ex^{qr}_m	0	ex^{qs}_m	exp^q_m	e^q_m	fd^q_m	u^q_m
	Region s	1							$z^s_{1,1}$	…	$z^s_{1,n}$	Z^s_1	fdu^s_1	ex^{sr}_1	ex^{sq}_m	0	exp^s_1	e^s_1	fd^s_1	u^s_1
		…							…	…	…	…	…	…	…	…	…	…	…	…
		m							$z^s_{m,1}$	…	$z^s_{m,n}$	Z^s_m	fdu^s_m	exp^{sr}_m	exp^{sq}_m	0	exp^s_m	e^s_m	fd^s_m	u^s_m
Total Intermediate Inputs (Z^R)			Z^r_1	…	Z^r_n	Z^q_1	…	Z^q_n	Z^s_1	…	Z^s_n									
Total intermediate consumption/final uses (fu^R)			fu^r_1	…	fu^r_n	fu^q_1	…	fu^q_n	fu^s_1	…	fu^s_n									
Gross value added at basic prices (Primary Inputs) (v^R)			v^r_1	…	v^r_n	v^q_1	…	v^q_n	v^s_1	…	v^s_n									
Total output at basic prices (x^R)			x^r_1	…	x^r_n	x^q_1	…	x^q_n	x^s_1	…	x^s_n									
Imports CIF (im^R)	Region r		0	…	0	im^{rq}_1	…	im^{rq}_n	im^{rs}_1	…	im^{rs}_n									
	Region q		im^{qr}_1	…	im^{qr}_n	0	…	0	im^{qs}_1	…	im^{qs}_n									
	Region s		im^{sr}_1	…	im^{sr}_n	im^{sq}_1	…	im^{sq}_n	0	…	0									
	Total Imports(Row)		imp^r_1	…	imp^r_1	imp^q_1	…	imp^q_n	imp^s_1	…	imp^s_n									
	Total Imports		m^r_1	…	m^r_1	m^q_1	…	m^q_n	m^s_1	…	m^s_n									
Total Supply (s^R)			s^r_1	…	s^r_n	s^q_1	…	s^q_n	s^s_1	…	s^s_n									

Source: GUS (2019); authors' calculations. Note: For notations, please refer to Table 4.

5.2. Estimation of Regional Intermediate Demand

The first step in constructing the MRIOTs is to approximate the regional intermediate demands. To this end, we estimate the regional technical coefficients using simple location quotients (SLQ). These quotients, calculated for every regional industry, measures its ability to fill the demand from other industries in the region and the regional final demand. SLQs can in principle be replaced by one of its alternatives, such as purchases-only LQs, cross-industry LQ or semilogarithmic LQs but, in light of existing evidence, such replacements hardly affect the results (Bonfiglio 2005; Riddington et al. 2006).

In our study, regional intermediate demand was estimated as follows. First, we calculated the national technical coefficients proposed by Leontief and Strout (1963); second, we used the LQ approach to estimate the regional technical coefficients; and finally, we estimated regional intermediate demands by multiplying the regional technical coefficients with the corresponding regional production of that product. Specifically, LQs are used to derive interregional input coefficients, A^R from a matrix of national direct input coefficients, A^N. A^N is computed from the aggregated NIOT as:

$$a_{ij}^N = \frac{Z_{ij}^N}{x_j^N}, \tag{1}$$

where Z_{ij}^N denotes the inter-industry sales and x_j^N denotes gross output in sector j and superscript N stands for the national value. The LQ technique is also used to calculate regional intermediate demand and interregional flows. The LQ approach is also used to derive coefficients of regional specialization in sector i:

$$LQ_i^R = \frac{x_i^R}{\sum_i x_i^R} \Big/ \frac{x_i^N}{\sum_i x_i^N}, \tag{2}$$

In Equation (2), the denominator quantifies the proportion of national sector i's output, x_i^N, to the total output $\sum_i x_i^N$, while the numerator is the corresponding proportion of output in the regional sector i. Usually, LQs are computed using the regional sectoral gross value added (GVA_i^R) or regional sectoral employment ($empl_i^R$), hence the Equation (2) for region R, sector i becomes:

$$LQ_i^R = \frac{GVA_i^R}{\sum_i GVA_i^R} \Big/ \frac{GVA_i^N}{\sum_i GVA_i^N} \tag{3}$$

or

$$LQ_i^R = \frac{empl_i^R}{\sum_i empl_i^R} \Big/ \frac{empl_i^N}{\sum_i empl_i^N}. \tag{4}$$

Equation (2) implies that, if a sector i from region R has $LQ_i^R = 1$, the region is self-sufficient with respect to product i. If $LQ_i^R > 1$, then sector i not only supplies all necessary inputs, but it also exports some excess output. Conversely, if a sector's $LQ_i^R < 1$, then the region can only supply a fraction of the required input and must import product i from other regions. Hence, the interregional direct input coefficient a_{ij}^R can be defined as:

$$a_{ij}^R = \begin{cases} a_{ij}^N & if\ LQ_i^R \geq 1 \\ a_{ij}^N LQ_i^R & if\ LQ_i^R < 1 \end{cases}, \tag{5}$$

where i, j stand for sectors and superscripts R and N stand for regional and national, respectively.

Finally, the intermediate input of regional sector j, $Z_{i,j}^R$ for products of sector i is estimated as:

$$Z_{i,j}^R = a_{ij}^N x_j^R, \tag{6}$$

where x_j^R denotes the regional production of commodity j and $a_{ij}^N = \frac{Z_{ij}^N}{x_j^N}$ the national sectors j's intermediate input coefficient for sector i' s product, assuming identical technologies.

5.3. Estimation of Regional Value Added and Regional Primary Inputs

In order to determine value added, we have to estimate its components, listed earlier, and add them up. First, in order to approximate the regional compensation of employees (i.e., wages and social security contribution, $comp_i^R$) for sector i, the available information of regional compensation of employees is utilized in the following form:

$$comp_i^R = \frac{comp^R}{\sum_{R=1}^{R\in N} comp^R} comp_i^N, \quad (7)$$

where $comp_i^R$ represents the regional compensation of employees of sector i in region R, $comp^R$ is the regional compensation of employees, and $comp_i^N$ represents total national regional compensation of employees of sector i. $\sum_{R=1}^{R\in N} comp^R$ is the total national compensation of employees.

To determine regional other taxes less subsidies on production ($othtax_i^R$) for sector i, the available information on regional other taxes and subsidies of production is utilized; hence, we have:

$$othtax_i^R = \frac{othtax^R}{\sum_{R=1}^{R\in N} othtax^R} othtax_i^N, \quad (8)$$

where $othtax_i^R$ and $othtax_i^N$ are (respectively) regional and national other taxes less subsidies on production of sector i. $\sum_{R=1}^{R\in N} othtax^R$ is the total national other taxes less subsidies on production.

Similarly, we approximate the regional net operating surplus (i.e., profits, $\mathrm{nos}^{\mathrm{N}}$) of each sector i:

$$nos_i^R = \frac{nos^R}{\sum_{R=1}^{R\in N} nos^R} nos_i^N, \quad (9)$$

and regional consumption of fixed capital (i.e., depreciation, $\mathrm{cap}^{\mathrm{N}}$) of sector i:

$$cap_i^R = \frac{cap^R}{\sum_{R=1}^{R\in N} cap^R} cap_i^N, \quad (10)$$

A relatively similar approach is applied in the case of gross value added (v_j^R). In this step, regional gross value-added data published on a regional level for sector i are adjusted to estimate the regional level of value added as follows:

where v_i^R represents the gross value for sector i in region R, v_i^N represents the national gross value added to sector i by product, v_i^R is the gross value added of sector i in the region R, and v_i^N represents the national gross value added to sector i.

$$v_i^R = \frac{v_i^R}{\sum_{R=1}^{R\in N} v^R} v_i^N \quad (11)$$

Having determined the above components, the regional gross value added for each sector i and region R is equal to:

$$v_i^R = comp_i^R + othtax_i^R + cap_i^R + nos_i^R, \quad (12)$$

5.4. Regional Output and Taxes

Taxes less subsidies on products (tax^R) are estimated using the regional gross value added as a proxy. Specifically,

$$tax_i^R = \frac{gva^R}{\sum_{R=1}^{R\in N} gva^R} tax_i^N, \quad (13)$$

where tax_i^R represents taxes less subsidies on the products of sector i. For region R, gva^R is the regional gross value added and tax_i^N represents national level of taxes less subsidies on the products of sector i. $\sum_{R=1}^{R\in N} gva^R$ is the total national gross value added.

The total regional output (x^R) was estimated using the regional gross value added as a proxy. Specifically,

$$x_i^R = \frac{gva^R}{\sum_{R=1}^{R\in N} gva^R} x_i^N, \quad (14)$$

where x_i^R represents total regional output of sector i in region R, gva^R is the regional gross value added, and x_i^N represents the national level of total regional output of sector i. $\sum_{R=1}^{R\in N} gva^R$ is the total national gross value added.

Hence, the following equations can be obtained. Total intermediate consumption (fu_j^R) in purchasers' prices is computed as the difference between output (x_j^R) and gross value added (v_j^R):

$$fu_j^R = x_j^R - v_j^R. \quad (15)$$

Finally, we can calculate the total intermediate consumption in basic prices (Z_j^R) as the difference between regional total intermediate consumption/final uses (fu_j^R) and regional taxes less subsidies on products (tax_i^R):

$$Z_j^R = fu_j^R - tax_i^R. \quad (16)$$

5.5. Estimation of Regional Final Domestic Use

The final domestic use (fdu^R) includes final consumption expenditure by: households (hhc^R), non-profit organizations serving households ($npish^R$) and by general government (gov^R), as well as gross fixed capital formation ($gfcf^R$) and changes in inventories and valuables (civ^R).

To approximate the regional final consumption expenditure by households (hhc^R) for product i, regional household income is utilized as:

$$hhc_i^R = \frac{hi^R}{\sum_{R=1}^{R\in N} hi^R} hi_i^N, \quad (17)$$

where hhc_i^R represents the final consumption expenditure of product i in region R, hi_i^R is the regional household income, and hi_i^N represents total national household income for product i. $\sum_{R=1}^{R\in N} hi^R$is the total national household income.

To approximate the final consumption expenditure by the government (gov^R), we use the available information on total regional household income as:

$$gov_i^R = \frac{hi^R}{\sum_{R=1}^{R\in N} hi^R} gov_i^N, \quad (18)$$

where gov_i^R represents regional final expenditure by the government of product i in region R, hi_i^R is the regional household income, and gov_i^N represents final expenditure by government of product i. $\sum_{R=1}^{R\in N} hi^R$ is the total national household income.

The regional final consumption expenditure by non-profit organisation serving households ($npish^R$) is approximated using the available information on total regional household income:

$$npish_i^R = \frac{hi^R}{\sum_{R=1}^{R\in N} hi^R} npish_i^N, \quad (19)$$

where $npish_i^R$ represents regional final expenditure by non-profit organisations serving households of product i in region R, hi_i^R is the regional household income, and $npish_i^N$ represents the national final expenditure by non-profit organizations serving households for product i. $\sum_{R=1}^{R\in N} hi^R$ is the total national household income.

With respect to the gross fixed capital formation, we used information on sectoral investment to regionalise the national total capital formation, as follows:

$$gfcf_i^R = \frac{gfcf^R}{\sum_{R=1}^{R\in N} gfcf^R} gfcf_i^N, \quad (20)$$

where $gfcf_i^R$ represents the gross fixed capital formation of product i in region R, $gfcf^R$ is the regional gross fixed capital formation, and $gfcf_i^N$ represents the total national gross fixed capital formation for product i. $\sum_{R=1}^{R\in N} gfcf^R$ is the total national gross fixed capital formation.

Changes in inventories and valuables (civ^R) are estimated using the regional gross value added as a proxy:

$$civ_i^R = \frac{gva^R}{\sum_{R=1}^{R\in N} gva^R} civ_i^N, \quad (21)$$

where civ_i^R represents changes in inventories and valuables of product i in region R, gva^R is the regional gross value added, and civ_i^N represents the national level of changes in inventories and valuables of product i. $\sum_{R=1}^{R\in N} gva^R$ is the total national gross value added.

5.6. Estimation of Intra-Regional and Regional Trade Flows with the Rest of the World

Due to the fact that subnational regional trade statistics are usually not available, the estimation of regional imports and exports remains one of the biggest challenges for I–O modelers. Admittedly, the problem has attracted substantial attention in literature and several methodological avenues were proposed to overcome this missing data issue[1].

One class of the avenues for regionalising trade statistics relies on non-survey methods, such as the hybrid approach suggested by Lahr (1993), LQ, or commodity balance (CB) approaches. The main criticism here is that these methods do not adequately account for the size of regional trade (Harris and Liu 1998; Tohmo 2004). Further, Richardson (1985) claims that the LQ and CB approaches tend to overestimate regional multipliers, because they are not able to capture simultaneous exportation and importation of commodities, known as cross-hauling (Kronenberg and Többen 2011).

In response to this critique, Kronenberg (2009) developed a cross-hauling adjusted regionalisation method (CHARM), that utilises an observation that cross-hauling is a function of the heterogeneity of industry outputs. Hence, if industry output is independent of the region of origin, there would be no cross-hauling. CHARM is a supply–demand pool method, accounting for cross-hauling simultaneous imports and exports of the same industrial output

The original CHARM formula, as introduced by Kronenberg (2009) defines cross-hauling (q_i) as the difference between the trade volume (i.e., exports plus imports, $e_i + m_i$) and the modulus of net exports (i.e., of exports minus imports, $|(e_i - m_i)|$). Here it is used to estimate regional imports and exports given a national type A or E IOT (see more details in Többen and Kronenberg (2015), along with information (estimates or survey-based methods) on regional intermediate consumption, gross output, and domestic final use. The main idea of the CHARM approach is to compute the shares of cross-hauling

observed in national trade with the rest of the world and then use these shares to calculate regional shares.

The extended version of the RIOT is depicted in Table 5. Többen and Kronenberg (2015) assume that adequate estimates of the regional $\boldsymbol{Z}$ matrix (regional intermediate demand, influenced by regional technology) and the regional $\boldsymbol{d}$ vector (regional final demand, influenced by regional preferences) are available or can be constructed on the basis of superior data. Following Többen and Kronenberg (2015), we explain the steps used to estimate intra-regional and regional trade flows with the rest of the world.

On a regional level, we must consider both international and interregional trade flows. At the regional level, imports include interregional as well as international purchases. Therefore, we have interindustry flows within the region and the interregional imports necessary to meet the total technological demand in the system. Similarly, the exports are often divided into those within the country (interregional) and those on the foreign account.

Considering both international and interregional trade flows, we first calculate international trade flows, specifically, regional international (row—rest of the world) trade flows by regionalising national known data on foreign exports and imports. For exports, we assume that the share of foreign exports is equal to the share of regional output $(\frac{x_j^R}{x_j^N})$ on the national level of output by sector.

Regional exports to the rest of the world are then estimated as:

$$e_j^{R\,row} = \frac{x_j^R}{x_j^N} e_j^{N\,row}. \tag{22}$$

We further assume that the share of imports from the rest of the world is equal to the share of total regional domestic use of product j $(fu_i^R + Z_i^R)$ to the national one $(fu_i^N + Z_i^N)$; hence, total regional imports from the rest of the world are estimated as:

$$m_j^{row\,R} = e_j^{row\,N} \frac{fu_j^R + Z_j^R}{fu_j^N + Z_j^N}, \tag{23}$$

Furthermore, regional gross imports and exports are estimated via the refined version of Kronenberg's CHARM (Kronenberg 2009). According to Kronenberg (2009), this refinement is necessary due to the fact that the original CHARM may yield estimates for regional imports and/or exports that exceed the total regional output of domestic consumption. Hence, a refined version of CHARM is developed, which yields regional export and import estimates, consistent with the assumption of zero re-exports (for details see Többen 2014). For the refinement, an upper limit is imposed for each regional product for which cross-hauling caused by product differentiation is possible. Each trade flow exceeding:

$$\min(x_j^R, Z_j^R + fdu_j^R) \tag{24}$$

cannot be explained by product heterogeneity, so that the upper limit for regional exports or imports involved in regional cross-hauling is:

$$\min\left(x_j^R, Z_j^R + fdu_j^R\right) = \max(\min(e_j^R, m_j^R). \tag{25}$$

Equation (25) can be interpreted as the maximum cross-hauling potential of a region or a nation. Next, we calculate the modified version of cross-hauling as the share of cross-hauling observed in international trade in the maximum cross-hauling potential:

$$\widetilde{h}_j^N = \frac{q_j^N}{2*\min(x_j^R, Z_j^R + fdu_j^R)}. \tag{26}$$

The denominator is multiplied by two, as q_j^N consists of both exports and imports. If one assumes $\widetilde{h}_j^N = \widetilde{h}_j^R$, that is, the share of regional cross-hauling in the regional cross-hauling potential is the same as in the nation, regional cross-hauling may be estimated as:

$$\tilde{q}_j^R = 2 * \widetilde{h}_j^R * \min(x_j^R,\ Z_j^R + fdu_j^R), \tag{27}$$

Regional gross imports and exports are then calculated as:

$$e_j^R = \frac{tv_j^R + b_j^R}{2} = \frac{q_j^R + \left|b_j^R\right| + b_j^R}{2} \tag{28}$$

and

$$m_j^R = \frac{tv_j^R - b_j^R}{2} = \frac{q_j^R + \left|b_j^R\right| - b_j^R}{2}. \tag{29}$$

For the integrated estimation of regional trade with the rest of the world (row) and the rest of the nation (roc), it is important that regional foreign trade does not contain re-exports. This approach is used for the initial MRIOT estimate.

Hence, in the first step, the share of cross-hauling of regional foreign trade in the national cross-hauling potential is used instead of the national counterpart as:

$$\widetilde{h}_j^{R\,row} = \frac{q_j^{R\,row}}{2 * \min(x_j^R, Z_j^R + fdu_j^R)}. \tag{30}$$

It is then assumed that $\widetilde{h}_j^{R\,row} = \widetilde{h}_j^{R\,roc}$, which seems a more plausible assumption, as product heterogeneity is rather a characteristic of the diversification of regional industries than of the product group itself. $\widetilde{h}_j^{R\,row}$ can thus be expected to better capture the features of regional industries and thereby the heterogeneity of regional product output.

In the second step, for the estimation of regional cross-hauling in trade flows with the rest of the country, $\widetilde{h}_j^{R\,roc}$ is applied to the remaining regional cross-hauling potential after accounting for regional foreign trade:

$$\tilde{q}_j^{R\,roc} = 2 \times \tilde{h}_j^{R\,roc} \times \min(x_j^R - e_j^{R\,row};\ Z_i^R + fdu_j^R - m_j^{row\,R}) \tag{31}$$

The subtraction of regional foreign trade in (31) ensures the estimates are consistent with

$$x_j^R < e_j^R$$

and

$$Z_i^R + fdu_j^R < m_j^R.$$

Regional gross imports and exports are then calculated as:

$$e_j^{R\,roc} = \frac{q_j^{R\,roc} + \left|b_j^{R\,roc}\right| + b_j^{R\,roc}}{2} \tag{32}$$

and

$$m_j^{R\,roc} = \frac{q_j^{R\,roc} + \left|b_j^{R\,roc}\right| - b_j^{R\,roc}}{2}, \tag{33}$$

where $b_j^{R\,roc} = x_j^R + m_j^{row\,R} - x_j^R - fdu_j^R - e_j^{R\,row}$ denotes the interregional trade balance of region R.

The estimation of interregional trade completes the process of constructing individual regional tables for Poland. The remaining work requires the three individual tables to be linked through interregional trade flows, as well as allocating domestically produced

and imported products to industries and final demand sectors. The CHARM method is employed to complete these two final steps.

For each product, we assemble row and column sums of an origin–destination (O–D) matrix whose diagonal elements are zero. After eliminating the off-diagonal elements, the O–D matrix is obtained (see Table 6).

Table 6. Origin–destination matrix with CHARM sums.

	Exports (ex^R)			**Total Interregional Exports ($exp_1^{r\,roc}$)**	**Total Exports (ROW)**
	Region r	**Region q**	**Region s**		
Region r	0	t_1^{rq}	t_1^{rs}	$exp_1^{r\,roc}$	$texp_1^r$
	…	…	…	…	…
	0	t_m^{rq}	t_m^{rs}	$exp_m^{r\,roc}$	$texp_m^r$
Region q	t_1^{qr}	0	t_1^{qs}	$exp_1^{q\,roc}$	$texp_1^q$
	…	…	…	…	…
	t_m^{qr}	0	t_m^{qs}	$exp_m^{q\,roc}$	$texp_m^q$
Region s	t_1^{sr}	t_m^{sq}	0	$exp_1^{s\,roc}$	$texp_1^s$
	…	…	…	…	…
	t_m^{sr}	t_m^{sq}	0	$exp_m^{s\,roc}$	$texp_m^s$
Total	$m_i^{r\,roc}$	$m_i^{q\,roc}$	$m_i^{s\,roc}$		$\sum_p e_i^{p\,roc} = \sum_p m_i^{roc\,p}$

Source: National input–output tables (2015); Statistics Poland (28 June 2019 release); authors' calculations. Note: The shaded elements are those to be estimated, whereas the unshaded ones are assumed to be known. Reproduced from Sargento et al. (2012); $p = r + q + s$.

Further, for each product the sum of regional exports to the rest of the country is constrained to be equal to the sum of regional imports from the rest of the country:

$$\sum_p e_j^{R\,roc} = \sum_p m_j^{R\,roc}.$$

For the estimation of the off-diagonal elements, the geographical distance between two regions is assumed to have no influence on the scale of bilateral trade flows. For the final MRIOT, the effect of distance is captured by the constraint on interregional trade flows, which is based on transportation data.

In the first step, the regional origins of imports from other regions are allocated according to their market share in total interregional exports, excluding exports of the importing region:

$$\tilde{t}_j^{rs} = \frac{m_j^{roc\,s}}{\sum_{r \neq s} e_j^{r\,roc}}, \tag{34}$$

In the second step, total purchases of industries, Z_j^N, and domestic final demand sectors are split according to their geographical origins. To do this, we calculate regional purchase coefficients for two types of intraregional purchases, i.e., those from other regions, and from the rest of the world. Having those two types of coefficients, we can rule out re-exports as shown by Lahr (1993):

$$rpc_j^{rr} = \frac{(x_j^r - \tilde{t}_j^r)}{(x_j^r - \tilde{t}_j^r + m_j^{row\,r} - \tilde{t}_j^r - e_j^{r\,row})}, \tag{35}$$

$$rpc_j^{sr} = \frac{\tilde{t}_j^{sr}}{(x_j^R + \tilde{t}_j^r + m_j^{row\,r} - \tilde{t}_j^r - e_j^{r\,row})}, \tag{36}$$

$$rpc_j^{row\,r} = \frac{m_j^{row\,r}}{(x_j^R - \tilde{t}_j^r + m_j^{row\,r} - \tilde{t}_j^r - e_j^{r\,row})}. \tag{37}$$

As there is no further information about the propensity of individual industries or final demand sectors to consume imported products, for each product j in region r,

industries and domestic final demand sectors are assumed to have the same average propensity to import. This assumption allows us to apply the regional purchase coefficients to the total uses of product j in region r by industry i or final demand sector k. For intraregional purchases:

$$z_{ji}^{rr} = rpc_j^{rr} * z_{ji}^{rr}$$

and

$$d_{jk}^{rr} = rpc_j^{rr} * d_{jk}^{r}.$$

For international purchases ($r \neq s$):

$$z_{ji}^{sr} = rpc_j^{sr} * z_{ji}^{r}$$

and

$$d_{jk}^{sr} = rpc_j^{sr} * d_{jk}^{r}.$$

For purchases from foreign countries:

$$z_{ji}^{row\,r} = rpc_j^{row\,r} * z_{ji}^{r}$$

and

$$d_{jk}^{row\,r} = rpc_j^{row\,r} * d_{jk}^{r}.$$

This procedure generates a non-survey regionalized multiregional supply–use table, but the table is not yet balanced. As the application of (18) does not ensure the sum of exports to other regions to be equal to the CHARM estimates of gross exports to the rest of the country, regional product output is not equal to total use for that product. For this reason, matrix balancing methods such as RAS have to be applied.

As final steps in the creation of MRIOTs, we express total exports ($texp_i^R$) of the region as the sum of internal (ei_i^R) and external exports (e_i^R), and total imports:

$$e_i^R = ex_i^R + exp_i^R, \tag{38}$$

$$m_i^R = im_i^R + imp_i^R. \tag{39}$$

Now, we can fill in the final missing information in RIOTs—final use:

$$fu_i^R = fdu_i^R + e_i^R. \tag{40}$$

The total final regional use (fu_i^R) is equal to the regional domestic use (fdu_i^R) plus total exports (e_i^R).

Furthermore, the total use (u_j^R) is the sum of the total intermediate consumption (Z_j^R), final domestic use (fdu_j^R), and total exports (e_j^R):

$$u_j^R = Z_j^R + fdu_j^R + e_j^R. \tag{41}$$

We can alternatively estimate import from other regions as the gap between total use, production, and foreign imports:

$$im_i^R = u_i^R - x_i^R - m_i^R. \tag{42}$$

To conclude, we express the total regional supply (s_i^R) as the sum of output (x_j^R) and total imports ($timp_j^R$):

$$s_i^R = x_j^R + m_j^R. \tag{43}$$

Single RIOTs are then combined into MRIOTs and balances are verified.

For any region to the rest of Poland, trade can be obtained from row and column sums in the interregional trade matrix on an O–D basis (see Table 6). Those row and column sums can be further disaggregated using several methods, including gravity models or mechanical and mathematical methods, such as the RAS algorithm.[2]

As mentioned earlier, here we follow an alternative path, proposed by Többen and Kronenberg (2015) and generate the initial values by allocating imports or exports from the rest of the country to the regions of origin according to their market shares in total interregional imports or exports (except exports of the importing region or vice versa):

$$exp_i^{rs} = \frac{exp_i^{roc\,s}}{\sum_p exp_i^{p\,roc} - exp_i^{s\,roc}}, \quad (44)$$

where exp_i^{rs} denotes the exports from region r to region s, $\sum_p t_i^{p\,roc}$ denotes the exports of all other regions in sector i (except region r) to the rest of Poland, and $p = r + q + s$.

With the calculated export and import shares of the regions in hand, we are able to allocate its total respective values of a specific region to their region of origin.

We believe that this procedure of constructing MRIOTs allows for their use for macroeconomic simulations. The next step would be to use the constructed MRIOTs for developing a static and a dynamic regional CGE model for policy analysis in the context of the regional Polish economy.

6. Conclusions

As tools for investigating relationships between sectors and regions at the subnational level, MRIOTs are particularly useful in larger and more heterogenous countries. Poland meets these criteria—it is a relatively large country (by European standards) and an internally heterogenous one. In spite of this, RIOTs designed for aiding regional policy as well as performing macroeconomic simulations in this country were not compiled so far.

In this study, we thus compiled RIOTs for three distinct macro-regions, namely the eastern rural one, the more urbanized western areas with easier access to the EU markets, and the residual central belt.

To capture the distinctive features of regions and interregional connections, a database was built at the voivodship (NUTS-2) level using the most recent Polish NIOT. NUTS 2 regions were subsequently aggregated into three macro-regions, exhibiting distinct economic structures and other dissimilarities, which make them useful objects for the purpose of analysing possible differences in responses to internal and external shocks.

As such, the primary data used in this study are from a single-country static I–O table for Poland, based on the 2015 NIOT obtained from Statistics Poland (28 June 2019 release). The regionalisation of the NIOT was based on non-survey methods. In the first stage, the NIOTs are aggregated from 77 to 11 sectors and then subsequently regionalised by means of non-survey techniques, using the available regional data from Eurostat and the Polish Statistical Office local data bank (BDL). Specifically, data on employment at the national and regional levels with the structures of activities identical to the NIOT and some additional socio-economic indicators, such as income tax base and percentage of the national value added produced within the region, were employed. We constructed the MRIOTs in the following four steps. First, regional output by branch was estimated, using data on employment by industry, which led us to constructing regional supply tables. Second, primary inputs and the intermediate use of commodities were estimated under an assumption of equal technologies and subsequently adjusted based on regional superior information. Third, final commodities were estimated drawing upon a household survey on consumption expenditure. Fourth, regional imports and exports were estimated using the modified version of the CHARM developed by Kronenberg (2009).

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Notes

1 See Kronenberg and Többen (2011) for an in-depth discussion.

2 See Wiebe and Lenzen (2016), Distefano et al. (2020) and Gabela (2020) for a comprehensive review of these methods and an in-depth discussion over their performance.

References

(Alikaj and Alexopoulos 2014) Alikaj, Mirsida, and Yiorgos Alexopoulos. 2014. Analysis of the economy of region of western Greece. An application of the social accounting matrix (SAM). *Procedia Economics and Finance* 14: 3–12. https://doi.org/10.1016/S2212-5671(14)00679-0.

(Anagnostou and Gajewski 2019) Anagnostou, Ageliki, and Paweł Gajewski. 2019. Heterogeneous impact of monetary policy on regional economic activity: Empirical evidence for Poland. *Emerging Markets Finance and Trade* 55: 1893–906. https://doi.org/10.1080/1540496X.2018.1531751.

(Bonfiglio 2005) Bonfiglio, Andrea. 2005. *Can Non-Survey Methods Substitute for Survey-Based Models? A Performance Analysis of Indirect Techniques of Estimating I-O Coefficients and Multipliers*. *Working Papers 230*. Marche: Universita Politecnica delle Marche Dipartimento di Scienze Economiche e Sociali.

(Cazcarro et al. 2013) Cazcarro, Ignacio, Rosa Duarte, and Julio Sanchez Choliz. 2013. Multiregional Input-Output Model for the Evaluation of Spanish Water Flows. *Environmental Science & Technology* 47: 12275–83. doi:10.1021/es4019964.

(Cieślik 2005) Cieślik, Andrzej. 2005. Regional characteristics and the location of foreign firms within Poland applied. *Economics* 37: 863–74.

(Chidlow et al. 2009) Chidlow, Agnieszka, Laura Salciuviene, and Stephen Young. 2009. Regional determinants of inward FDI distribution in Poland. *International Business Review* 18: 119–33. doi: 10.1016/j.ibusrev.2009.02.004.

(Distefano et al. 2020) Distefano, Tiziano, Marta Tuninetti, Francesco Laio, and Luca Ridolfi. 2020. Tools for reconstructing the bilateral trade network: A critical assessment. *Economic Systems Research* 32: 378–94. https://doi.org/10.1080/09535314.2019.1703173.

(Eding et al. 1999) Eding, Gerard, Jan Oosterhaven, Bas de Vet, and Henk Nijmeijer. Constructing regional supply and use tables: Dutch experiences. In *Understanding and Interpreting Economic Structure*. Edited by Geoffrey J. D. Hewings, Michael Sonis, Moss Madden and Yoshio Kimura. Berlin/Heidelberg and New York: Springer.

(Gabela 2020) Fournier Gabela, Julio Gustavo. 2020. On the accuracy of gravity-RAS approaches used for inter-regional trade estimation: Evidence using the 2005 inter-regional input–output table of Japan. *Economic Systems Research* 32: 521–39. https://doi.org/10.1080/09535314.2020.1753662.

(Gajewski 2015) Gajewski, Paweł. 2015. Regionalne zróżnicowanie efektów impulsu polityki pieniężnej w Polsce. *Gospodarka Narodowa* 278: 27–47.

(Gajewski 2016) Gajewski, Paweł. 2016. Regionalne krzywe Phillipsa w Polsce a efekty polityki pieniężnej. *Ekonomista* 214: 501–19.

(Gajewski and Tchorek 2017) Gajewski, Paweł, and Grzegorz Tchorek. 2017. What drives export performance of firms in Eastern and Western Poland? *European Planning Studies* 25: 2250–71. https://doi.org/10.1080/09654313.2017.1355890.

(Gallego and Lenzen 2009) Gallego, Blanca, and Manfred Lenzen. 2009. Estimating Generalised regional input–output systems: A case study of Australia. In *The Dynamics of Regions and Networks in Industrial Ecosystems*. Edited by Matthias Ruth and Brynhildur Davidsdottir. Cheltenham: Edward Elgar Publishing.

(Golemanova 2018) Golemanova, Antoaneta, and Aleš Kuhar. 2018. *Input-Output Model for the South-East Region in Bulgaria, Working Paper*. Sofia: UNWE.

(GUS 2019) Statystyczny, Główny Urząd. 2019. Bilans przepływów międzygałęziowych w bieżących cenach bazowych w 2015 roku. Available online: www.stat.gov.pl (accessed on 3 March 2021).

(Harris and Liu 1998) Harris, Richard ID, and Aying Liu. 1998. Input-output modelling of the urban and regional economy: The importance of external trade. *Regional Studies* 32: 851–62. https://doi.org/10.1080/00343409850118004.

(Hudson 2010) Hudson, Ray.2010. Resilient regions in an uncertain world: Wishful thinking or practical reality? *Cambridge Journal of Regions, Economy and Society* 3: 11–25. https://doi.org/10.1093/cjres/rsp026.

(Isard 1951) Isard, Walter. 1951. Interregional and regional input-output analysis: A model of a space-economy. *The Review of Economics and Statistics* 33: 318–28.

(Kronenberg 2009) Kronenberg, Tobias. 2009. Construction of regional input-output tables using nonsurvey methods the role of cross-hauling. *International Regional Science Review* 32: 40–64. https://doi.org/10.1177/0160017608322555.

(Kronenberg and Többen 2011) Kronenberg, Tobias, and Johannes Többen. 2011. Regional Input–Output Modelling in Germany: The Case of North Rhine-Westphalia. MPRA Paper 35494. Available online: https://mpra.ub.uni-muenchen.de/35494/ (accessed on 23 September 2021).

(Lahr 1993) Lahr, Michael L. 1993. A review of the literature supporting the hybrid approach to constructing regional input–output models. *Economic Systems Research* 5: 277–93. https://doi.org/10.1080/09535319300000023.

(Liang et al. 2007) Liang, Qiao-Mei, Ying Fan, and Yi-Ming Wei. 2007, Multi-regional input–output model for regional energy requirements and CO_2 emissions in China. *Energy Policy* 35: 1685–700.

(Leontief and Strout 1963). Leontief, Wassily, and Alan Strout. 1963. *Multi-Regional Input-Output Analysis*. New York: St. Martin's Press.

(Malik et al. 2014) Malik, Arunima, Manfred Lenzen, Rômulo Neves Ely, and Erik Dietzenbacher. 2014. Simulating the impact of new industries on the economy: The case of biorefining in Australia. *Ecological Economics* 107: 84–93. https://doi.org/10.1016/j.ecolecon.2014.07.022.

(Martin and Sunley 2015) Martin, Ron, and Peter Sunley. 2015. On the notion of regional economic resilience: Conceptualization and explanation. *Journal of Economic Geography* 15: 1–42. https://doi.org/10.1093/jeg/lbu015.

(Oosterhaven et al. 2018) Oosterhaven, Jan, Dirk Stelder, and Satoshi Inomata. 2008. Estimating international interindustry linkages: Non-survey simulations of the Asian-Pacific economy. *Economic Systems Research* 20: 395–414.

(Radvanski and Lichner 2018) Radvanský, Marek, and Ivan Lichner. *Regional Input-Output Tables of Czech Republic—Reviewing the CHARM Method*. Working Paper. Slovakia: Slovak Academy of Sciences.

(Richardson 1985) Richardson, Harry W. 1985. Input-output and economic base multipliers: Looking backward and forward. *Journal of Regional Science* 25: 607–61. https://doi.org/10.1111/j.1467-9787.1985.tb00325.x.

(Riddington et al. 2006) Riddington, Geoff, Hervey Gibson, and John Anderson. Anderson. 2006. Comparison of gravity model, survey and location quotient-based local area tables and multipliers. *Regional Studies* 40: 1069–81. https://doi.org/10.1080/00343400601047374.

(Sargento et al. 2012) Sargento, Ana LM, Pedro Nogueira Ramos, and Geoffrey JD Hewings. 2012. Inter-regional trade flow estimation through nonsurvey models: An empirical assessment. *Economic Systems Research* 24: 173–93.

(Sila and Juvančič 2005) Sila, Urban, and Luka Juvančič. 2005. Regional input-output table: The case of Eastern Slovenia. *Jahrbuch der Österreichischen Gesellschaft für Agrarökonomie* 13: 121–34.

(Többen 2014) Többen, Johannes. 2014. *Construction of Multi-Regional Supply-Use Tables: Experiences from Germany's Federal States, Forschungszentrum Jülich*. Jülich: Institute of Energy and Climate Research–Systems Analysis and Technology Evaluation (IEK-STE).

(Többen and Kronenberg 2015) Többen, Johannes, and Tobias Heinrich Kronenberg. 2015. Construction of multi-regional input–output tables using the CHARM method. *Economic Systems Research* 27: 487–507. https://doi.org/10.1080/09535314.2015.1091765.

(Tohmo 2004) Tohmo, Timo. 2004. New developments in the use of location quotients to estimate regional input–output coefficients and multipliers. *Regional Studies* 38: 43–54. https://doi.org/10.1080/0034340031000163226 2.

(Wiebe and Lenzen 2016) Wiebe, Kirsten S., and Manfred Lenzen. To RAS or not to RAS? What is the difference in outcomes in multi-regional input–output models? *Economic Systems Research* 28: 383–402. https://doi.org/10.1080/0034340031000163226 2.

(Yi et al. 2007) Yi, Ilseuk, Norihiro Itsubo, Atsushi Inaba, and Kanji Matsumoto. 2007. Development of the interregional I/O based LCS method considering region-specifics of indirect effects in regional evaluation. *The International Journal of Life Cycle Assessment* 12: 353–64.