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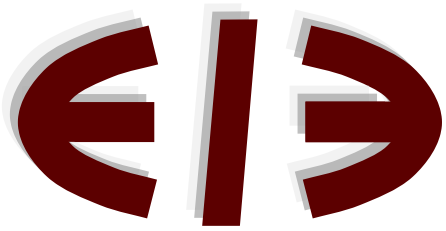

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RHOMOLO: A Dynamic General Equilibrium Modelling Approach to the Evaluation of the EU's Regional Policies

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Abstract: This paper introduces the spatial dynamic general equilibrium framework RHOMOLO, being currently developed at the European Commission. The model is constructed following the concept of recursively-dynamic Spatial Computable General Equilibrium (SCGE), which ensures a sequence of Walrasian equilibriums over time, and incorporates the key elements of the New Economic Geography (NEG) by capturing the forces of economic agglomeration and dispersion. RHOMOLO has both regional and sectoral dimensions, which implies enormous computational dimensions and presents challenges in terms of data availability and computational feasibility. The design of the model reflects the objectives of Cohesion Policy, and a broader understanding of impact assessment, which goes beyond pure economic effects.

Keywords: Economic modelling, spatial dynamics, policy impact assessment, regional development, economic geography, spatial equilibrium, SCGE.

JEL classification: C63, C68, D58, F1, F12, H41, O1, O31, O40, R13, R3, R4.

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1. INTRODUCTION

1.1 Purpose of the paper

The objective of the paper is to provide an outline of the structure and capabilities of the Regional HOlistic MOdeL (RHOMOLO), which is being developed for DG REGIO for the purpose of undertaking impact assessment of Structural and Cohesion Fund expenditure. The RHOMOLO model builds on a prototype, which was built for five European countries (Germany, Poland, Slovak Republic, Czech Republic and Hungary) by external consultants (TNO). The RHOMOLO model integrates the economic, spatial, and social dimensions in a unique framework, which explains the use of the term 'holistic'.

- Inter-regional links within a New Economic Geography (NEG) framework;
- inter-temporal dynamic features with endogenous growth engines;
- integrated public sector incorporating a multi-level governance system.

RHOMOLO can be used not only for ex-ante Cohesion and Regional Policy (CRP) impact assessment but also for ex-post impact assessment, other policy simulations and comparison between the policy scenarios. RHOMOLO incorporates the following three important features:

1.2 Historical modelling context

In order to better understand the need for a new model, it is useful to take a brief history lesson in the way that the modelling of Cohesion Policy has been undertaken at the European Commission and what lessons have been learned from the past modelling experience.

Previous models: HERMIN and QUEST

Ever since the inception of cohesion policy there has been a need to assess its impact, but only a few models stand the test of time as having been used continuously to analyse impacts across the Member States on a consistent basis. Although, there are many reduced-form[2] models looking at the impact of Cohesion Fund expenditure, there are only few that take a broader view and attempt to incorporate feedback effects. Two such models that have been used for impact assessment of cohesion policy by the European Commission in the past are the HERMIN and QUEST models.

The HERMIN model was developed in the 1980s (as a spin-off from the EC-led HERMES modelling system) to investigate the impact of Cohesion Fund spending on the Irish economy programmes and were subsequently extended during the following two decades to cover all the cohesion countries (initially Portugal, Greece and Spain within the EU15, then southern Italy, and more recently the New Member States). It has been (and continues to be) widely used for the purpose of Cohesion Policy

[2] The term reduced-form is used to define models looking at a particular aspect of Cohesion Policy, e.g. the effect on regional convergence, and can often be single-equation estimations.

analysis by the European Commission, with models for each Member State developed (see, for example, Bradley, Untiedt and Mitze (2007)). The HERMIN model has a mix of neoclassical long-term (e.g. supply-side effects on human and physical capital) and Keynesian short-term features (e.g. multiplier effects generated through increased expenditure) and a limited sectoral disaggregation.

In addition to HERMIN, the QUEST model of DG ECFIN has been used to assess the impact of Cohesion policy expenditure (see Varga and in't Veld, 2009). In contrast to HERMIN, QUEST is a general equilibrium model with forward-looking behavioural equations grounded in microeconomic theory and based on the inter-temporal optimisation of households and firms. In addition, households adjust their behaviour in the expectation of future tax payments arising from higher public expenditure, while real interest and exchange rates are determined endogenously, so that possible crowding-out effects can be taken into account. However, QUEST is a country-level model with no regional or sector disaggregation.

Court of Auditors report

In 2006 the European Court of Auditors produced a special report which reviewed the ex-post evaluations of Objective 1 and 3 programmes 1994-99. The HERMIN macroeconomic model was used to simulate the macroeconomic impact of Structural Fund interventions. The Court report noted that the macroeconomic model "suffered from significant limitations", and concluded that if such models are to be used for evaluating economic impacts of funds then they should take proper account of the specific features of the economies being analysed, as well as making better use of the micro-data generated at project level. More specifically, the report noted particular difficulties with the HERMIN model's applicability to policy impact assessment:

- too-strong an emphasis on the manufacturing sector, given the increasingly tradeable nature of services and the importance of tourism to some regional areas;
- econometric approach, i.e. model parameters based on period averages from 1980, unable to cope with the structural change that is endemic in regions that are undergoing rapid shifts during the period of analysis;
- exclusion of private sector co-financing and subsequent spillover effects, e.g. 'crowding-in';
- use of elasticities based on US regional literature to cope with the supply-side effects of the Structural Funds, i.e. human and physical capital stock augmentation.

The criticism of the Court of Auditors, together with developments in the theory of New Economic Geography, which had been gaining momentum during the 1990s and was starting to generate empirical applications in the last decade, may have led to thoughts that the kind of changes needed to bring the HERMIN model up to date were too great to be made within the confines of the model's structure and that a new modelling approach was required.

Forces for change

Useful though it was, the perceived problems with the HERMIN model provided a pressure to react and consider a new modelling approach. Also, despite the availability of the HERMIN and QUEST models, neither allowed regional coverage of impacts, despite the fact that Cohesion Policy is place-based and many of the objectives are regional in nature. While the currently developed the regionalised version of the HERMIN model for Poland answers some of the criticism about lack of regional detail, the main Keynesian structure of the model remains (which does not incorporate NEG theory), as does the issue of suitable time series data for appropriate estimation of model parameters, and international linkages.

In addition to the need for a model capable of delivering regional results, the findings of the Barca Report (Barca, 2009) have contributed to a need to look beyond the purely economic effects of policy impact, with a suggested reformulation of Cohesion Policy around six core priorities: innovation, climate change, migration, children, skills, and ageing[3]. Indeed, for some time now a three-pronged approach has been followed, namely to look (where relevant) at economic, social and spatial dimensions. Neither the HERMIN nor the QUEST models were designed to investigate spatial and social impacts, and so the RHOMOLO model was aimed at filling this gap in the modelling space of European Commission.

1.3 Structure of the paper

The next section of this paper describes the key elements of the EU Cohesion Policy and derives implications for policy modelling requirements in RHOMOLO. The following section seeks to describe some specific features of the RHOMOLO model. There is too much information on the model to include in a paper (for a full description, see the model manual – IPTS, 2010), so the focus will be on three main areas:

- incorporation of NEG theory;
- modelling inter-temporal dynamics;
- capturing the integrated effects of public policies.

In addition, there is a section on the limitations of the model, as there are clearly some things that the model cannot do or is not suited for, together with assumptions which could be questioned. In the conclusion to this paper, as well as summarising the findings thus far, the focus is on how the RHOMOLO model can be used to contribute to the likely future direction of Cohesion Policy.

[3] The themes and likely future of Cohesion Policy will be reviewed again in the Conclusions section of this paper.

2. THE EU COHESION POLICY

2.1 Overview of the EU Cohesion and Regional Policy

The EU Cohesion and Regional Policy (CRP) contributes to three EU policy objectives: Convergence, Regional Competitiveness and Employment, and European Territorial Cooperation (Council Decision. 2006/702/EC). In line with the three policy objectives, the CRP is financed through three EU Funds: the European Fund for Regional Development (EFRD), the European Social Fund (ESF) and the European Cohesion Fund (ECF) (European Commission, 2010).

The rationale of the Convergence objective is to promote growth-enhancing conditions and factors leading to a convergence for the least-developed Member States and regions (Council Decision. 2006/702/EC). In EU-27, this objective concerns 84 regions within 17 Member States with a total population of 154 million. The eligibility criterion is per capita GDP at less than 75 % of the Community average. The amount available under the Convergence objective is EUR 281 billion, representing 81.1 % of the total. Most of this money (57.8%) comes from the ERDF. The ECF contributes 24.7% and the ESF contributes 18.5% (European Commission, 2010).

The Regional Competitiveness and Employment objective aims at strengthening competitiveness and attractiveness, as well as employment, through a two-fold approach (Council Decision. 2006/702/EC). First, development programmes should help regions to anticipate and promote economic change through innovation and the promotion of the knowledge society, entrepreneurship, the protection of the environment, and the improvement of their accessibility. Second, more and better jobs should be supported by adapting the workforce and by investing in human resources. In EU-27, a total of 168 regions are eligible, representing 314 million inhabitants. The total budget of EUR 55 billion represents around 16% of the total allocation. This objective covers regions in 19 Member States. Most of the money (56.5%) comes from the ERDF. In addition, the ESF contributes 43.5% of the total expenditure (European Commission, 2010).

The European Territorial Co-operation objective strengthens cross-border co-operation through joint local and regional initiatives, trans-national co-operation aiming at integrated territorial development, and interregional co-operation and exchange of experience (Council Decision. 2006/702/EC). The population living in cross-border areas amounts to 181.7 million. However, all EU regions and citizens are covered by one of the existing 13 transnational co-operation areas. EUR 7.8 billion (2.3 % of the total) are available for this objective. All programmes under the European Territorial Co-operation objective are financed through the ERDF (European Commission, 2010).

In order to achieve these objectives, the CRP implements a wide variety of programmes (sets of policy instruments). In the 2007 – 2013 financial period there are 86 CRP programmes (Commission Regulation (EC) No 1828/2006). The programmes and their expenditure shares are reported in Ferrara, Ivanova and Kancs (2010).

According to Ferrara, Ivanova and Kancs (2010), the 86 CRP programmes cover a broad spectrum of areas including the economy, society, transport, education, culture, environment etc. They differ with respect to the allocated expenditure share, the set of regions where the programmes are implemented, and in terms of their composition (programme's share in each region's CRP budget). Moreover, they are financed through different funds, aim at different CRP objectives, and their role changes with economic development.

2.2 Implications for the modelling framework

The complexity and multi-dimensionality of the CRP has important implications for the modelling framework. A policy-relevant and theoretically consistent modelling of the CRP requires a conceptual framework, which accounts for many factors affecting the impact of policies, such as the CRP implementation details, offers a sufficient variety of channels of adjustment to policy shocks, provides the necessary sectoral and regional detail, imposes the principles of co-financing and additionality, accounts for the multi-objectivity of programmes, and can replicate the dynamics of regional economy adjustment to policy shocks. The key requirements are summarised below.

Policy implementation details. As discussed in the previous section, the CRP is implemented through 86 different programmes. These programmes have different weight in terms of the total expenditure ranging from 0.01% (Support to compensate additional costs due to climate conditions and relief difficulties) up to 5.4% (TEN-T Railways) representing in such a way the Community's priorities. Moreover, the expenditure shares vary between years over the Financial Period 2007-2013. Third, the composition of the CRP programmes varies significantly between regions and Member States. Hence, the modelling framework must be able to accommodate programme-, year- and objective-specific policy interventions.

Channels of adjustment. Different CRP programmes affect different actors, e.g. skilled workers, unskilled workers, firms, etc. in different ways. For example, 'measures to improve access to employment and increase sustainable participation and progress of women' will reduce the entry costs of workers into the labour market. The 'developing human potential in the field of research and innovation, in particular through post-graduate studies' will affect mainly the supply of skilled workers in the regional economy through lower schooling costs. Hence, the conceptual framework should offer sufficient interfaces for simulating all key policies and programmes in the exact way they affect regional actors, e.g. reducing fixed and variable market entry and exit costs, affecting skilled and unskilled worker supply and demand, changing incentives for firm investment and production behaviour, etc.

Sectoral detail. Some of the CRP programmes are sector specific, i.e. directly they affect only the targeted sectors. For example, the renewable energy measures affect, above all, the energy sector. In contrast, horizontal programmes affect all sectors of the economy. For example, 'integrated projects

for urban and rural regeneration' will affect all sectors in the regional economy (though not necessarily in the same intensity). The conceptual framework should be able to model both horizontal and vertical measures, as well as allow for a nested sectoral detail, which can be extended when more data becomes available. Second, intra-industry trade, as well as sector specific factor and intermediate input intensities should be accounted for. Finally, inter-sectoral substitution possibilities on the input demand and production side would enrich the adjustment channels, through which regional economies adjust to policy shocks, and hence are highly recommended.

Regional detail. Different CRP policies are implemented in different regions. Even if the same programmes were implemented in different regions, because of the spatial heterogeneity of regions, their impact would be different. Moreover, through spatial interactions, "non-treated" neighbouring regions are affected as well. This implies that the conceptual framework should account both for spatial heterogeneity of regional economies as well as for the inter-regional linkages, which leak the policy induced effects to other regions.

Programme co-financing. The CRP support is subject to co-financing, which means that EU provides only matching funds to individual projects that are part of the operational programmes and that the EU funds are matched to a certain extent by national expenditure (Annex III of Regulation 1083/2006). The co-financing shares are programme specific. In addition, the co-finance differs by the source of the funds: national versus regional. This requires that the conceptual framework allows for a multi-level government framework with programme-, region- and governance-specific budgets.

Programme additionality. The CRP support is subject to additionality, which requires that the EU Structural Funds are additional to domestically-financed expenditure and are not used as a substitute for it (Article 15 of Regulation 1083/2006 and Annex II of Regulation 1083/2006). For those programmes, which are directed to individual firms (as opposed to providing public goods, such as, infrastructure), also the beneficiary firm must co-finance the project (Article 55 of Regulation 1083/2006). In praxis, however, because Member States are not required to create new budgetary expenditure to co-finance the CRP support, existing national resources that are used to finance similar areas of national interventions are sometimes 'earmarked' to co-finance Structural Fund transfers. As a result, depending on the region and measure, the total spending increases by less than sum of the Structural Fund transfers and the additionally required national funding. Hence, the conceptual framework must be able to model both additionality and substitutability of national and EU programmes.

Multi-objectivity of programmes. Most of the CRP programmes are multi-objective, i.e. several objectives are addressed and/or affected by the same (or similar) programmes. This implies that a single programme has impact on several CRP objectives. For example, the construction and modernisation of railways (Programme 16) can be implemented in the context of all three CRP

objectives: Convergence, Regional Competitiveness and Employment, and European Territorial Cooperation. More generally, the impacts are multiple and affect various parts of the regional economies. Hence, in order to account for all policy induced effects, the modelling of the CRP requires a general equilibrium framework, which can account for policy impacts on the achievement of various objectives in a system of interlinked regional economies.

Dynamics. Most of the CRP programmes contain different types of investments. This implies that the aggregate impact will accumulate over several years. In addition, the policy impact on regional economies is non-linear and non-monotonic in time and programme- and project-specific. For the conceptual framework this implies that the CRP programmes should be modelled in a dynamic framework, which allows at least for a year-by-year policy impact assessment.

3. THE RHOMOLO V.1 MODEL

3.1 Introduction

The modelling structure of RHOMOLO is based on a class of models known as a spatial computable general equilibrium, SCGE for short. Typically, SCGE models are micro-founded general equilibrium models using utility and production functions to describe household, firm and government decisions, and which incorporate the modelling of (dis)economies of scale, external economies of spatial clusters of activity, continuous substitution between primary production factors and material inputs in the case of firms, and between different consumption goods in the case of households. In order to do this, firms are usually assumed to operate under economies of scale in markets with monopolistic competition of the Dixit-Stiglitz (1977) type, which allows for differentiated products implying variety, and therefore allows for cross hauling of close substitutes of the same products between regions.

The RHOMOLO model utilises the notion of the representative economic agent, which aims to capture the behaviour of each population group or sector through that of a single aggregate agent. It is further assumed that the behaviour of each such aggregate agent is driven by optimisation criteria such as maximisation of utility or minimisation of costs.

3.2 Incorporation of NEG theory

RHOMOLO is above all a regional model in which results at Member State level are the sum of regional effects. Each country in RHOMOLO consists of several NUTS2 regions, which are connected by inter-regional trade flows of goods and services as well as interregional migration flows. Trade takes place between the regions of the same country as well as between the regions of different countries. The pattern of inter-regional trade flows depends upon the preferences of consumers for buying goods from particular destinations and upon the prices of goods and associated transportation costs. Transportation costs in RHOMOLO differ by type of good and depend upon the distance and

quality of infrastructure between the regions of origin and destination. The larger is this distance the higher are the transportation costs, and better is the transport infrastructure the lower are the transportation costs.

The term New Economic Geography (NEG) emerged in the early-1990s and has gained much attraction for its arguments on centralising and decentralising forces in the geographic economic space, which could lead to convergence or divergence of regional incomes. In the NEG literature, initiated by the seminal papers of Krugman (1991) and Krugman and Venables (1995), the idea of agglomeration economies, as originally suggested by Marshall´s externalities, and of cumulative causation, was revived. The central concepts of this theory are aggregate economies of scale, the home market effect and the existence of trade costs. As to the first, economic activity tends to concentrate in large-scale agglomerations not only because of internal returns to scale of the firm´s production, but also because of externalities which produce external returns to scale. Producer contacts, and those to intermediary goods producers and customers, labour market pooling, and spill-over effects produce these externalities. As to the second, in the spatial context, economic activity will initially locate near to market demand (home market effect). Together with the third central element, transport costs, agglomeration advantages and the home market effect can produce centralizing forces in the stage of modest economic integration. Only if transport costs, or market barriers, are sufficiently reduced, will dispersion of economic activities set in.

RHOMOLO attempts to capture the key forces identified in the NEG theory by including four spatial effects in its structure:

1 *The market-access effect*. In RHOMOLO monopolistic firms will want to locate themselves in a big market and export to smaller markets. In this way they minimise transport costs and optimise their chances of being the most competitive supplier in all regions.

2. *The variety effect*. In RHOMOLO monopolistic firms (and consumers) will want to locate themselves in a big market with the greatest variety to increase productivity (and utility for consumers) via a larger choice of intermediate inputs (and final demand goods) due to Dixit-Stiglitz preferences

3. *The cost of living effect*. In RHOMOLO goods tend to be cheaper in a region with more economic activity since consumers in this region import less and reduce their transport costs. This attracts consumers.

4. *The market-crowding effect*. In RHOMOLO monopolistic firms have an incentive to locate themselves in regions with few competitors to avoid strong competition.

While the first three effects are agglomeration forces, as they encourage concentration of economic activity in space, the last effect is dispersionary. Trade costs, commuting costs and the regional availability of land and housing determine the relative strength of these forces. A model with only

agglomeration forces would ultimately lead to an economy concentrated in a single region. A more realistic model should also take countervailing dispersion forces into account.

Changes in transport costs trickle down through the economy, affecting regional (as well as national) economic development. Transport costs affect prices directly and affect logistical costs and labour costs that influence the production process. The interaction between regional labour supply and demand and wages results in both national and regional changes in vacancies and unemployment. Changes in regional production affect intermediate demand, consumption and variety through the variety effect, the market-access effect, and the market-crowding effect.

A demonstration of the RHOMOLO model's potential for identifying the heterogeneity of transport cost impacts was provided for the 5th Cohesion Report (European Commission, 2010, p254), whereby the implications of improved trans-European infrastructure for Poland were modelled on the basis of 2007-2013 ex-ante expenditure allocations and the expected reduction in transport cost resulting from the improvement in the TEN-T network as a consequence of cohesion policy investment.

3.3 Inter-temporal dynamics

RHOMOLO is a recursively dynamic model and allows analysis of each period of the simulation time horizon, not just the beginning and end period, as is the case with static CGE models. This horizon is currently set until 2030 but in principle it can be extended for longer time periods. However, the longer is the simulated period, the larger is the confidence interval of the simulation results. For each year of the time horizon, RHOMOLO calculates a set of various economic, social and spatial variables (see Section 2.4 for more information).

The RHOMOLO model is recursive over time involving dynamics of physical and human capital accumulation and technology progress, stock and flow relationships and adaptive expectations. A recursive dynamic structure is composed of a sequence of several temporary equilibria. These equilibria are connected to each other through physical and human capital accumulation as well as through accumulation of R&D knowledge stock, changes in migration flows and the number of operating firms. Economic growth in RHOMOLO depends positively on investments in R&D and education, linked through total factor productivity (TFP). By investing in R&D and education each region is able to catch-up faster the region technological leader and better adopt its technologies.

TFP is the portion of output not captured by the amount of inputs (i.e. labour, capital, energy, land) used in production. As such, its level is determined by how efficiently and intensely the inputs are utilised in production. The main elements assumed to explain the growth in TFP in RHOMOLO are human capital, R&D expenditure, technology transfer and a measure of absorptive capacity. Sector and region-specific TFP growth depends also on endogenous and exogenous region-specific parameters and on the TFP level relative to the technological frontier (leader region) as well as the region's own absorptive capacity.

RHOMOLO adopts the leader-follower model is used (as formulated in Benhabib and Spiegel, 2005), which means that the further a region is from the leader, the higher is the potential for the region to catch-up. Investments in R&D, as well as and in conjunction with, the level of education / human capital, are also assumed to positively influence the rate of growth of regional productivity. However, there might be situations in which the previous three elements are not able to drive, by themselves, the process of growth of an economy. Strong investments in R&D, or high distance to the technology leader, if not accompanied by a sufficient level of human capital, might not translate in higher productivity. This is why the TFP specification used in RHOMOLO includes an interaction term, to capture the combined effect of the three factors, able to measure the capacity of a region to absorb knowledge and technology developed elsewhere, and to translate it into growth.

3.4 Capturing the integrated effects of Cohesion Policy

The term 'integrated' in this context means the ability to capture more than just economic effects, i.e. to also look at the impact of Cohesion Policy on the social cohesion.

Economic effects

At its heart, RHOMOLO is a macro-economic model, and so most variables describe economic development. Key variables such as GDP, GDP per capita, productivity (average labour or TFP) are readily available as are components of demand such as consumers' expenditure, government expenditure, investment, and trade. The sectoral dimension of RHOMOLO allows investigation of agriculture, manufacturing and services performance, while a detailed treatment of the labour market also allows employment to be monitored.

Social effects

In terms of the social side of the economy, households in RHOMOLO are differentiated by several income classes allowing to capture their specific consumption patterns and savings behaviour. Households with higher incomes consume more luxury goods and have higher savings. The differentiation of household income allows the calculation of statistics that measure the distribution / equality of income, such as the Gini coefficient or the relative measure of at-risk poverty (proportion of people below a threshold of 60% of median disposable income[4]). More importantly, simulations with the RHOMOLO model allow us to investigate what impact Cohesion Policy has on such measures.

Unemployment is included (and allowed to exist) in RHOMOLO, although the assumption is that unemployment represents an equilibrium choice between labour and leisure at the prevailing wage rate. In other words, the labour market does not have to clear (demand does not have to equal supply)

[4] See http://www.eapn.org/index.php?option=com_content&view=article&id=58&Itemid=54&lang=en for more information from the European Anti-Poverty Network.

but the lack of clearance still represents an equilibrium. Unemployment at regional level is modelled by using a wage curve (see Blanchflower and Oswald, 1994), which links real wages to the unemployment rate. This is done by three levels of education: high, medium and low, which in turn relate to standard ISCED definitions.

4. LIMITATIONS OF THE RHOMOLO V.1 MODEL

The description of the RHOMOLO model so far may give the impression that the RHOMOLO can perform any type of impact assessment that is desired for any area of EU policy. The reality is however somewhat different, and for this reason it is important to be aware of the limitations of the model as well as its capabilities. The most important of them are listed below.

4.1 Data availability

Regional data in Europe is notoriously sparse, particularly when it comes to the most interesting variables, such as R&D, migration, FDI and trade. The modelling of labour and capital flows in RHOMOLO is strongly influenced by data availability, as there are no data about these flows at NUTS2 level for the whole of EU. Intra-country migration data are available at NUTS2 level; and inter-country migration data are available at the national level (for details see Brandsma, Kancs and Persyn, 2011). Capital flows (FDI) data are available only at the country level; hence the model is calibrated to only country-to-country flows of capital. For their investments, countries draw from a pool of funds which consists of domestic savings and of savings coming from other EU countries and the RoW. This pool is assumed to be distributed among the regions and sectors by an investment bank funding physical capital investments according to a specified investment rule.

The modelling of interregional trade flows is again largely determined by data availability (see Ivanova, Kancs and Stelder, 2011). The only data available at EU-wide level are the data on the total origin-destination flow of commodities between the regions by type of commodity. There is no information available about the trade between regions in services. There is also no information available about differences in the geographical mix of the commodities bought by different sectors and households in the region. The lack of data results in a simplified structure of the model, which assumes no trade in services between the regions. There is also no difference in the geographical mix of the commodities bought by various sectors and households in a particular region. Under this assumption, the decisions of both sectors and households about buying commodities from a particular EU region are modelled as the decision of a representative agent called a "wholesaler". There is one wholesaler per region and per commodity type, who decides upon the geographical mix of commodities. Regional households and sectors further use the composite commodity, which is produced by the wholesaler. In this way both production sectors and households use the same geographical mix.

Even with the simplifying assumptions that are made, a sizeable amount of missing regional data used in RHOMOLO that needs to be estimated. The underlying technique used to do this is called *entropy*, which is a method of data estimation which uses information from a system to achieve consistency with the other elements contained within it, i.e. the structure of the model is used to impose constraints, such as adding up or proportionality, that act to help shape the filling out mechanism. Although, as a CGE model, there is much less emphasis and need for long time series of data, the extent to which the data used are in fact estimated should be borne in mind.

4.2 Treatment of R&D and innovation

The launch of the Innovation Union provides a pathway through which the goals of the Europe 2020 Strategy can be mapped out – from this it is clear that innovation is a key component in ensuring both growth and jobs in Europe over the coming decade. Innovation is a very broad concept, with the Innovation Union containing over 30 action points (each with their own set of initiatives) and the Innovation Scorecard containing 25 indicators.

However, the concept of innovation narrows considerably, when having to actually measure and model it at the sub-national level. The methodology report for the 2009 Regional Innovation Scoreboard (Pro Inno Europe, 2009) notes how the number of indicators available at regional level has gradually increased over the past decade, with 8 available and a few more which are possible to collect[5]. The report also distinguishes between three different dimensions of innovation analysis which serve to describe the innovation process and how indicators fit within it. Table 2 shows these three dimensions, along with those indicators that are listed as available and possibly available.

Table 2: Innovation indicators from RIS, 2009

Innovation Dimension	Description	Available	Possible
Enablers	Main drivers of innovation that are external to the firm	Tertiary education Life-long learning Public R&D expenditure Broadband access by household	
Activities	Firms' direct activities in the innovation process	Business R&D expenditure Non-R&D innovation expenditure EPO patents	SMEs innovating in-house Innovative SMEs collaborating with others
Outputs	Outputs of firms' innovation activities	Employment in medium-high & high-tech manufacturing Employment in knowledge-	Product / process innovations Marketing and / or

[5] It should be noted that coverage is not complete across the Member States, with sampling issues often preventing the Community Innovation Survey being used to obtain sub-national information.

Innovation Dimension	Description	Available	Possible
		intensive services	organisational innovators Resource efficiency innovators New-to-market sales New-to-firm sales

Within RHOMOLO, the number of variables which could be classified as representing innovation reduces further. Among enablers, tertiary education and public R&D expenditure are covered. Firms' activities are represented mostly through business R&D expenditure. Outputs could be measured through employment, sales, or exports among medium-high-tech manufacturing, although the sectoral disaggregation of RHOMOLO does not allow a detailed distinction to be made and so some degree of judgement would be required. In addition, spillover effects (both within and across sectors/regions/countries) could be measured by the effects in low-tech sectors, or by looking more generally at average measures of resource efficiency. As the Innovation Union takes more centre stage and filters through to all areas of Europe 2020, it will be important to see how the RHOMOLO model can be improved upon to capture the main features and mechanisms of this strategy.

4.3 Reliance on other models / information

As with any model, there are boundaries drawn (not often explicit) around those things that are dealt with internally, and those that rely on external or exogenous inputs. RHOMOLO is no exception to this, and there are some areas that could be improved upon in future to enhance the workings of the model. Examples of areas that currently benefit from combined runs with other Commission's models include:

- investment in transport infrastructure

In the RHOMOLO simulation previously mentioned for the 5th Cohesion Report, it was necessary to obtain information on the expected reduction in transport costs as a result of the infrastructure investment. Such detail was provided by the TRANSTOOLS model.

- R&D and innovation policy

The work with the R&D module is ongoing, as the most effective combination of human capital, R&D expenditure, and formulation of technology convergence is derived from the available data. The potential degree of disaggregation available in RHOMOLO makes such estimates subject to some degree of uncertainty, however, particularly if they are based on recursive dynamics. For this reason, it makes sense to link the R&D policy simulations of RHOMOLO to those of a fully dynamic model with inter-temporal optimisation of economic agents. The closest model in this respect is the DG ECFIN's QUEST, which as previously mentioned has also been used for Cohesion Policy simulations. Such links are already established, as they represent the direction in which the modellers are thinking

in terms of what methods will get the RHOMOLO model working most effectively in the quickest time possible.

4.4 Finance and money

RHOMOLO models a real economy with no inflation or banking sector. All prices are relative prices and calculated in terms of the numeraire (GDP deflator). Because there is no banking sector in the model economic agents do not have the possibility to borrow money and the interest rate is fixed exogenously. This feature of the model is not so much a drawback for the type of modelling that RHOMOLO is involved with, although it is possible that imposing credit constraints on consumers and producers might make the simulations more realistic in the post-financial crisis world of today. There is also the suggested development of new financial instruments within Cohesion Policy to help increase investment and reduce risk. Possibly an improved treatment of finance in the model would help in this regard.

5. CONCLUSIONS

The RHOMOLO model represents an advanced on previous impact assessment tools for Cohesion (and potentially other) policy. Firstly because it provides detail at sub-national level, and secondly because it allows for a more integrated form of analysis, incorporating economic, social and spatial variables to give a more balanced measure of impact. Over the next few years the development will continue with the aim to broaden the geographical coverage to all NUTS2 regions of EU27 and to deepen the theoretical underpinnings to properly reflect state-of-the-art knowledge in spatial analysis. The quantification of NEG theory on such a scale is also a relatively new development, and modelling experiments of this type are quite ground-breaking. This means that the results from the model should be examined in detail and compared with more bottom-up case studies and against the real world in general in order to establish an "external consistency" to match the internal consistency that is already achieved through the model's theoretical underpinnings.

Looking forward from a policy perspective, the 5th Cohesion Report acknowledges the challenges ahead for Europe and the need for Cohesion Policy to integrate with the Europe 2020 strategy as well as other elements such as the Innovation Union. The report also notes that "Higher-quality, better-functioning monitoring and evaluation systems are crucial for moving towards a more strategic and results-oriented approach to cohesion policy." It is clear that the RHOMOLO model will have a place in these systems of evaluation. It is also true that thematic concentration on a smaller number of priority actions is also something that can be experimented with in a modelling context.

Finally, coming back to the Barca report, it has already been noted that the suggested re-focussing around six possible candidates for core priorities requires a modelling approach that goes beyond the

traditional economic one. In addition, the emphasis on place-based policy would seem to require a place-based (bottom-up) approach to modelling, at the very least where sub-national variation and effects can be identified. Moreover, the approach to impact assessment has to be open to further changes in direction according to how the future of policy is determined for the coming period and beyond.

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