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

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Abstract

This paper describes some of the features of a new dynamic general equilibrium framework (RHOMOLO) being developed at the European Commission (JRC-IPTS, together with DG REGIO) for evaluating EU Cohesion Policy. The design of the model reflects the objectives of Cohesion Policy, and a broader understanding of impact analysis which goes beyond pure economic effects and also considers environmental and social indicators. The model has both regional and sectoral dimensions – regionally, the aim is for complete NUTS2 (NUTS1 for Germany) coverage of the EU27, while the potential sector coverage is 23 – all of which leads to very large modelling dimensions and presents challenges in terms of data availability. The model is constructed using the concept of Dynamic Spatial Computable General Equilibrium (DSCGE), which ensures Walrasian equilibrium in a sequence of model solutions over time, and also incorporates elements of New Economic Geography (NEG) in the way it captures the forces of economic agglomeration and dispersion.

[1] The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.
[2] This paper draws on work performed by the contractors (TNO and their consortium) who have been engaged to construct the prototype version of the RHOMOLO model, and in particular makes use of various project reports produced during the past two years (see TNO, 2009a,2009b,and 2010).

1. INTRODUCTION

1.1 Purpose of the paper

The objective of this paper is to provide an outline of the structure and capabilities of the regional holistic (RHOMOLO) model which is being developed by DG Regio and JRC-IPTS for the purpose of making an impact assessment of Structural and Cohesion Fund expenditure. A prototype of the RHOMOLO model is currently being built for five European countries (Germany, Poland, Slovak Republic, Czech Republic and Hungary) including all their NUTS2 regions (NUTS1 in case of Germany), with the aim of extending it to all Member States in the next two years. The model integrates the economic, environmental, and social dimensions in a unique framework, hence the use of the term 'holistic'.

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

- linking regions within a New Economic Geography (NEG) framework;
- having inter-temporal dynamic features with endogenous growth engines;
- including detailed public sector interventions;
- incorporating a multi-level governance system.

1.2 Historical modelling context

To better understand the need for the RHOMOLO model it is necessary to take a brief history lesson in the way that the modelling of Cohesion Policy has been undertaken and what lessons have been learned from this and from the assessment of this modelling.

EC-based models: HERMIN and QUEST

Ever since the inception of Cohesion policy there has been a need to model 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 partial[3] models looking at the impact of Cohesion fund expenditure, there are few that exist to take a broader view and attempt to incorporate

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

feedback effects. Two such models that do exist, and which have been used by Commission Services, 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, and more recently the New Member States). It has been (and continues to be) widely used for the purpose of Cohesion Policy analysis by the European Commission, with models for each Member State developed and in some cases regional economies, eg southern Italy (see, for example, Bradley, Untiedt and Mitze (2007)). The HERMIN model has a mix of neoclassical long-term (eg supply-side effects on human and physical capital) and Keynesian short-term features (eg 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, the QUEST model is forward-looking, with 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. It is a country-based model with no 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 went on to say 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 the ex post 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, ie 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, eg 'crowding-in';

- use of elasticities based on US regional literature to cope with the supply-side effects of the Structural Funds, ie human and physical capital stock augmentation.

To be fair to the HERMIN model, not all these criticisms are directly to do with the model, and at the time it was seen as the best tool that was available for the purpose. However, the criticism of the Court of Auditors, together with developments in the theory of regional economics through the field of New Economic Geography which had been gaining momentum during the 1990s and was starting to generate empirical applications in the early part of 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.

Other 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. It should also be noted at this point that a regionalised version of HERMIN is being developed for Poland by WARR and EMDS (see http://www.funduszestrukturalne.gov.pl/English/Evaluation/HERMIN+Model/ for more information). Although this 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.

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[4]. Both the QUEST and HERMIN models only focus on the economic impact of Cohesion Policy, however, ignoring the environmental aspect, for example on greenhouse gas emissions. The E3ME[5] model has been used for some environmental analysis of Cohesion funds[6] along the lines of sustainable development, but here, as with the previous two models, the analysis is limited to the Member State level despite the obvious region-specific / spatial impact of much of the policy. Clearly, neither HERMIN nor QUEST are designed to investigate environmental and social impacts, and so the RHOMOLO model is aimed at filling this gap in the modelling space as well.

[4] The themes and likely future of Cohesion Policy will be reviewed again in the Conclusions section of this paper.
[5] See http://www.camecon.com/ModellingTraining/suite_economic_models/E3ME.aspx.
[6] See http://www.ec.europa.eu/regional_policy/sources/docconf/budapeval/work/ekins.doc.

1.3 Remaining sections

The next section of this paper seeks to describe some specific features of the RHOMOLO model. There is too much information on the model to include in a single paper (for a full description, see the model manual – IPTS, 2011), so the focus will be on three main areas:

- incorporation of NEG theory;
- inter-temporal dynamics;
- capturing the integrated effects of Cohesion Policy.

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.

2. RHOMOLO MODEL DESCRIPTION

2.1 Introduction

The modeling structure of RHOMOLO is based in a class of models known as a spatial computable general equilibrium, SCGE for short. Typically, SCGE models are micro-founded comparative static 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 type (Dixit and Stiglitz, 1977) which allows for heterogeneous products implying variety, and therefore allows for cross hauling of close substitutes of 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. In this respect, the model is neo-classical and assumes average cost pricing and no excess profits.

2.2 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 (or NUTS1 in case of Germany) 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. The 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 forces identified in NEG theory by including four spatial effects in its structure:

1 The market-access effect. 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. 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. 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. 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.

An early 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 better 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.

2.3 Inter-temporal dynamics

RHOMOLO is a 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 environmental indicators (see Section 2.4 for more information).

The RHOMOLO model is recursive over time involving dynamics of physical and human capital accumulation and technological progress, stock and flow relationships and adaptive expectations. A recursive dynamic is a structure 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.

In summary, TFP is the portion of output not explained by the amount of inputs (ie 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 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.

In its basic form, 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.

2.4 Capturing the integrated effects of Cohesion Policy

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

Economic effects

At its heart RHOMOLO is an economic model, and so most indicators describe economic development. Headline indicators 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 five income classes allowing capture of 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[7]). More importantly, simulations with the 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) 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.

Environmental effects

There are numerous channels through which the environment is measured and modelled in RHOMOLO. Firstly, production is associated with greenhouse gas (GHG) and non-greenhouse gas emissions, particularly through associated energy use for GHG emissions. Secondly, water and waste management are explicitly identified in the economic activities of households and firms, as water is an important input while waste generation (hazardous and non-hazardous) is an important output which can affect the environmental quality of a region. Thirdly, from the household sector perspective, environmental quality, measured through changes in emission levels, enters as part of the welfare function. Because RHOMOLO distinguishes types of household by income quintile, the effect of environmental quality impacts can be allowed to differ between poor and rich income groups.

Indeed, environmental quality is one of the main factors of the households' welfare function such that changes in the levels of emissions have a direct impact upon the welfare of the households. Different income classes in the model are influenced differently by the changes in emission levels of various pollutants. Local pollutants have more impact upon the poor household groups, who live closer to the industrial sites and areas with dense traffic. The evaluation of emissions by each household group

[7] 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.

depends upon its willingness-to-pay. It is assumed that the willingness-to-pay is closely correlated with the income of the household. Rich households put a higher value to the emissions than the poor ones. The willingness-to-pay of the households is determined endogenously in the model and influences their respective welfare function.

In addition, all production activities in the RHOMOLO model are associated with emissions and environmental damage. The model incorporates the representation of all major greenhouse gas (GHG) and non-greenhouse gas (non-GHG) emissions. Emissions in the model are associated either with the use of energy by firms or with the overall level of the firms' outputs. In general GHG emissions are associated with the energy inputs whereas other emissions are associated with the total outputs of the sectors.

The table below summarises the main types of economic, social and environmental indicators available in RHOMOLO (at regional level unless otherwise indicated).

TABLE 1: TYPES OF INDICATOR AVAILABLE IN THE RHOMOLO MODEL

Economic	**Social**	**Environmental**
GDP, GDP per capita, and agglomeration measures	Income distribution (Gini coefficient, poverty measures)	GHG and non-GHG emissions
Productivity (labour, total factor) and unit labour costs	Unemployment (by education type)	Energy use and intensity
Sectoral output and specialisation indices	Wages (by sector)	Land use
Consumer spending	Education levels and spending on education	Freight transport
Investment spending (by sector), including FDI (national level only)	Net migration	
Government spending (various categories) and revenues	Accessibility and integration	
Trade balance and openness to trade		

TABLE 1: TYPES OF INDICATOR AVAILABLE IN THE RHOMOLO MODEL		
Economic	**Social**	**Environmental**
Employment (by sector and education type)		
R&D expenditure		

Cohesion Fund expenditure

While dealing with the topic of the effects of Cohesion Policy, it is worthwhile explaining how the inputs are managed in this process, in other words – how does the Cohesion Fund expenditure get translated into information that the RHOMOLO model can use to perform its simulations?

As is well known, Cohesion Policy expenditure is organised along 86 categories of expenditure. Clearly, these different types of expenditures have a mix of supply and demand-side effects, and while some are able to be identified directly into expenditures within the RHOMOLO model, others are more general and have to be accommodated in a more approximate way.

For the *demand-side* of the model, the following procedure is undertaken:

(i) Identify which of the 86 Cohesion Policy instruments can be directly mapped to the 23 sectors in RHOMOLO.

This has been done for 13 types of CP instrument. In the case of Cohesion Policy instruments which are related to increases in governmental expenditure but which could not be directly mapped to RHOMOLO sectors an assumption is made that they increase governmental expenditure proportionally. This means that this additional expenditure is allocated between RHOMOLO sectors according to their share in the base year (2007).

(ii) Identify the group of CP instruments which are related to building physical infrastructure and physical capital of production sectors.

Here it is assumed that these expenditures are distributed as additional demand for physical investment goods such as construction, machinery, electronics etc. These physical investment goods can be bought not only from the region where ECP expenditure is taking place but also from other regions of the same country. The shares of physical investment goods by type and by region are calculated using the data of the base year from regional Social Accounting Matrices (SAMs).

(iii) Identify the group of CP instruments which are interpreted as subsidies or transfers to production sectors and reduce their costs.

In case the transfers are given to SMEs the CP expenditure is distributed between sectors in the region according to the production value of SMEs in this particular sector. In case the transfers are given to all sectors, they are distributed between them proportionally to value of production. In case of these CP instruments the channel of demand side effect is also the channel of supply side effect.

All CP instruments have their own *supply-side* effects and are categorised into the following groups:

1. Have direct impact on capital stock of one of RHOMOLO sectors.
2. Reduce transportation costs between the regions.
3. Reduce emissions coefficient of GHG emissions.
4. Increase the share of incinerated waste.
5. Increase the share of treated waste water.
6. Increase R&D expenditure and hence influencing TFP.
7. Increase human capital stock and hence influencing TFP.

It follows from this that, for the construction of ex-ante model simulations, information on complete and unambiguous allocation of future expenditures of Structural and Cohesion Funds to the regions is required, ie, information on, how much will be spent, in which regions the resources will be spent, and in which category of expenditure or fields of intervention. Problems of regional allocation arise due to the fact that part of the funding remains at Member State level and part of it involves more than one region, eg, for transport infrastructures or cross-border co-operation[8]. This ambiguity of allocation is a major problem for ex-post evaluations of the regional impact of Cohesion Policy.

2.5 Limitations of the RHOMOLO model

The description of the RHOMOLO model so far may make it seem like a model that can perform any type of impact assessment that is desired for any area of Commission Services. The reality is somewhat far from that, and for this reason it is important to be aware of the limitations of the model as well as its capabilities. Some of the most important are listed below.

[8] For the period 2007-13, it is only possible to allocate 41.5% of the total EU funding directly to regions at NUTS2 level.

- Data availability

Regional data in Europe are notoriously sparse, particularly when it comes to the most interesting data 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 NUT S2 level however, hence RHOMOLO models only intra-county between-region migration flows. Meanwhile, capital flows (FDI) data are available only at the country level; hence the model covers 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. 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 about the trade between regions in services. There is also no information 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 the regional data used in RHOMOLO needs to be filled in. The 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, ie 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.

- Treatment of R&D / 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 promoting 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[9]. The report also distinguishes between three different dimensions of innovation analysis which serve to describe the innovation process and how indicators fit within it. The table below 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-intensive services	Product / process innovations Marketing and / or organisational innovators Resource efficiency innovators New-to-market sales New-to-firm sales

Within RHOMOLO, the number of indicators which could be classed 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

[9] 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.

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.

- 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 require external assistance are as follows:

- 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 times as a result of the infrastructure investment. Such detail was provided by the TRANSTOOLS model.

- environmental policy that could change energy efficiency

Environmental expenditures from Cohesion Policy might well be expected to improve the use with which energy is made by firms and households. Such changes in energy efficiency cannot currently be captured by RHOMOLO, and so would need to be estimated elsewhere and imposed on the model.

- TFP simulations

The work with the TFP side of the model 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 estimated data. For this reason, it might make sense to link or tie the TFP simulations of RHOMOLO to those of a more well-established model that is more used to aggregate-type simulations. The closest model in this respect is the DG EcFin model, QUEST, which as previously mentioned has also been used for Cohesion Policy simulations. Such links are far from established, but 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.

- 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.

3. CONCLUSIONS

The RHOMOLO model represents an advance 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 environmental indicators to give a more balanced measure of impact. The model is still in prototype form, however, covering a limited number of Member States and still not fully-functional in terms of all its modelling capabilities. Over the coming years the development will continue with the aim to broaden the geographical coverage to all EU27 regions and to deepen the methodological 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". The RHOMOLO modelling system will have a place in the quantitative evaluation of policy options. It is also true that thematic concentration on a smaller number of priority actions is 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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