Merging macroeconomic and territorial determinants of regional growth: The MASST4 model

Roberta Capello, [1] Andrea Caragliu[2]

Abstract

While prior econometric forecasting models focus on either macroeconomic or territorial aspects as drivers of regional growth, the fourth version of the MAcroeconomic, Sectoral, Social, Territorial (MASST4) model merges these two conceptual approaches to regional growth. Mechanisms of territorial complexity governing regional development theories, like agglomeration economies, or structural changes in innovation modes, are included into a formal model in a way to simultaneously activate regional growth and mediate macroeconomic growth impacts. Moreover, a longer time series than in previous versions of the MASST model now allows to take account of the structural changes taking place in EU economies as a consequence of the recent crisis. The model now also models the effects of the decrease in EU integration stemming from populistic waves in politics taking place in EU countries. The paper also presents an application of the MASST model to a reference scenario.

Keywords: regional growth models, economic crisis, regional productivity, urbanization economies, dynamic innovation patterns

JEL classification codes: R11, R12, O11

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[1] Politecnico di Milano, ABC Department, Piazza Leonardo da Vinci, 32, BLD 5, 20133 Milan (MI), Italy. E-mail address: roberta.capello@polimi.it.

[2] Politecnico di Milano, ABC Department, Piazza Leonardo da Vinci, 32, BLD 5, 20133 Milan (MI), Italy. E-mail address: andrea.caragliu@polimi.it.

1. Introduction

The remarkable industrial and geographic heterogeneity in the response to the crisis (Martin et al., 2016; Giannakis and Bruggeman, 2017; Lo Cascio et al., 2018), the persistency of some of the contraction-induced effects, new politically sensible decisions on the future of the European Union introduced complexity in the way regional economic growth can be modeled for forecasting purposes. In general, regional forecasting models do not explicitly take into consideration structural changes in the economy. Most such tools (Brandsma et al., 2015; Varga and Sebestyén, 2017), in fact, are based on long-run theoretical equilibrium conditions, translated into Vector Auto Regression (VAR) relations, which, while based on solid theoretical grounding, fall short of a sound toolbox to assess off-equilibrium variations.[3] Others, merging Input-Output (IO) tables with econometric tools, gain more insight into short-run employment fluctuations, at the cost of less interpretative power in long-run permanent changes (Masouman and Harvie, 2018).

Among regional econometric growth models, the Macroeconomic, Sectoral, Social and Territorial (MASST) model has evolved over the last decade to be a useful complement to VAR and IO methodologies in explaining structural relations among regional growth-enhancing factors and long-run regional growth paths (Capello, 2007; Capello and Fratesi, 2012; Capello et al., 2017). The MASST model is a regional econometric growth model built to simulate regional growth scenarios in the medium and long-run (typically, over a 15-20 years' time horizon); it strikes a balance between quantitative forecasts as in standard VAR models and qualitative foresights as typically done in long run scenario simulation exercises, producing what have been termed *quantitative foresights* (Capello et al., 2008). First, structural relations between explanatory and dependent variables in various national and regional equations are estimated over a long run time span. Next, coefficients thus

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[3] The MASST model bears important similarities w.r.t. the GMR model by Varga and coauthors, in that both strive to integrate a macroeconomic and a regional sub-model. The main difference between these two approaches lies in the forecasting nature of the MASST model, against the GMR's aim to assess policy impacts. See e.g. Varga et al. (2020) for a recent discussion of the state of the art of the GMR model.

estimated are exploited for simulating likely future growth patterns, given internally coherent sets of assumptions forming regional growth scenarios.

Despite the remarkable level of complexity of the model in its third generation, in which the number and the complexity of the effects of the 2007-2008 crisis have been taken into account (Capello et al., 2017), the important political and economic novelties mentioned above prompted structural advances of the model, with the aim to strengthen its structure. This paper aims at providing an in-depth discussion of the crucial advances brought about in the model.

The first advance of paramount importance (technically speaking the easiest) was the need to update the database, with the goal to grasp the ways countries re-emerge from the crisis, and adjust their economies along new, never explored before, growth paths. In several regions, the economic landscape has been left changed for good. While during the crisis increased competition from areas hosting de-localized manufacturing and tertiary activities left many EU and US regions with a persistent unemployment rate (Autor et al., 2013; Dustmann et al., 2014; Hoffmann and Lemieux, 2016), a resurgence of manufacturing activities seems to be a new trend in Europe, driven by the new Industry 4.0 technological paradigm. Highly selective in terms of benefitting countries and regions, the re-launch of manufacturing activities in Europe is neither geographically, nor industrially evenly spread: some sectors are under strain, while some, especially in more technologically advanced regions, are actually gaining (Capello et al., 2015; Groot et al., 2011). The new MASST4 model presents utterly new estimates of both the regional and national sub-models, based on a full panel structure for the national part of the model, and on a three-periods (pre-crisis; crisis; after-crisis) panel structure for the regional sub-model.

The second advance of paramount importance is the strengthening of the merging between macroeconomic, national, trends and regional ones. While prior econometric models focus on either macroeconomic or territorial aspects for explaining regional growth, MASST4 further merges these two conceptual branches, by broadening the scope of the endogenous territorial features of MASST3,

and integrating them with macroeconomic aspects. In MASST, traditional territorial growth determinants simultaneously activate regional growth and mediate macroeconomic growth impacts. In other words, the effects of the crisis, and the ways out of the great contraction of different areas, are due to structural differences in regional development patterns, growth-enhancing factor endowments, all calling for sound toolboxes capable of differentiating otherwise space-blind effects in terms of different geographic areas. In MASST4 the crucial territorial growth determinants have been enlarged to embrace three important new political / economic trends that will influence future growth paths.

The first new trend is of a political nature, and refers to a major unexpected change in structural economic relations, that is hard to capture with standard regional econometric growth models. We refer here to the recent decision made by the UK to leave the EU (henceforth, for short "*Brexit*"). Following a much debated referendum held in the UK on June 23, 2016, UK decided to withdraw its membership of the European Union, which had been gained after a decade of negotiations starting in 1961 and ending only in 1973 with the UK's admission to the European Union, together with Ireland and Denmark (UK and EU, 2018). As often the case, this politically sensible decision has prompted several debates, both among academics (e.g. Chen et al., 2018; Bachtler and Begg, 2017; Brakman et al., 2018) as well as among practitioners, with frequent rebukes on either side, too often thrown without sound research and solid methodological tools capable of interpreting the likely effects of similar decisions. What is nevertheless becoming clear is that the future will strongly be influenced by the scope and quality of such trends, and tools for scenario building cannot ignore the existence of such political decisions. The MASST4 model has been restructured for also modeling the effects of Brexit and of possible future increase in administrative, economic and legal international borders within the EU (Capello et al., 2018a).

The second trend refers to the role played by cities in stimulating national growth. Academics and policymakers debate on whether the presence of large capital cities, catalyzers of new and qualified

activities, plays a role in driving countries out of the crisis, or whether the presence of such large economies, more directly hit by the crisis, and thus fighting the social costs generated by the downturn, prevents a full recovery at Country level (Parkinson et al., 2015; Capello et al., 2015; Dijkstra et al., 2015). MASST overcomes this debate, and embraces the idea that the role of cities in the stimulating national economies lies in their ability to adjust to the new challenges. Therefore, the structural change of cities, in terms of functions hosted, in governance of local problems, in institutional quality, in cooperating with other cities, explain agglomeration economies and their role in aggregate growth. MASST4 endogenizes agglomeration economies, which in the model depend on structural changes of local economies.

The third trend calling for a more sophisticated toolbox is the paramount importance of the new technological paradigm (the so-called Industry 4.0 revolution) for the future of Europe. Over the past 20 years, Europe has been steadily deindustrializing (Drucker, 2014; Rodrik, 2016). However, recent evidence (Wink et al., 2016) suggests that, to a limited extent and under specific local conditions, this medium run trend may be reversing, in particular for high-tech industries that drive the fourth industrial revolution (Lee et al., 2015). The new paradigm, based on new knowledge developed in very limited hotspots, and diffused on the basis of the presence of wise, advanced and forward looking adopters, able to change their organizational, managerial and economic structure around new and unprecedented routines, drastically changes the possibilities of competitiveness, increasingly depending on new modes of innovation and learning processes. Given the importance of the diffusion of the new technological paradigm on the future of countries and regions, the MASST4 model has been revised. The probability of a regional economy to go through a structural evolution in its innovation modes (Asheim, 2012; Capello and Lenzi, 2018) is now included in the model.

In the rest of the paper we will explain in detail these advances. Section 2 synthetically describes the structure of the MASST model, with an emphasis on the advances in the structure of the most recent version of the tool. Section 3 discusses the advances in the national sub-model, and highlights the

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major results obtained by the estimates in terms of structural changes taking place in the after-crisis period. Section 4 deals with the regional sub-model and highlights in particular the major novelties of this tool. These include the endogenization of dynamic agglomeration economies, the introduction of dynamic regional patterns of innovation, the endogenization of regional productivity, dynamics in manufacturing employment patterns, the way Brexit effects are simulated, and the introduction of a full panel structure. Section 5 presents an application of the MASST4 model to a Reference scenario, which beyond purely extrapolating from present long run trends also takes into account the main structural changes taking place in the aftermath of the 2007/2008 economic crisis. Lastly, Section 6 concludes and discusses some possible further future developments of this class of models, while also highlighting possible implications of our work for regional policymakers.

2. The new structure of the MASST4 model

The basic structure of MASST4 clearly reflects prior versions. The model is a regional econometric growth model comprising two main subcomponents, viz. a national and a regional sub-model. The units of observation are European Union's 28 countries, observed at the NUTS2 level.[4] While national GDP growth is built on aggregate demand-side features, regional differential growth depends mostly on supply-side elements. Both the national growth rate and the regional differential growth rate feed regional growth.

In order to generate future growth rates, the MASST model first estimates structural relations among exogenous and endogenous variables; next, the equation parameters thus identified are exploited to calculated predicted values for the dependent variables, with both exogenous and endogenous variables, the former tending to previously predetermined targets. Target values are set according to internally coherent sets of assumptions of possible future combinations of context conditions that

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[4] NUTS (Nomenclature of Territorial Units for Statistics) is the European Union's classification of regional units, comprising a hierarchical structure form Countries (NUTS0) to the rough equivalent of US counties (NUTS3) (EUROSTAT, 2016a).

depict specific scenarios. Advances have been introduced both in the estimation and in the simulation procedure.

The new structure of the MASST4 model is graphically summarized in Figure 1 below, where the cause-effect structural economic relationships, on which the MASST model is based, are represented. Figure 1 shows the national component of the MASST4 model on the left-hand side, and the regional component on the right-hand side. The sum of the two provides regional growth rates. The MASST4 model endogenizes six national equations and eleven regional equations.[5]

On the demand, macroeconomic side, the novelties of MASST4 rest on the longer time series on which estimates are run. Time dummies differentiating the impacts of different exogenous variables on the exogenous ones allow to highlight if structural breaks exist in the long term relationships of macroeconomic variables. Structural relations are estimated by means of heteroskedasticity-robust Ordinary Least Squares, or Fixed Effects (where appropriate), respectively. Among the main alternatives, seemingly unrelated regressions would on the one hand take account of the likely correlation among structural equations errors, thus allowing increasing efficiency and precision in the estimates; however, misspecification in one equation could easily transmit to other model relations.

As anticipated in Section 1, another alternative would entail resorting to dynamic models such as vector auto regressions (VARs) or vector error correction models (VECMs), as frequently done in competing forecasting models. This second choice would imply two major advantages with respect to the structural equations model here built, viz. (i.) a superior performance in short-fun forecasting, and (ii.) a better capacity to assess single-policy exogenous shocks in the modeling exercise. Both advantages would not be needed within our empirical framework, though, because the MASST4 model is built to produce long-run forecasts based on coherent sets of assumptions, i.e. a scenario. In

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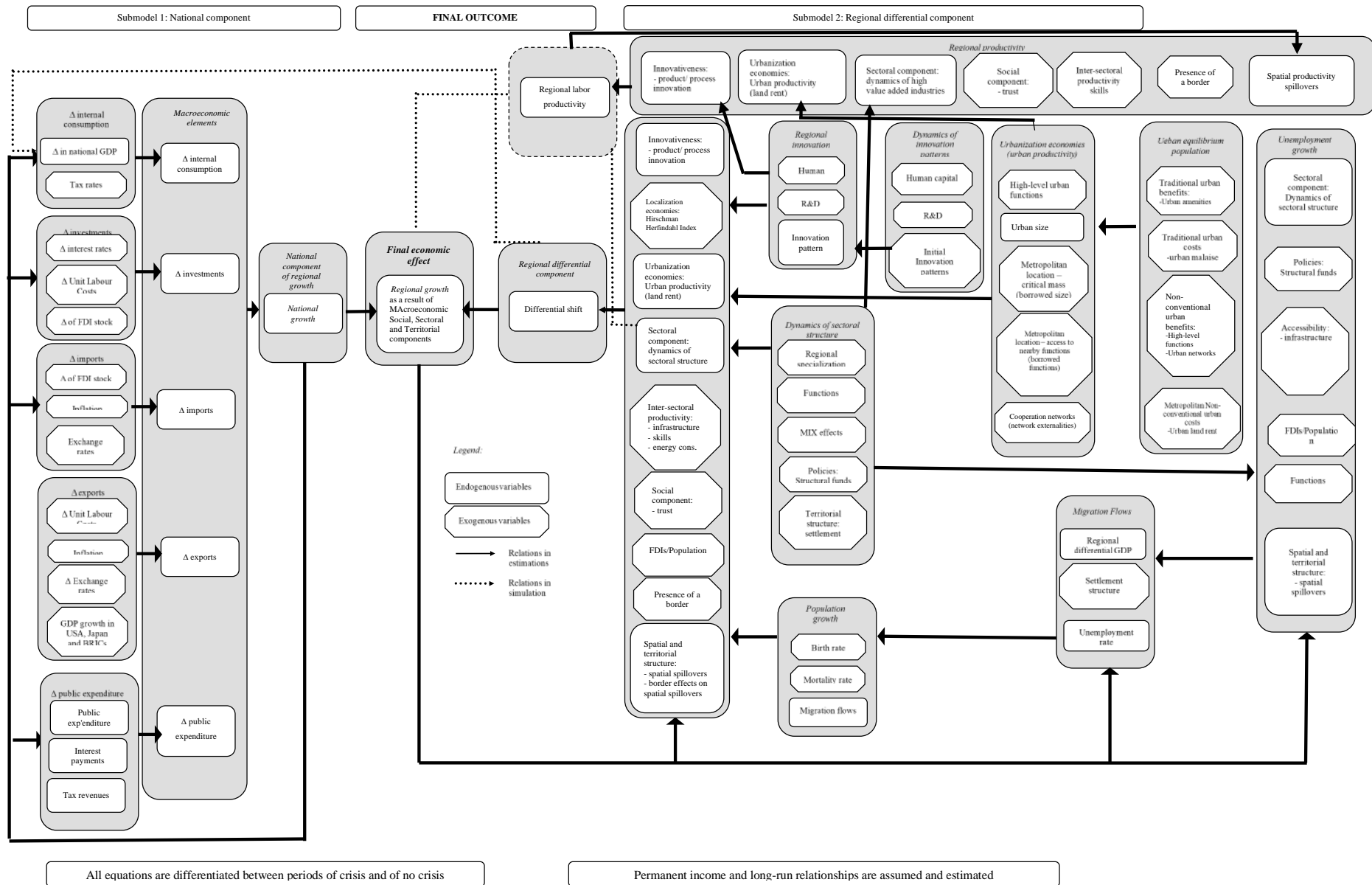[5] For a comprehensive list of endogenous and exogenous variables, see Technical Appendix A1.

Figure 1. Structure of the MASST4 model
Source: Authors' elaboration

this sense, VECMs would not allow the set-up of complex scenarios with combinations of conditions subsumed under the same theoretical umbrella.

Changes at the macroeconomic level are not reflected in a new structure for the model, whereas advances in the regional sub-model are clearly detectable. A new equation is included for the explanation of productivity levels. The spatial heterogeneity in the fall of productivity subsequent to the first economic shock in 2008 causes several issues in MASST3 because productivity, previously included in the model as exogenous parameter, would call for assumptions on the side of the modeler. Adding a new after-crisis period, in which the heterogeneity of regional productivity is larger than ever, called for endogenizing this variable. Sectoral composition, innovation capacity, agglomeration economies, human capital, social capital are sources of productivity; the latter, in its turn, explains regional differential growth.

A second additional equation models urbanization economies. MASST3 considered equilibrium urban size as the unique source of agglomeration economies. MASST4 maintains an equilibrium size, obtained as the result of the balance between benefits and costs, and makes a step forward by introducing this equilibrium size in the equation explaining agglomeration economies. The last ones depend on equilibrium city size, and on additional important variables, like functions hosted, city-networking skills, one the size of cities located nearby ("*borrowed size*" in Alonso, 1973, reprised in Meijers, 2013), and the functions hosted by nearby cities (the "*borrowed functions*" concept introduced in Camagni et al., 2016; Camagni and Capello, 2020).

An additional advance of MASST4 lies in the introduction of an equation explaining the probability for a region to move to different, more complex, innovation modes. Increases in human capital and in R&D activities push regions to innovation modes based on new knowledge, produced within the region, rather than on knowledge or innovation produced elsewhere, and brought into the region through different channels. The new innovation modes that a region experiences explain, in their turn,

the degree of product and process innovation developed, and, ultimately, regional growth differentials.

A last and interesting advance in this version of the model is the role attributed to international borders within the EU. This border effect is not included through a single equation; therefore, it does not appear in Figure 1 as an additional equation. We instead proceed as follows. First, we introduce a dummy variable equal to 1 when the region shares an international border, and zero otherwise. This dummy is interacted with growth assets in different equations and, when significant, maintained in the model. Next, growth spillovers are calculated on the basis of a geographical distance and a trade proximity matrix between region pairs.[6] The two matrices (geographical and trade flows) are then used to discount GDP growth of other regions before summing GDP growth of all other regions as the growth spillover of a specific region. In the simulation stage, the two matrices can be modified according to the assumptions on the role of borders. Lastly, at the simulation stage we can make different assumptions on the year when Brexit will actually take place, by drastically increasing the coefficients in the geographical and trade matrices between single European regions and UK regions. As a consequence of these assumptions, growth spillovers decrease, thus capturing the losses that both UK regions and EU regions suffer from re-establishing international borders between the UK and the EU.

All these advances have been achieved without altering the original characteristics of the MASST model. The MASST4 model is simultaneously generative, and distributive. It is a generative growth model, in that regional growth is interpreted mainly as a competitive process (Richardson, 1973). In this class of models, regional growth is seen as a "*zero-sum allocation and distribution of production*" (Harris, 2011, p. 914), and a region's growth takes place at the expense of another's (Richardson, 1978, p. 145). In the MASST4 model, the economic performance of a region depends mainly on its

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[6] The regional sectoral input-output table has been made available by the JRC group responsible for the Rhomolo model in Seville. We would like to thank the colleagues in Seville for sharing their Input-Output matrix.

institutional context, i.e. on the national performance. Institutional features, organizational quality, and competitiveness in international trade influence regional economic performance; in the MASST4 model, the global economy acts as a trigger to regional economic performance through the increase in the demand for Country's products, within a classical Keynesian aggregate demand setting.

The MASST4 model remains also distributive; national growth rates are distributed to single regions depending on their factor endowments, which explain regional differential shifts (Garcilazo and Oliveira Martins, 2015). In this sense, regional differential performance is mostly a supply-side mechanism, with both tangible (accessibility; regional policy expenditure; energy efficiency) and intangible (trust; human capital; quality of governance) assets making regions more competitive with respect to the Country mean.

Exogenous variables tend instead to reach in the long run predetermined targets whose value is set depending on the set of assumptions underlying a scenario.

A final important remark on the MASST4 model is related to the important effort in building a comprehensive data base covering the universe of EU NUTS2 regions. In the 2013 version, these comprise 276 administrative units, with a panel structure covering the period 2000 through 2017 for the national model and comprising for the first time a full panel structure for the regional model as well. For this last data base, Table A2 in Technical Appendix A1 shows a full list of data sources, indicators, and time availability for each variable included in the estimates discussed in the rest of the paper. Thus, the first year for which MASST4 produces simulated growth rates is 2018, and the simulation process reaches 2035. A longer simulation would lose credibility in that constant coefficients in the estimated structural equations would become less and less meaningful as the economic structure itself of EU regions adjusts.

A specific mention is due to the construction of the urban database. Building on Camagni et al. (2016), we collected data for all EU NUTS2 regions matching each largest city within each NUTS2 region to the region in the data base. Among explanatory variables, we measure high-level functions with

the share of high-level professions in each region, calculating the share of labor force employed in the ISCO 88 aggregate category 1, including "*legislators, senior officials and managers*".

Borrowed size is instead calculated as the spatially-lagged population living in nearby metro areas discounted by physical distance (Eq. 1):

$$borrowed\_size_c = \sum_{j=1}^{n} \frac{pop_j}{w_{geo_{c,j}}}, \forall c \neq j \tag{1.}$$

where *c* and *j* indicate two cities, w_{geo} is an *nXn* distance weight matrix formalizing the geographical interdependence between city pairs,[7] and *pop* represents city population levels.

Borrowed functions are calculated as the spatially-lagged high-level functions in other cities, discounted by network distance (Eq. 2):

$$borrowed\_functions_c = \sum_{j=1}^{n} \frac{functions_j}{w_{networks_{c,j}}}, \forall c \neq j \tag{2}$$

In their turn, long-distance networks are measured with the number of Framework Programme co-participations of research institutions located in each NUTS2 region, for the 5th, 6th, and 7th rounds of the programme.

We also control for the effects of functions located in close geographical proximity by calculating the spatial lag of functions discounted by the geographical weight matrix.

Lastly, it is worth stressing that the dependent variable, urban productivity, is measured with urban land rent. "*Urban rent is usually interpreted as the rent paid to the house owner. However, house prices represent the capitalized rent over time, and for this reason may be chosen as a proxy for urban rent. Land rent is measured here as the average prices of apartments located in the Central Business District of the cities analyzed*" (Camangi et al., 2016, p. 146). Since urban land rent is a very

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[7] The spatial connectivity definition adopted is based on simple geodesic distance between centroids.

space-specific indicator, we calculated average house prices for apartments located in the CBD of the largest NUTS3 region within each NUTS2, and then matched these values to each NUTS2 in the data base.

Sections 3 and 4 discuss the main advances and the results of the estimates, with a particular focus on the changes in the structural relationships in national and regional economies.

3. Advances in the National Sub-model

The national sub-model is based a traditional Keynesian structure, each component of the aggregate demand depending on its standard macroeconomic components, as with previous versions. All components have been re-estimated with the inclusion of a third period, covering the after-crisis years, but no significant variation with respect to the estimates shown in Capello et al. (2017) has been detected, except for the investment growth function.

With the inclusion of the third period, evidence exists that this variable behaves differently in the three periods. In order to better highlight these differences, we both run a baseline model with a breakdown in two periods, as done in Capello et al. (2017), and then re-run with the three periods. Results are reported in Table 1.

When only the pre-crisis and the crisis periods are taken into consideration, estimations (Table 2, column 1) provide evidence of a negative impact of the contraction period (2008-2012) on the growth of national investment; all else being equal, this slowdown is equal to a 7 per cent contraction on a yearly basis. All other relevant controls, with the exception of FDI intensity, are significantly associated to investment growth, with the expected sign. We included a control for lagged GDP growth, in a Keynesian fashion; the response to outstanding interest rates and the cost of labor; and an Error Correction Model (ECM) component.

Table 1 (second column) shows that an augmented equation taking the third (2012-2016) period into account highlights some relevant differences. While most other controls remain significant and hold

the same direction of association (with the exception of Unit Labor Costs), the inclusion of the after crisis period dummy shows that some important differences emerge between the crisis and the after-crisis period, namely:

Dependent Variable	Investment growth rate 1995-2012	Investment growth rate 1995-2016
Constant	-1.29** (0.55)	0.435 (0.514)
FDI growth rate (t-1)	0.01 (0.00)	0.189** (0.087)
GDP growth rate (t-1)	0.68*** (0.18)	0.387** (0.151)
Interest rate	-0.49*** (0.00)	-0.018*** (0.002)
Unit labour cost	-0.15*** (0.02)	-0.001 (0.001)
Crisis dummy	-0.07*** (0.01)	-0.076*** (0.011)
Investment trends	-1.15*** (0.10)	-0.807*** (0.102)
Speed of adjustment of investment to the long run trend	-0.41*** (0.05)	-0.427*** (0.039)
After-crisis dummy		-0.067*** (0.013)
GDP growth rate (t-1) in the after-crisis period		1.920*** (0.359)
Method of estimation	Fixed effects	Fixed effects

Table 1. Determinants of investment growth for the pre-crisis, crisis, and after-crisis periods

*Note: *= significant at the 90% confidence level; **= significant at the 95% confidence level; ***= significant at the 99% confidence level. Heteroskedasticity-Robust Standard Errors in brackets*

(i.) In the after-crisis period, investment growth has further slowed down, although at a slower pace with respect to the contraction period. The resurgence of this important component of the aggregate demand in EU economies is taking place at a very slow rate;

(ii.) In the aftermath of the great contraction, investments remain very volatile and their dependence on lagged GDP growth rates is roughly six times as large as in standard periods, as evidence by the interaction between the after-crisis dummy and the ECM component.

This result is in line with the stylized facts showing that the economic performance of EU countries diverged quite substantially over the past two decades, and that the productivity slowdown of some of them dates back to well before the inception of the great contraction.

4. Advances in the Regional Sub-model

4.1 Structural changes in manufacturing employment growth

The importance of the fourth industrial revolution for the future of Europe's growth called for a particular importance to the manufacturing employment growth equation. The following equation has been estimated:

$$
\Delta manemp_{r,T-t} = \alpha + \sum_{j=1}^{n}\sum_{t=1}^{3}\beta_{j,t}SPEC_{j,t} * d_t + \sum_{t=1}^{3}\gamma_t urban * d_t + \sum_{t=1}^{3}\delta_t rural * d_t +
$$
$$
+ \sum_{t=1}^{3}\zeta_t CEEC * d_t + \sum_{t=1}^{3}\eta_t MHLF * d_t + \sum_{t=1}^{3}\vartheta_t MLF * d_t + \sum_{z=0}^{1}CEEC_z * W * \Delta manemp_{r,T-t}
$$

(3)

In Eq. (3.):

(i.) specialization in different manufacturing industries (*SPEC*) measures the mix/demand component (a region grows in employment in sectors where demand is higher). Across different NACE 2-digit industries,[8] specialization is measured as the location quotient of each manufacturing sector with the EU28 as the common benchmark;[9]

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[8] NACE is the Statistical Classification of Economic Activities in the European Community (the acronym coming from the French term "*nomenclature statistique des activités économiques dans la Communauté européenne*"). Presently at the second version, it has been established by Regulation (EC) No 1893/2006.

[9] The alphabetical order with which industries are listed also (imperfectly) matches the increasing technological complexity of the involved manufacturing activities, as also testified by the high-tech and medium-high tech reclassifications of manufacturing activities discussed in EUROSTAT (2018) and regularly updated on the EUROSTAT data base.

(ii.) *urban*, *rural*, and *CEEC* a NUTS2 region's settlement structure is mainly urban or rural,[10] or if the region is located in one of the Central and Eastern European Countries (CEECs), i.e. those joining the EU since 2004;

(iii.) functions in the area (MHLF and MLF, respectively representing medium-high level and medium-level functions) measure qualified jobs that may occasionally be subject to unemployment more than non-qualified ones;

(iv.) employment dynamics in neighboring regions which might influence employment growth; these are also interacted with a dummy equal to 1 if the region is located in CEECs, and 0 otherwise.

All over these estimates, we also introduce time dummies, capturing the differences in the effects in two periods (crisis and after-crisis period), keeping the pre-crisis period as the benchmark. Table 2 shows results of the estimates.

Results uniformly show a statistically significant positive impact of low-tech industries in the pre-crisis period, with a progressive decrease in this impact. At the same time, while initially (i.e. before the 2007-2008 crisis spread to Europe) manufacturing jobs were created despite regions being specialized in high-tech sectors, the crisis has again stressed the importance of focusing on technologically advanced manufacturing as means to shelter against the windfall of global economic turmoil. The differences in the estimates of this equation in the different periods demonstrate that a structural change is occurring, and that in the after-crisis period in most technologically advanced sectors a re-industrialization process is taking place, as suggested by some literature (Wink et al., 2016). This supports the idea that a forecasting tool has to be able to grasp such structural changes if future growth trajectories have to be simulated.

Dep. variable	*Manufacturing employment growth*		
	β	Std. Err.	Significance level
Constant term	0.98	0.02	***

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[10] A detailed definition of how agglomerated, urban, and rural regions are defined according to the ESPON 1.1.1 project is provided in the Technical Appendix.

Specialization in rubber and plastics	0.01	0.003	*
Specialization in rubber and plastics in period 2	-0.01	0.005	**
Specialization in rubber and plastics in period 3	-0.01	0.004	*
Specialization in non-metallic minerals	0.02	0.005	***
Specialization in non-metallic minerals in period 2	-0.02	0.005	***
Specialization in non-metallic minerals in period 3	-0.01	0.005	***
Specialization in metals	-0.004	0.004	
Specialization in metals in period 2	0.005	0.005	
Specialization in metals in period 3	0.007	0.005	¥
Specialization in transportation devices	-0.007	0.004	¥
Specialization in transportation devices in period 2	0.004	0.004	
Specialization in transportation devices in period 3	0.01	0.005	*
Other manufacturing	0.01	0.01	¥
Other manufacturing in period 2	-0.01	0.01	¥
Other manufacturing in period 3	-0.02	0.01	¥
Structural funds supporting business creation	0.07	0.05	¥
Dummy urban region	0.02	0.003	***
Dummy urban region in period 2	-0.02	0.005	
Dummy urban region in period 3	-0.01	0.005	**
Dummy rural region	0.01	0.005	*
Dummy rural region in period 2	0.01	0.01	
Dummy rural region in period 3	-0.02	0.01	***
Dummy CEEC countries	-0.03	0.005	***
Dummy CEEC countries in period 2	-0.001	0.001	
Dummy CEEC countries in period 3	-0.02	0.01	*
Specialization in medium-high-level functions	-0.05	0.01	***
Specialization in medium-high-level functions in period 2	0.05	0.01	***
Specialization in medium-high-level functions in period 3	0.04	0.01	***
Specialization in medium-level functions	0.03	0.01	***
Specialization in medium-level functions in period 2	-0.03	0.01	***
Specialization in medium-level functions in period 3	-0.02	0.01	**
Employment growth spatial spillovers	-0.01	0.001	***
Employment growth spatial spillovers in CEECs	0.02	0.01	**

Number of obs.	572
R^2	0.43
Joint F-test	53.32***
Country dummies	Yes
Robust standard errors	Yes
Method of estimation	Pooled OLS

Table 2. Determinants of manufacturing employment growth

Note: *= significant at the 90% confidence level; **= significant at the 95% confidence level; ***= significant at the 99% confidence level.

4.2   Structural changes in urban growth

As explained above, the new version of the model estimates the advantages for regional growth stemming not only from city size, but from the type of function hosted, the degree of networking with other cities, the size of neighboring cities (borrowed size) and the functions hosted by other cities, discounted both by geographical distance and by the inverse of proximity in cooperation (these being labeled "borrowed functions"). This approach starts from Camagni et al. (2016) and is formalized as in Eq. (4.):

$$
\begin{aligned}
urban\_productivity_{c,t} = {} & \alpha + \beta_1 * population_{c,t-1} + \beta_2 * population^2_{c,t-1} + \beta_3 * urban\_functions_{c,t-1} + \\
& + \beta_4 * borrowed\_size_{c,t-1} + \beta_5 * W_{geo} functions_{c,t-1} + \beta_6 * borrowed\_functions_{c,t-1} + \\
& + \beta_7 * network\_externalities_{c,t-1} + \varepsilon_{c,t}
\end{aligned}
\tag{4.}
$$

Results are presented in Table 3, and provide strong evidence of a time-varying role for the physical component of agglomeration economies, namely the pure density effect here captured by the linear and squared population terms. In the original model discussed in Camagni et al. (2016), these two terms suggested a monotonically increasing relationship between city size and urban productivity. This is in line with both the urban economics consensus (Segal, 1976; Ciccone and Hall, 1996; Combes et al., 2010) as well as with the theoretical predictions of the New Economic Geography (Krugman et al., 1999).

MASST4 estimates contribute this interpretation by showing that this relationship changes over time, capturing structural changes in the way cities generate advantages to regional growth. In our results, the impact of the linear city size term significantly increases over time, while the squared population term decreases monotonically. Taken together, these two results suggest that some form of decreasing returns to scale are increasingly important for European cities, although pure size effects appear to crucially matter both during, as well as after, economic contractions. This result can be graphically represented as in Figure A1 in Technical Appendix A3, where the solid line shows the relationship between city size and urban land rent for period 1, while the dashed and dotted lines refer to periods 2 and 3, respectively.

Dep. Variable	Log urban land rent		
	β	Std. Err.	Significance level
Constant term	9.94	0.69	***
Urban population (levels)	-0.24	0.09	***
Urban population in period 2	0.46	0.08	***
Urban population in period 3	0.57	0.13	***
Urban population (square)	0.05	0.02	***
Urban population (square) in period 2	-0.07	0.02	***
Urban population (square) in period 3	-0.10	0.02	***
High-level functions	0.09	0.05	*
Borrowed size	-1.93	0.91	**
City networks	0.1	0.01	***
Borrowed functions	0.33	0.08	***
Spatial lag of high-level functions	-0.31	0.15	**
Rank-size rule	0.001	0.03	
Number of obs.	828		
R^2	0.43		
Joint F-test	26.31***		
Country dummies	No		
Robust standard errors	Yes		
Method of estimation	Pooled OLS		

Table 3. Determinants of urban productivity

*Note: *= significant at the 90% confidence level; **= significant at the 95% confidence level; ***= significant at the 99% confidence level.*

All other parameter estimates, while presenting no significant interaction with period dummies, are in line with results discussed in Camagni et al. (2016). Irrespective of the period, urban productivity is positively associated to high-level professions, urban networks, and borrowed functions. We find instead a negative and statistically significant relationship between borrowed size and urban productivity on the other hand. A negative estimate suggests the existence of what is commonly referred as *agglomeration shadow* (Burger et al., 2015; Partridge et al., 2009): in this case, cities close to large urban agglomerations tend to be, all else being equal, less productive than otherwise identical cities that are spatially more isolated from large cities. The theoretical explanation is that cities close to larger cities mostly rely on the efficiency of the nearby larger cities, and are therefore less prone

or less able to increase their efficiency. Instead, city networks have a positive and significant value: being linked to other cities makes a city, ceteris paribus, being more productive than others, as theoretically expected.

Moreover, results for the borrowed functions suggest a positive and significant association with urban productivity (Camagni et al., 2016; Capello, 2000); having access to a larger pool of high-level functions increases cities' productivity. A word of caution is here required. This variable has been calculated at NUTS2 level, by taking the NUTS3 level of each NUTS2 a city belongs to as an average value. This may introduce a bias in the estimates, since a city may have higher nearby functions only because it is part of a NUTS2 hosting other NUTS3 regions with many high-level functions. In order to correct for this potential bias, we introduced the spatial lag of high-level functions. Moreover, the negative estimate for the parameter of the spatially lagged high-level function variable provides evidence of the increasing relevance of concentrated location patterns for high-level urban functions: cities being close to hotspots of high-level professions tend, ceteris paribus, to be less productive than cities that are spatially sheltered from this potential competition.

Because data are collected at NUTS2 level, a second possible bias may occur in the estimates if the structure of the urban system is not controlled for. We therefore include a measure of the slope of the within-region rank-size rule to control for the fact that regions hosting large metro areas attracting substantial shares of the regional population may behave differently from those characterized by a network of medium-sized cities. This indicator is calculated as follows. For each NUTS2 region, population levels of each NUTS3 region are ranked in decreasing order. Next, a linear regression is performed to calculate the slope of the rank-size distribution. The estimated parameter is used as a measure of the slope of the urban hierarchy within each NUTS2 region.

The inclusion of this control does not modify the main results of the estimates. Moreover, the rank-size parameter is itself insignificantly associated to urban productivity (p-value=0.97). Taken

together, these results suggest that agglomeration economies do not depend on the hierarchical structure of a particular region.

4.3 Endogenous regional economic productivity

Another crucial development of the most recent version of the MASST model is related to the explanation of regional productivity. Up to the third generation of the model, economic productivity growth was treated as an exogenous target, i.e. without an equation formalizing the theoretical expectations about its future growth. With the MASST4 model, this shortcoming has been amended and we need not formulate ex-ante expectations of future productivity growth rates any longer. Instead, the importance of different factors relevant for explaining productivity growth at the regional level are estimated, and their parameters used in simulation exercises.

Productivity depends on the following regional characteristics:

(i.) innovation, both product and process, activities (Capello and Lenzi, 2013a);

(ii.) presence of cities as generators of agglomeration economies (Mitra, 1999; Clark et al., 2018). Despite the fact that both urban and regional productivity ultimately depend on spatial externalities, the literature on the former differs quite substantially from studies explaining the latter. On the one hand, agglomeration economies advantages decline quite rapidly with space (Rosenthal and Strange, 2003); on the other hand, at wider spatial scales, other factors may matter more than diversity in explaining spatial externalities (Caragliu et al., 2016). Moreover, productivity advantages at the firm level form externality fields that are best captured at the regional level (Caliendo et al., 2018);

(iii.)   presence of high-value added activities, both in terms of functions and of production processes (industries; Porter, 2003);

(iv.)   policies supporting entrepreneurship (Acs and Armington, 2004);

(v.) intangible elements like trust, social capital and sense of belonging (Zak and Knack, 2001);

(vi.)   presence of borders, that causes self-selection among productive and non-productive firms by hampering the exploitation of scale economies in a reduced-size market (Melitz, 2003; McCallum, 1995);

(vii.)   technological interdependences and knowledge exchange that, as suggested by Ertur and Koch (2007, 2011), through proximity effects can influence the performance of local areas. Proximity is not only geographical; knowledge may be exchanged through different types of proximity, like cultural, social and institutional proximities, that facilitate cooperation (Boschma, 2005; Torre, 2008; Caragliu, 2015). An interregional input-output matrix with industrial trade flows data proxies different types of proximities, and is in this sense used as a discount measure for productivity of other regions.

The estimated equation is therefore the following:

$$
\begin{aligned}
regional\_productivity_{r,t} &= \alpha + \beta_1 * innovation_{r,t-1} + \sum_{t=1}^{3} \beta_{2,t} * urban\_productivity_{r,t-1} + \sum_{k=0}^{1} \beta_{3,k} d_{k,t-1} * HT_{r,t-1} + \\
&+ \beta_4 * trust_{r,t-1} + \beta_5 * HLF_{r,t-1} + \beta_6 * SF_{r,t-1} + \sum_{z=0}^{1} \beta_{7,z} d_{z,t-1} * prod\_spillovers_{r,t-1} \beta_8 * trade\_spillovers_{r,t-1} + \\
&+ dummy\_outliers_{r,t-1} + \varepsilon_{c,t}
\end{aligned}
\tag{5.}
$$

In Eq. (5.):

(i.) *regional_productivity* is calculated as regional Gross Value added in constant 2010 Euros divided by regional labor force;

(ii.)*innovation* represents the share of product and/or process innovation generated by the regional innovation module (Section 4.4 below);

(iii.)   *urban_productivity* is in its turn estimated as described in Section 4.2 above;

(iv.)   *HT* stands for High-Tech industries, and represents, by means of a Location Quotient, the intensity of high-tech manufacturing and knowledge-intensive services in NUTS2 regions (EUROSTAT, 2016b);

(v.) *HLF* indicates high-level functions (as described in Section 2);

(vi.)   *SF* stands for structural funds supporting business formation;

(vii.)   Lastly, *trade_spillovers* and *prod_spillovers* represent the spatially lagged values of regional productivity levels mediated by the trade and geographical weight matrices above described, respectively.

Results of these estimates are presented in Table 4.[11]

Dep. variable	Regional labor productivity		
	β	Std. Err.	P-value
Constant term	24.02	5.73	***
Product or process innovation	18.35	5.92	***
Urban productivity	1.29	0.82	¥
Urban productivity in period 2	-0.15	0.12	¥
Urban productivity in period 3	-0.04	0.15	
Border regions dummy	3.36	1.47	**
Specialization in high-tech industries	199.6	40.38	***
Specialization in high-tech industries in border regions	-85.18	40.48	**
Trust	20.2	5.12	***
High-level functions	1.13	0.71	¥
Structural funds supporting business creation	0.03	0.01	***
Spatial Productivity spillovers	-0.001	0.000	**
Spatial Productivity spillovers in CEECs	0.001	0.000	***
Trade productivity spillovers	0.04	0.01	*
Dummy for productivity outliers (top 10% of the distribution)	23.63	4.00	***
Number of obs.	511		
R^2	0.93		
Joint F-test	42.66***		
Country dummies	Yes		
Robust standard errors	Yes		
Method of estimation	Pooled OLS		

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[11] The estimates here presented are based on pooled OLS. Still, given the panel structure of our regional data set, the GMM would be preferable (Belotti et al., 2017). However, GMM estimates require a perfectly balanced panel data set, a condition that is unfortunately not met by our data. As a robustness check, GMM estimates have also be obtained with the same spatial weights matrix adopted in the pooled OLS regression, and this alternative specification required us to restrict the data set to the 128 regions for which we have a full-fledged panel data set. Results, available upon request, qualitatively confirm the main messages shown Table 5, although some parameters become no longer significant, due (probably) to the major loss of information from the missing data. The main difference lies in the estimated spatial spillover effect for Western regions, that now becomes positive significant. Still, this comes at a major loss of information from previous period observations. Also, the missing observations prevent us from using this specification in the simulation stage of the MASST model, that needs full data availability for all NUTS3 regions in the simulation data base, from which lever variables are moved to their simulation targets.

Table 4. Determinants of regional productivity growth

Note: ¥= significant at the 80% confidence level; *= significant at the 90% confidence level; **= significant at the 95% confidence level; ***= significant at the 99% confidence level.

All explanatory variables are found to be positively and statistically significantly associated to the dependent variable. In particular, productivity is explained by regional innovation (de Groot et al., 2006; Capello and Lenzi, 2013a), social capital (as captured by the average level of trust; Bjørnskov and Méon, 2015), the presence of high-level functions (Camagni et al., 2016), spending in structural funds dedicated to the support of business activities (Fratesi and Perucca, 2014), and specialization in high-tech industries.

Our estimates also suggest the relevance of border location in the exploitation of high-tech industries. In fact, a recent methodology to detect border effects in regional growth has been proposed in Capello et al. (2018b). This methodology focuses on regional supply-side border effects, decomposed in terms of border-related inefficiencies (in exploiting local resources: *efficiency needs*) and insufficient endowment of resources (*endowment needs*). While the latter are identified when growth-enhancing assets are poorly present in a region, the former are found when a territorial capital asset is negatively and significantly interacted with a border region dummy. In the estimates presented in Table 5, this is the case for the specialization in high-tech industries: all else being equal, regions specialized in high-tech activities but located on the border between two or more EU countries are less prone to fully reap the benefits of this crucial asset. This result can be usefully compared with Varga and Sebestyén (2017), who find that this effect is significant for the west borders of CEEC regions. This hints at the possibility for developing regions to attract knowledge because of their proximity to more developed areas.

We also included two vectors of productivity spillovers, one calculated on the basis of a geodesic distance weight matrix, the other based on a trade flows matrix. The rationale of the former needs little explanation: being close to productive regions enhances the chances that a region becomes itself more productive, all else being equal (Ertur and Koch, 2007). More recently, however, interregional

trade flows have been increasingly employed to open the black box of technological interdependence (Cortinovis and Van Oort, 2019). For this indicator, we exploit the latest (2010) interregional Input-Output (IO) table compiled by the EU Joint Research Centre in Seville, Spain. The IO table reports the value in constant Euros of trade flows from and to each EU NUTS2 regions. This matrix is then row-standardized and employed as a standard spatial weight matrix to calculate trade-mediated productivity spillovers.

Estimated spillovers parameters yield unexpected results. Geographic spillovers are found to be positively associated to productivity gains only in Central and Eastern European countries. In the rest of the EU28, being close to high-productivity regions is found to negatively affect a region's own productivity. While the two estimated coefficients are roughly equal in magnitude, the overall effect of geographic spillovers is slightly positive, although insignificant.[12]

Trade-mediated spillovers are instead found to be positively and significantly (p-value<0.1) associated to regional productivity levels. By means of reverse-engineering imported products, trading partners get access to new technologies that can, through subsequent R&D processes, replaced with new local products and processes (Javorcik, 2004; van Pottelsberghe de la Potterie and Lichtenberg, 2001; Caragliu, 2015).

A more detailed discussion is due for the effects of urban productivity. In line with what implicitly suggested by the increasing relevance of agglomeration diseconomies (Section 4.2), results in Table 5 suggest that, while being positively associated to aggregate (regional) productivity gains, urban productivity's role may have been declining over the last decade, both during as well as after the end of the crisis. While only marginally significant (p-values< .2), results are nevertheless suggestive and call for further research: is the role of cities as engines of regional growth decreasing over time? We believe this to be a very fertile future research avenue.

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[12] Results are not reported; they are available upon request from the authors.

4.4 Dynamics of territorial patterns of innovation

A well established literature has produced vast consensus on the role of regional innovation as a major driver of regional economic growth. The link between regional innovation and regional economic performance (originally conceived in terms of a linear relationship) has been advocated by works revolving around the idea that different types of localized externalities enhance the process of knowledge generation and diffusion among firms located in the same area. This is the case of the Milieu Innovateur (Aydalot, 1986; Aydalot and Keeble, 1988; Bellet et al., 1993; Camagni, 1991), the Learning Region (Lundvall and Johnson, 1994), and the Regional Innovation Systems (Cooke et al., 1997) theories. These externalities are often justified with the imperfect public nature of knowledge. What cannot be easily be codified (i.e., tacit knowledge) would be best conveyed by means of face-to-face contacts.

Over the last decade, this consensus has been partially replaced by a more nuanced picture. In particular, the literature brought consensus over the fact that innovation may take place in different ways, supported by different inputs (R&D activities, as well as knowledge created outside and brought into the region thanks to bright entrepreneurs) or can be the result of an imitative process. The different modes of innovation (termed *regional patterns of innovation*) are the result of local preconditions allowing a region to develop some types of learning process rather than others. Regional innovation patterns, in fact, represent alternative spatial variants/combinations of context conditions and of specific modes of performing and linking the different phases of the innovation process, supported and changing according to specific relational structures embedded in the local society (Capello and Lenzi, 2013a). The regional patterns of innovation identified empirically where in a number of five, namely:

1) European science-based area, composed of strong knowledge and innovation-producing regions specialized in general-purpose technologies and with the highest degree of scientific knowledge acquisition from and exchange with other regions.

2) applied science area, similar to the first conceptual innovation pattern, albeit differing in terms of scientific knowledge, being in this pattern an applied rather than a science knowledge;

3) smart technological application area, consisting of regions with a knowledge intensity lower than in the previous two cases, although not negligible, and a high level of creativity, which enables the translation of applied and formal knowledge (sourced outside the region) into innovation;

4) smart and creative diversification area, differing from the former in terms of the prevailing cognitive base, stemming in this case from high degree of local capabilities and creativity;

5) imitative innovation area, including regions with some propensity to innovate by imitating through varying degree of creativity and adaptation of already existing innovations developed elsewhere.

No superior type of regional pattern of innovation; instead, each of them represents the best way for learning processes for the context of a particular region (Capello and Lenzi, 2013a). These modes have been subsequently empirically identified on the universe of NUTS2 regions.

The MASST3 model already included the static version of this conceptual framework. However, it has however been recently recognized that regions may evolve from one pattern of innovation to another when the local functional and relational conditions allow them to move towards another mode of learning. The determinants of shifts across regional innovation patterns, previously neglected, have been identified, as it is a major element in capturing the evolution in the structural ways in which regions learn (Capello and Lenzi, 2018). In the MASST4 model another major improvement has been obtained, in particular including an equation estimating the determinants of changes in territorial patterns innovation patterns over time, a crucial aspect for a regional growth forecasting model in a period in which competitiveness is also based on the advent of a new technological paradigm, that of "Industry 4.0" (Schwab, 2017).

Following Capello and Lenzi (2017), the change in the regional patterns of innovation is estimated through the probability that a region changes its innovation pattern, assumed to depend on the R&D capacity, human capital, specialization in high tech sectors, population density, technological diversification and the different regional innovation patterns of the regions, measured by regional dummy variables (Eq. 6):

$$\Pr(\text{CHANGE OF INNOVATION PATTERN}_r) = f(R \& D_r, HC_r, LQ_{\text{HIGH TECHr}},$$
$$\text{POPULATION DENSITY}_r, \text{TECHNOLOGICAL DIVERSIFICATION}_r, \qquad (6.)$$
$$IIA_r, SCDA_r, STAA_r,)$$

In Eq. (6.), IIA_r (Imitative innovation area), $SCDA_r$ (Smart and creative diversification area) and $STAA_r$ (Smart technological application area) are dummy variables measuring whether a region belongs to one of those regional innovation patterns, the reference category being the Applied science area.

Results of these estimates are presented in Table 5.

Dep. Variable	Probability to change territorial patterns of innovation		
	β	Std. Err.	Significance level
Constant term	-1.60	0.15	***
R&D intensity	0.08	0.03	***
Human capital	0.02	0.00	***
Specialization in high-tech	0.21	0.05	***
Moving from an Imitative Area	0.92	0.12	***
Moving from a Smart and Creative Diversification Area	0.49	0.09	***
Moving from a Smart Technological Application Area	0.29	0.09	***
Spatial lag of population density	1.60	0.13	***
Method of estimation	Spatial Error Model		
Lambda	-2.28	0.52	***
Number of obs.	242		
R^2	0.64		
Joint F-test	26.31***		
Country dummies	Yes		
Robust standard errors	Yes		

Table 5. Determinants of the dynamics of regional innovation patterns

Estimates are obtained as follows. First, the data base collected for the analyses presented in Capello and Lenzi (2017) has been integrated for all NUTS2 regions not initially in the data.[13] Next, the preferred model in the original analysis[14] has been run with the exclusion of non-statistically significant variables. In Table 6, results present the expected sign and significance. As with the original case, the interesting result is that the probability to change pattern is relatively higher for regions belonging to the imitative area, and decreases when moving towards more complex R&D-related patterns; the critical mass of R&D activities needed to achieve science-based learning processes is not easy to reach, and not really crucial for non-science based regions to get dynamic efficiency advantages from their learning modes.

Several robustness checks have also been performed. First, the exclusion of insignificant variables is run one by one, in order to verify that such exclusion does not affect our estimates; results of this first control suggest that indeed this is not the case.

Next, we also verified whether any of the explanatory variables suffers from border effects (see Section 4.3); again, none of the controls is found to be significant when interacted with a dummy variable capturing the border location of the NUTS2 regions in the sample.

4.5   Brexit and borders

A regional econometric growth forecasting model cannot ignore the relevant changes that are taking place at the institutional level in the EU. Among those, the rise of discontent and thereby populism takes a prominent role. Among the many political elections and referenda held on EU membership,

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[13] In Capello and Lenzi (2017), the unit of observation is the NUTS2 region in the 2010 version.
[14] In Capello and Lenzi (2017), this is shown in Column 5 in Table 2, p. 7.

by far the one that had to date the most relevant consequences is the UK's decision to quit the EU (henceforth, Brexit).

Several works have been recently trying to capture the likely long run effects of Brexit, but any such attempt clashes with the fact that as of today the way this process will actually take place (hard vs. soft Brexit) is still unclear (Fingleton 2018; Dhingra et al., 2017). In the (for many, worst case) scenario whereby Brexit would happen with a complete cancellation of all free trade and movement agreements previously signed by the UK and the rest of the EU, costs may be quite substantial. Beyond pure geographic distance, international trade has been consistently found to be remarkably lower than interregional one (Mc Callum, 1995; Capello et al., 2018b).

Building a common market, fostering intra-European trade, and allowing the free movement of people between EU countries has engendered relevant advantages that have been frequently advocated to call for a further integration of the countries joining the EU. Consequently, the partial or total reversal of the common regulations making up the common market would have major consequences (Cecchini et al., 1988). Estimates on the extent of the losses to the incomplete construction of a common EU market range from 2.2 per cent (Ilzkovitz et al., 2007) to 12 per cent of EU's GDP (Campos et al., 2014).

In the MASST4 model we model Brexit effects in the simulation part. Simulations are performed starting from 2018. Its effects are modeled since 2020, because of the effective day when Brexit became effective (Jan. 31, 2020). Consequently, until 2019 included the UK is treated as a full-status EU member, in particular in terms of the geographic and trade-induced spillovers it engenders on, and it benefits from, the rest of the EU28. From 2020 onwards, we increase distance between UK and EU27 (EU28 minus the UK) in calculating geographic and trade spillovers and we set it to the maximum among the remaining sample. From a geographic point of view, this is the equivalent of fictionally relocating the UK in the Atlantic Ocean, where the most remote NUTS2 regions are. From a trade perspective, this is tantamount to assuming that UK's regions' trade decreases to the smallest

trade flow registered between any other EU28's region couple. This allows us to decrease the intensity of technological interdependence between EU and UK regions, thus minimizing the process of knowledge diffusion that fosters regional productivity gains and enhances the regional shift component.

5   An application of the MASST4 MODEL: A reference scenario for European regions

5.1.   Definition of reference scenario and quali-quantitative assumptions

In order to highlight the potential of the MASST4 model, a reference scenario has been built and is here presented. The reference scenario differs from a sheer baseline scenario in that while the latter has to be interpreted as a trend-based scenario, the former is not a simple extrapolation of past trends. A Reference scenario, beyond simply looking at extrapolating long run trends, also captures the effects of structural changes taking place in the aftermath of the 2007/2008 economic contraction. In the reference scenario, a series of pre -crisis macroeconomic conditions are unlikely to be replicated in the post-crisis scenario: high volatility of investments of the post crisis period will continue; a normal reactivity of investment growth to GDP growth will be replaced by a high reactivity of investment growth to GDP growth, even if decreasing in the long term; free international trade between US and EU is replaced by the present risk of protectionist measures between US and EU, which leads to a lower increase in export with respect to the past long term trend.

Instead, some crisis trends are likely to continue in the future, namely: permanent controls on national deficits and debts; some controlled exceptions of public expenditures for low-growing and indebted countries (due to political risks, like many recent political elections showed), there will be a low inflation rate, the expansionary monetary policy (quantitative easing) is expected to end soon.

In the industrial sphere, a stop in the deindustrialization of the European economy is assumed, and instead an initial launch of high-tech industry in Europe, under the influence of the new technological

paradigm "*Industry 4.0*", and a consequent increase in high-value added services related to the adoption of Industry 4.0 related technologies. Lastly, a slow catching-up in R&D expenditure and a slow increase in human capital in Central and Eastern European Countries, following the post-crisis trends.

In the institutional sphere, Brexit is included since 2020. Moreover, even if some regional independency requests take place, no regional independence takes place. A redistribution of the European budget will take place in favor of new fields - security and migration - decreasing the share of budget devoted to cohesion policies and CAP, setting national shares to the levels decided in the EC (2018), and maintaining regional shares as in the 2014-2020 programming period.

The qualitative assumptions have been translated into quantitative levers in the fourth version of the MASST model (see Table A.2 in Technical Appendix A2).

5.2   Aggregate results

Results depict the main tendencies, major adjustments to change, relative behavioral paths of regional GDP growth (and regional employment growth) in each region under the assumptions presented above. Given the nature of the MASST model, generating quantitative foresights rather than forecasts, results provided represent tendencies of the variables and not precise forecasts.

Table 6 represents the results of the average annual growth rate between 2018 and 2035 for different economic variables. The Table reports the quantitative foresights for EU28, for EU without UK and for Eastern and Western countries respectively.

	Average GDP growth rate	Average productivity growth rate	Average total employment growth rate
EU28	1.60	0.34	0.27
EU27 without UK	1.61	0.35	0.28
United Kingdom	1.49	0.02	0.35
Old15	1.59	0.17	0.24
CEECs	1.72	0.75	0.38

Table 6. Annual average GDP, productivity and employment growth 2018-2035

The following main tendencies emerge:

- from a macroeconomic point of view, the Reference scenario is characterized by a stable relaunch after the crisis, with an average yearly growth rate of 1.6% for EU 28. This rate would be slightly higher (1.61%) were the United Kingdom dropped off the list, due to its lower performance determined by the negative economic consequences of Brexit (+1.40%);

- CEECs countries still display faster growth rates w.r.t. Old15 Countries (1.72% against 1.59%) but the difference has remarkably abated;

- Old15 Countries are characterized by a slow increase in overall productivity, in line with the warnings laid down in OECD (2017);

- the difference between Old15 and New13 is more consistent in terms of productivity than in terms of employment growth. CEECs countries are likely to experience a second transition, although a less problematic one with respect to the one experienced in the late 1990s, towards a more equilibrated, endogenous pattern of development. Old15 countries instead are entering a stage of re-launch thanks to an advanced and pervasive use of new technologies and the benefits of what is commonly known as 'Industry 4.0'.

Moreover, results can also be broken down at the Country level, as shown in Table 7 below.

Country	Average GDP growth rate
Austria	1.54
Belgium	1.34
Bulgaria	1.97
Croatia	1.35
Cyprus	1.74
Czech Republic	1.46
Denmark	1.79
Estonia	2.04
Finland	1.19
France	1.60
Germany	1.72
Greece	1.38
Hungary	1.79
Ireland	1.74
Italy	1.60
Latvia	1.81
Lithuania	1.67
Luxembourg	1.60
Malta	1.92
Netherlands	1.45

Poland	1.74
Portugal	1.58
Romania	1.70
Slovakia	2.02
Slovenia	1.44
Spain	1.37
Sweden	1.50
United Kingdom	1.49

Table 7. GDP, productivity, manufacturing and service employment average annual growth rates by country and for EU - 2018 – 2035

Among Old15 countries, top performers (in terms of GDP) include Germany and Denmark; among CEECs, Estonia, Slovakia, Bulgaria, and Hungary stand up. Two countries of the group that were relatively slow in the recovery from the crisis, namely Italy and Cyprus, are showing better performances, narrowing the gap with respect to the mean EU growth rate, while Finland and Greece are still facing difficulties. Some western countries that were performing very well before the crisis, namely Ireland and then were severely touched by the crisis (with Portugal) are now performing a little less than the EU average.

5.3. Regional results

Figure 2 shows annual average GDP growth rates between 2018 and 2035 in EU NUTS2 regions. The map no longer displays the macro-regional patterns present in the recent past (e.g. the East-West divide and the North-South differentials that emerged in the early stages of the crisis). Regional growth rates now converge around to the mean and diverging behaviours involve some single regions (like Castilla Leon, Algarve, Languedoc-Roussillon, Croatia, North-Western regions in Greece and the Aegean islands, and southern Sweden).

Some dualism is still left in terms of regional GDP growth rates within single countries, and even more so in terms of per capita GDP levels. The major and more evident cases refer to:

- the Eastern part of Poland with respect to the more dynamic western (and particularly South-Western) part of the country and to the capital region of Warsaw;
- the Eastern and Southern part of Greece, with respect to the core, central area;

- the Mediterranean axis in France, less dynamic than the rest;

- some regions in the Italian Mezzogiorno, like Abruzzo, Calabria and Sicily;

- the eastern part of Denmark, including Copenhagen, less dynamic than the rest of the country;

- some scattered regions in UK.

Figure 2. Average annual GDP growth rate – 2018-2035

Source: Authors' elaboration, on the basis of the MASST4 model

- Most major cities their neighbourhoods tend not to be the most dynamic within their countries. Major diffusion processes of new technologies will be taking place in middle-income regions and medium-size cities.

6 Conclusions

This paper presents the main innovations introduced in the fourth generation of the MASST model. The need for these updates is motivated by the major structural changes emerging after the end of the 2007-2012 financial crisis. As a consequence of these changes, it would not be appropriate to interpret the world emerging from the crisis with the same toolbox the economics profession used before.

The main innovations introduced in the model include the structurally diverging performance of groups of countries and the consequences of the choice of the UK to leave the EU (at the national level), and dynamic patterns of innovation, after-crisis structural changes in manufacturing employment, regional productivity determinants, and dynamic agglomeration economies (at the regional level). These aspects cannot be left out of a regional growth forecasting model, given their importance in interpreting future development trajectories.

Moreover, the new built-up of the MASST model allows a more effective assessment of the relations whose structure has evolved as a consequence of the changes induced by the crisis. These can be summarized in terms of three major evolutions:

(i.) at the national level, investments have remained sensibly more volatile in the aftermath of the crisis, and their sensitivity to GDP growth signals is much higher than in the long and stable moderate growth period prior to the crisis;

(ii.) at the regional level, manufacturing employment shows a remarkably higher importance of high-tech manufacturing industries in shaping future manufacturing employment growth rates. The increased relevance of being specialized in advanced manufacturing activities already emerged during the crisis, but in the years following its end has become ever more relevant;

(iii.) at the urban level, the link between city size and urban productivity shows clear signs of emerging agglomeration diseconomies, although pure size effects seem to matter increasingly more both during the crisis as well as in the subsequent period.

Taken together, these results pose relevant challenges both for academics as well as for policymakers. The former have remained solidly anchored to a theoretical and empirical toolbox interpreting regional economic growth as an equilibrium process; instead, the evidence suggests that off-equilibrium conditions may be a much closer representation of the true underlying mechanisms explaining regional performance. For policymakers, this point is even more relevant: acting on an ever-changing world represents a possibly tougher challenge with respect to thinking that crises just end leaving the world as it was before. In both cases, the MASST4 model can serve the aim of simplifying, and better understanding, these changing relations.

Lastly, on the basis of these findings, several future research avenues are wide open. The MASST4 model is a powerful tool capable of capturing the complexity of context conditions intertwined in comprehensive scenarios. The present conditions of the EU certainly call for many such exercises, and this model allows to formalize this attempt and provide sound evidence on the way the EU's economy will likely evolve over the next couple of decades.

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