Laboratoire d'Economie Appliquée de Grenoble

MODELING THE INDUSTRIAL DYNAMICS OF THE EUROPEAN METROPOLITAN AREAS DURING THE PROCESS OF ECONOMIC INTEGRATION : A SEMIPARAMETRIC APPROACH

(Forthcoming in Economic Modelling)

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- October 2013 -

JEL CODES : C14 ; C23 ; C26 ; O52 ; R1

Working Paper GAEL ; 2013-11

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Modeling the industrial dynamics of the European metropolitan areas during the process of economic integration: a semiparametric approach

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Abstract

The specialization patterns of metropolitan areas are crucial in characterizing the effects of economic integration in Europe. This paper aims to provide and estimate an econometric model that explains both sectoral specialization and sectoral dissimilarity, measured with the GINI and the KRUGMAN indexes, respectively, for 35 European metro areas during the period 1980-2005. A semiparametric approach is proposed to address the issues of non-linearity and separability. The econometric analysis indicates how the deepening of the processes of development and integration occurred in the last decades affected both specialization and similarity of the sectoral metropolitan structure, finally supporting a "specializing alike hypothesis".

Key words: Specialization, European economic integration, metropolitan areas, semiparametric models, Generalized Additive Models, interaction models, tensor product smooths.

JEL Classification: C14, C23, C26, O52, R1

1. Introduction

Metropolitan areas are engines of economic growth and development that concentrate populations and economic activities. This fact might even be considered *the striking feature of today's economic geography* (Fujita *et al.*, 1999). In Europe, the process of economic integration in recent decades appears to have primarily benefited the metropolitan areas, despite the European Commission's efforts to engender economic and social cohesion throughout the regions. The regional policies implemented through the structural funds under Objective 1 have repeatedly been considered ineffective (Boldrin and Canova, 2001; Gianetti, 2002; Brackman *et al.*, 2005; Mohl and Hagen, 2010). In fact, European economic integration has set complex dynamics in motion. Opposite movements prevail at different territorial levels of analysis: a convergence process at the level of member states coexists with divergence processes at the level of regions, both within and between member states (Puga, 1999; Fayolle and Lecuyer, 2000; Gianetti, 2002; Overman and Puga, 2002). This outward discrepancy suggests that, to the relative detriment of the lagging regions, certain locations – the metropolitan areas – have converged during the process of economic integration (Longhi and Musolesi, 2007).

In the nineties, the emergence of new trends of literature provided sound analytical bases to explain these facts. The choices for the location of production and investment have been explained by modeling increasing returns to scale. This process has resulted in the uneven regional distribution of activities, which is opposed to the perfectly balanced landscape predicted by the traditional theory (Combes *et al.*, 2008). Depending on assumptions concerning labor mobility across regions and the structure of the economies considered, concentration (Krugman, 1991) or specialization (Krugman and Venables, 1996; Fujita *et al.*, 1999) might occur. For Krugman and Venables (1996), *there is a possibility that Europe will develop an American-style economic geography with the growing integration of markets*, i.e., the clustering of activities around major regional locations serving European and global markets. According to the authors, the fall of the formal or informal trade barriers that have divided the European market can reach a level where industrial delocalization and specialization might occur. A relevant strand of the theoretical literature has followed these original studies (Fujita *et al.*, 1999, Combes *et al.*, 2008). Even if Krugman (2010) himself has recognized that the opposition between *American and European style geography* has been somewhat magnified, sound empirical evidence for how the EU economic geography evolved during the integration process has yet to be provided.

Specialization patterns indicate potential sources of growth or asymmetric shocks and are crucial in characterizing the effects of economic integration in Europe (Barrios *et al.*, 2003; Brülhart, 2001).

This study aims to fill the remaining gap in the empirical literature concerning the nature of the structural change arising during the integration process.

Different issues are at stake. The question of *where* economic activity will agglomerate is well documented; this question induces a focus on the metropolitan areas, which are the regional political or economic capital cities that concentrate the sources of agglomeration and sustain the wealth of nations. The question of *how* economic activity will agglomerate is not as well documented and is directly addressed here. Indeed, metropolitan areas, i.e., the *center* of the regional models, are more often opposed to *peripheries* and thus implicitly (and mistakenly) considered as homogenous areas. The highly relevant and poorly documented issue regarding the consequences of economic integration is the internal evolution of this *center*.

Two aspects have to be considered to fully understand the changes of the European economic geography. The first aspect refers to the sectoral changes *within* the metropolitan areas, i.e., the evolution of specialization during the process of European integration. The second aspect refers to the changes *between* metropolitan areas, i.e., the evolution of their similarities or dissimilarities during this process. As described by Krugman and Venables (1996, p. 960), the increasing specialization and dissimilarity of the industrial structure would be evidence of the emergence of *US-like industrial districts* in Europe. However, increasing similarities would indicate that some trends towards a homogeneous European city system are at work. These specialization dynamics characterizing the metropolitan areas along the economic integration process remain an ignored but key issue in Europe.

Because definitive predictions concerning the effects of integration on specialization are difficult to settle, empirical work is clearly called for. This study builds on the two basic messages of Leamer and Levinsohn (1994), which are quoted from Brackman *et al.* (2006), which are as follows: *don't treat theory too casually* and *estimate don't test.* Accordingly, our econometric analysis is inspired from well-grounded theoretical outcomes, which for instance helps us in choosing the explanatory variables but, at the same time, we do not directly follow a particular theory, and we do not intend to test competitive theories among themselves. Our econometric model is a simple reduced specification form aimed at providing insights on specialization patterns in Europe. Particularly, the adopted semiparametric approach allows us to relax most of the restrictive assumptions underlying the standard parametric specifications. We follow a branch of the literature (Imbs and Warziak 2003; de Benedicts *et al.*, 2009) that evidenced the relevance of taking into account nonlinearities when modeling specialization but we extend such literature in three primary directions. First, we alternatively model two very different measures of metropolitan specialization that capture *within* and *between* specializations. The former is measured using the Gini index, which is a common measure of specialization, whereas the latter is measured using the Krugman diversity index. Second, we adopt a semiparametric setting that allows us to extend the model of Imbs and Warziak (2003) by introducing additional relevant explanatory variables, such as the size of the local market and a proxy for realization of the single European market, other than economic development. Finally, a third extension removes the separability assumption, allowing us to assess the interactive effects of development and integration on specialization. The remainder of this paper is structured as follows: Section 2 summarizes the theoretical background and explains *why* and *how* the sectoral structures of the metropolitan areas can change over the course of the economic integration process. Additionally, this section identifies the most relevant determinants of specialization. Section 3 details the empirical specification and the econometric approach. The semiparametric setting we adopt is based on the generalized additive models (GAMs) approach and allows both controlling for unobserved heterogeneity and that multiple explanatory variables affect nonlinearly and additively the dependent variable. GAMs have been initially introduced by Hastie and Tibshirani (1990) and more recently have been developed both on theoretical and computational directions. Estimation relies on the decomposition of the smooth functions on spline basis; then a penalty term is added in the log-likelihood (Wood, 2003, 2006). In particular, the estimation algorithm is based on the approach proposed by Wood (2004) providing an optimally stable smoothness selection method which presents some advantages compared with previous approaches, such as the modified backfitting (Hastie and Tibshirani, 1990) or the Smoothing Spline ANOVA (e.g. Gu and Wahba, 1993). Smoothing parameter estimation and reliable confidence interval calculation is difficult to obtain with the modified backfitting, whereas Smoothing Spline ANOVA provide well founded smoothing parameter selection methods and confidence intervals with good coverage probabilities but at high computational costs. To avoid these problems, Wood (2000) among others suggests representing GAM using penalized regression splines, but leaves a number of practical problems, concerning convergence and numerical stability, unresolved. Wood (2004) developed it further by providing an optimally stable smoothness selection method whereas Wood (2008) provides a computationally efficient method for direct generalized additive model smoothness selection. A very appealing feature of the method proposed by Wood (2004) compared with other approaches is that it has been shown to perform very well even in the case of almost co-incident covariates. Despite their appeal, GAMs also present some caveats which are worth to mention. A first possible limitation of GAMs is that they are less general than fully non-separable models. These models, however, present difficulties in terms of interpretation, statistical feasibility (e.g. the curse of dimensionality problem) and identification (see e.g. Hoderlein and White, 2012 and Evdokimov, 2010) which are not present with GAMs. A second caveat with GAMs is that there is not yet a fully developed asymptotic theory. However, recently, some asymptotic results have been provided by Yoshida and Nato, 2012, 2013). In particular, Yoshida and Nato (2013) show the asymptotic normality of the penalized spline estimator in a GAM framework, thus generalizing the results of Kauermann et al. (2009) focusing on the penalized spline estimator in generalized linear models (GLMs). These recent improvements in GAM theory and computation can be implemented by using the Wood's (2012) mgcv R package where the default underlying fitting methods are given in Wood (2011 and 2004).

We then relax the additivity assumption by considering the interaction models (Ruppert *et al.*, 2003, Ch. 12) and scale-invariant tensor product smooths (Wood, 2006ac; Augustin *et al.*, 2009) are adopted to represent two-dimensional terms. Section 4 presents the results derived from our sample of 35 metropolitan areas observed over the period of 1980 – 2005 and confronts them with recent developments in the literature. Finally, section 5 offers a conclusion.

2. Background

2.1. Specializing alike or apart?

Specialization as a result of trade liberalization or economic integration can apparently be thought of as a good candidate for the famous list of *stylized facts* drawn by N. Kaldor (1961) and recently revised by Jones and Romer (2009). These *facts* are common to most economies, and every theory has to confirm these facts to obtain some relevance. Because the majority of dominant theories predict that the liberalization and integration of trade will trigger specialization, it is surprising that empirical studies have yet to be performed, especially at the regional level.

The analytical frameworks for building empirical assessments of specialization vary greatly. Brülhart (1998, 2001b), Longhi *et al.* (2002), or Combes *et al.* (2008) report three main theories that explain how higher specialization levels can be reached:

Neo classical theory is characterized by perfect competition and constant returns to scale; location is determined exogenously through comparative advantages and leads to inter-industry specialization.

New trade theory introduces increasing returns, product differentiation, and monopolistic competition into the model, thus restricting the exogenous elements to the market size (Helpman and Krugman, 1985). This theory predicts inter-industry and intra-industry specialization. As trade costs fall, the firms with increasing returns will tend to concentrate production in core markets – that is, the regions with the best market access – and thereby increase the degree of specialization.

New economic geography theory (*NEG*) finally establishes that location is endogenous and that regional specialization is the result of the spatial pattern of agglomeration of economic activity. The economies are identical in their initial factor endowments, where the relocation of firms or labor from one region to another triggers cumulative spatial or sectoral concentration (Krugman, 1991). When firms have *supply-side linkages*, they benefit by being located in regions gathering suppliers that are able to provide a large range of specialized inputs. In this case, economic integration brings specialization to sectors where supply-side and demand-side links are important.

This hypothesis of the equivalent initial factor endowments across locations is crucial to grasping how specialization occurs in the European integration process. The NEG is the first successful attempt to explain why *a priori* similar regions do not experience the same path of economic development (Behrens and Thisse, 2007) and how this uneven development leads to concentration or specialization patterns. Geography or historical chance (*first nature advantages*) can determine the location of economic activity; but once a particular pattern of specialization is in place, the pattern becomes self-sustaining and might be self-reinforcing when transport costs evolve (*second nature advantages*) (Krugman, 1991; Fujita *et al.*, 1999).

Even if economies are hardly identical in their initial factor endowments, changes in the economic integration processes can significantly reshape the geography. The relocation of firms or labor from one region to another triggers cumulative concentration and specialization patterns.

To paraphrase Brülhart (2001a), the question of *specializing alike or specializing apart?* perfectly summarizes the issue to be addressed. In addition to the traditional approaches of specialization, this question can be used to tackle the consequences of economic integration on the European landscape. The traditional approaches primarily featured models of *intra-metropolitan* spatial structures and considered cities as *floating islands* (Fujita and Mori, 2005). However, as emphasized by Ionnides and Overman (2004), the NEG has added important new spatial insights to the literature by building explicit models of *inter-metropolitan* spatial structures. These *inter-metropolitan* spatial sectoral dynamics are critical in terms of the structural change and evolution of the European landscape triggered by economic integration. It is a fact that economic and innovative activities are increasingly located in metropolitan areas. However, whether this occurrence is similar or dissimilar in terms of sectorial structure in metropolitan areas remains an unanswered question.

According to the early work of Krugman (1991), an important process of specialization in the main European metropolitan areas should occur during the process of economic integration. Is this process accompanied by increasing dissimilarities between these areas, *i.e.*, the emergence of districts, or by an evolution towards similar structures? According to the NEG theories, the deepening of the integration process or the creation of the *European single market* and related decreasing trade costs should militate for the first alternative. However, the existence of multiple equilibria and path dependencies – *history matters* – as well as the possible emergence of *three-ness* effects (Behrens and Thisse, 2007) argue against *a priori* assumptions on the specialization dynamics in Europe. Nonetheless, the process is still an important issue for regional policy, as complementarities and interdependencies between different specialized centers or between similar centers can foster different dynamics for the overall European development and growth. To the best of our knowledge, this conjecture has yet to be directly assessed empirically, *i.e.*, the models of the (dis)similarity of evolution across the main European metropolitan areas have not been implemented.

Regional specialization has been the object of developments in the literature. Samples as large as possible from the regions – given the constraint of availability of reliable data – at different levels of aggregation data – have been performed (NUTS1, NUTS2…) (Brülhart, Traeger, 2003; Hallet, 2002; Midelfart-Knarvik, Overman, 2002, Molle, 1997). Some studies have differentiated the regions by considering dummy variables for the central and peripheral regions (Ezcurra *et al.*, 2004). However, this study asserts that the center is not an homogenous entity (as it is usually considered in the literature), especially when economic integration is at stake. Indeed, the center - periphery dynamics are not greatly different analytically from the regional dynamics usually at work in a nation, which is what many papers finally focus on to overcome the data problems (Paluzie *et al.*, 2001; Suedekum, 2006). In fact, the ongoing change of the ’European center’ – which is made of previously independent national centers that have merged in an homogenous economic space – is the *main specificity* of the process of integration and is the basic issue to tackle in trying to grasp the evolution of the economic landscape in Europe. This study builds an empirical framework to address this issue.

2.2. Determinants of specialization

It is generally acknowledged that EU industrial dynamics have been shaped in recent decades by the process of economic integration. However, this process is complex and not completely or directly observable. Thus, this process will be apprehended in this study through a variety of information, such as *economic development* (Imbs and Wacziarg, 2003; Ezcurra *et al.*, 2006), which has been recognized as a main outcome of economic integration. Another factor able to trigger the cumulative processes of concentration or specialization should be the *creation of the single market* and its *completion* through the introduction of the Euro. Compared to the metropolitan areas of member states that have kept their own currencies, a given metropolitan area’s adhesion to the Euro zone can be considered to cut full trade costs. The deepening of the economic integration through the creation of Economic and Monetary Union has renewed old debates related to Optimal Currency Areas (Mundell, 1961) and generated an important literature (Barrios *et al.*, 2003, Rose, 2000). There are opposing and conflicting views concerning the dimension related to specialization (Midelfart, Overman, Venables, 2003). The first view, known as the *Krugman viewpoint* (Krugman, 2003), argues that the increased integration induced by the Euro could change the pattern of economic activities location and lead to increased specialization. Stronger effects are to be expected at the regional level, where specialization is higher. This process should result in increased intra and inter specialization of the metropolitan areas, and the emergence of an 'industrial district' like the geography in Europe. The second view, the *European Commission viewpoint*, argues that the consequence of increased integration is the development of intra-sectoral trade. Intra-sectoral trade is detrimental to inter-sectoral trade, and its development is in accordance with a general movement of convergence in Europe, which leads to lower (rather than more) sectoral dissimilarity. This is an important issue because of the well-known consequences of the cyclical synchronization and the asymmetric propagation of shocks across regions (Imbs, 2004, Pons-Novell and Tirado-Fabregrat, 2006).

Another additional explanatory factor that represents the *home market effect* will be apprehended by the size of the local labor market, whose effect is central in the NEG literature. Increasing returns induce an incentive to concentrate production of each variety of goods in one location; decreasing transport costs induce location in the area that offers a large market. This argument is now well known (Krugman, 1991). Centripetal forces are generated through a circular causation of forward linkages (the incentive of workers to be close to the producers of consumer goods) and backward linkages (the incentive for producers to concentrate were the market is larger). This self-reinforcing process leads to specialization. The gains derived from large local labor markets are particularly important. To date, many theoretical and empirical works have focused on the relationship between city size (which can be considered a good proxy for the size of the local labor market) and specialization, thus making various predictions that appear somewhat contradictory.[1]

Finally, the model should allow for other time-invariant factors, such as the country of the metropolitan area, the specific character of the capital cities, and the specific character of each metropolitan area considered. For examples, the character of each metropolitan area is embedded in

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[1]For example, Abdel-Rahman and Fujita (1993) report that diversified and specialized cities coexist, but in the emerging equilibrium diversified cities are larger than specialized cities. Using other assumptions, Abdel-Rahman (1994) reports the opposite finding. Empirically, Duranton and Puga (2000) find a slightly negative relationship between size and specialization for a sample of cities, whereas Henderson (1997) demonstrates that cities of similar size specialize in similar activities. He shows empirically that large metropolitan areas (over 500 000 inhabitants) tend to specialize more in services, while medium-sized cities (50 000 to 500 000 population) specialize more in traditional manufacturing activities, such as textiles, pulp, food, etc. Nevertheless, these works are primarily based on samples from American cities, and the empirical analysis of the European metropolitan areas, which is of particular relevance given the changes from the integration process, remains to be performed.

its time invariant *first nature advantages*, which is described by Krugman (1991) as the determinant of the initial conditions of the location of activities.

3. Econometric analysis

3.1. Data

It is quite a challenge to construct a sectoral disaggregated database of detailed economic variables for cities, especially when a time-series over long periods has yet to be built. This difficulty might explain the lack of empirical analyses of specialization in the EU. Various empirical studies (Aiginger and Rossi-Hansberg, 2006; Amiti, 1998; Brülhart, 1998, 2001b; Midelfart-Knarvik *et al.*, 2000; O'Donoghue and Townshend, 2005) have detailed the specialization processes in the European scene, but these studies usually address manufacturing sectors across countries or at the regional level within one country. Some exceptions exist, and these studies usually address the regions at the NUTS2 level for all the regions statistically available (Ezcurra *et al.*, 2006). When dealing with cities, it is essential to adopt lower levels of the territorial nomenclatures and to take tertiary activities into account.

Most of the database is from Cambridge Econometrics. The database is supplemented by specific information concerning adhesions to the Euro zone. Starting with Eurostat databases, Cambridge Econometrics has collected exhaustive information about the various sectoral variables of metropolitan areas over time: gross value added, in constant prices (1990 Euro), employment, compensation per employee (1990 Euro), population, working population, etc. The database contains the main European metropolitan areas during the period 1980-2005, and it is disaggregated into 14 sectors of activity (see Tables a1 and a2 in the Appendix). It covers a suitable period for analyzing the evolution of metropolitan specialization during the process of economic integration.

It is worth noting that it is difficult to delimit city boundaries because formal definitions of political or administrative units do not always cope directly with an economic analysis perspective. According to Cambridge Econometrics (Ereco, 2001), functional regions are much more relevant. Functional regions are defined as the territory over which different types of localities interact to create a functioning urban system. Obviously, the emphasis on functional interactions rather than formal boundaries raises significant data and definitional problems because such functionally–defined boundaries are imprecise and might change over time and from case to case. As Henderson (2005) stressed, *the idea in defining metro areas is to cover the entire local labor market and all contiguous manufacturing, service and residential activities radiating out from the* *core city, until activity peters out into farm or very low density development*. The definition of the metropolitan areas given by Cambridge Econometrics, and taken up here, is a compromise between the desire to specify an economically functioning system and the limitation imposed by data availability. NUTS3 regions are generally used to define metropolitan areas, and there is a recognition that cities are more often at the core of local economic interactions. This level of aggregation implicitly confines the analysis to a limited number of cities, but it allows for a quite large temporal coverage. Cambridge Econometrics builds from the Eurostat regional database using at the NUTS2 level sophisticated data filling methods that complement the Eurostat missing data from national sources (Sasha and Robins, 2005), according a methodology expounded in Ereco (2001). The same filling methods are used at the NUTS3 regions, using the filled NUTS2 database as main source. The bases offer particularly reliable data on market service sectors (Sasha and Robins, 2005), which is pivotal for this work on metropolitan areas.

3.2. Econometric specification, identification and estimation

Benchmark specification

The econometric specification is inspired from the seminal paper of Imbs and Wacziarg (2003) which adopts a semiparametric model allowing for a nonlinear effect of economic development, captured by *per capita* GDP, on specialization and assumes that such an effect is separable from both the individual effects and the error term.

This study intends to adapt such a model to assess the main dynamics of specialization of European metropolitan areas during the integration process that occurred over recent decades and aims to extend it in three main directions.

In the first extension, we alternatively model two very different measures of metropolitan specialization $(SPEC)$ and capture the *within* and *between* specializations, respectively (Krugman, 1991, Imbs, 2004, Brülhart, 2001b, Midelfart-Knarvik *et al.*, 2000):

- the *within specialization* is measured using the Gini index $(GINI)$, which is a common measure of specialization. The index is calculated as the ratio of the area that lies between the hypothetical line of equality and the Lorenz curve over the total area under the line of equality.
- the *between specialization* is measured using the Krugman diversity index $(KRUGMAN)$,

which is the difference between the sectoral structures of a metropolitan area i and that of all other metropolitan areas. It is a dissimilarity index. Taking the absolute values of the difference between the share of the sector *k* in the total activity, added over each sector, the Krugman index is computed as follows:

$$KRUGMAN_{it} = \sum_{k=1}^{14} abs\left(v_{it}^{k} - \overline{v_{it}^{k}}\right)$$

where v_{it}^{k} is the share of the sector k in city i at time t, and $\overline{v_{it}^{k}}$ is the share of the same sector in all other cities[2].

Second, we follow some recent advances on semiparametric modeling allowing us introducing multiple explanatory variables, rather than considering the economic development as the only observable determinant of specialization. The full set of explanatory variables considered is:

- *per capita* GDP (GDP), which measures economic development,
- active population $(MARKET)$, which measures the size of the local labor market and accounts for the home market effect,
- a categorical (factor) variable D_{EUit}, which characterizes the status of a metropolitan area i regarding European integration. European integration is a continuous process of widening (enlargement) and deepening (increased integration). Along the period of analysis, the metropolitan areas can thus be outside the EU ($D_{EUit} = 0$), belong to or join the Single Market ($D_{EUit} = 1$), and finally the Euro zone ($D_{EUit} = 2$). According to the NEG, this variable is pivotal for the location of activities and specialization over the integration process,

while the individual fixed effects, α_i, are introduced to take account to metropolitan time-invariant

[2] Our motivations behind the choice of the GINI and KRUGMAN indexes are the following. The GINI index has been chosen because it is a common measure of specialization and in particular its utilization allows making a direct comparison with relevant previous studies focusing at a higher level of territorial aggregation and use the GINI index (see e.g. Imbs and Wacziarg, 2003; Aiginer and Rossi-Hansberg, 2006). However, it has been recognized that there are some desirable criteria that a specialization index should have (such as the decomposability) which are not fulfilled by the GINI index (Palan, 2010; Bouguignon, 1979). The Herfindal index is another widely adopted index. Moreover, it fulfils more criteria than other indexes (including GINI). In our case, the GINI and Herfindal indexes are almost co-incident (correlation=0.96) and non reported estimates indicate that the results are fully insensitive to the choice between these two indexes. The KRUGMAN index has been chosen not only because it is a common and widely adopted measure of sectoral diversity but also because it fulfills almost all criteria (Palan, 2010) and in particular *"In cases where the analysis focuses on the development of economic structures over time, in which the appropriate estimation of specialization levels is important, the Krugman Specialization Index must be recommended since it is the only measure that possesses the criterion of the classification of industries"* (Palan, 2010).

characteristics, such as the first and second nature advantages possibly related to both specialization and development. The benchmark specification considered in the paper is given by:

$$SPEC_{it} = f_1(GDP_{it}) + f_2(MARKET_{it}) + \gamma D_{EUit} + \alpha_i + \varepsilon_{it} \tag{1}$$

Finally, we provide a third extension, which will be detailed later. This extension removes the separability assumption by considering the interaction models (Ruppert *et al.*, 2003).

Identification

A fully additive model, as described in Equation (1) can be estimated by adopting the Generalized Additive Model (GAM) framework methodology (Hastie and Tibshirani, 1990). The individual fixed effects can be treated as dummy variables by entering them parametrically to the model. They can also be treated as nuisance terms to be eliminated with a transformation. Both approaches have some relative drawbacks and benefits. Particularly, the former approach might be computationally costly, but, different from the latter, it does not suffer any identification problems.

Given the structure of our panel data set (small N and large T), it is not computationally costly to estimate the model directly without eliminating the individual effects. Thus, as in Mammen *et al.* (2009), Ordás Criado *et al.* (2009) or De Benedictis *et al.* (2008), we follow such an approach by including the individual intercepts in the parametric part of the level equation.[3]

The main relative advantage of such an approach is that the approach does not suffer from the possible (partial) lack of identification that arises when adopting a transformation approach, such as first differencing to eliminate the individual effects. Indeed, by differencing Equation (1) we obtain (see also Azomahou and Mishra, 2008; Azomahou *et al.* 2009, Su and Ullah, 2010):

$$\begin{aligned}(SPEC_{it} - SPEC_{it-1}) = {} & f_1(GDP_{it}) - f_1(GDP_{it-1}) + \\ & f_2(MARKET_{it}) - f_2(MARKET_{it-1}) + \\ & \gamma(D_{EUit} - D_{EUit-1}) + (\varepsilon_{it} - \varepsilon_{it-1}).\end{aligned}$$

However, some components of the functions f_1 anf f_2 might not be fully identified. As argued by Su and Ullah (2010, p.11), if for instance,

[3] It is worth to note that it is also possible to introduce the individual effects as random elements (Augustin *et al.*,2009).

$$f_1(GDP_{it}) = a + m(GDP_{it}),$$

then differencing does not allow for the identification of $f_1(GDP_{it})$, and eventually only $m(GDP_{it})$ can be identified. Moreover, such an approach doubles the non-parametric functions to be estimated. Thus, first differencing might be useful in practice when N is large compared to T, as usual in micro data, or to estimate a 'feedback effect' through the function $f\left(x_{it-1}\right)$, as in Azomahou and Mishra (2008).

Estimation

The estimation of Equation (1) is performed by adopting the method recently developed by Simon Wood by using the gam ( ) function of the mgcv R package (Wood, 2012). GAMs are generalized linear models where the linear predictor is specified as a sum of smooth functions of some or all of the covariates and can be generally expressed as: $g\left\{\mathrm{E}\left(y_i\right)\right\} = \mathbf{Z_i}\boldsymbol{\theta} + \sum_j f_j\left(x_{ji}\right)$, where g(·) is a smooth monotonic link function (in our case we have an identity link function), the y_i are observations on independent random variables from some exponential family distribution; $\mathbf{Z_i}$ is the ith row of $\mathbf{Z}$ and contains parametric model components, with corresponding parameter vector $\boldsymbol{\theta}$, and the f_j are smooth functions of the covariates x_j, which may be vector covariates, subject to identifiability constraints such as $\sum_i f_j\left(x_{ji}\right) = 0 \ \forall j$. The estimation is based on the maximization of a penalized likelihood by penalized iteratively reweighted least squares (P-IRLS) (Wood, 2004). Penalized Regression Splines are adopted as a basis to represent the uni-dimensional smooth terms (Wood, 2003, 2006ab). The smoothing parameter values are selected by the GCV (Generalized Cross Validation) criterion [4], and statistical inference is made by computing 'Bayesian p-values' (Wood, 2012). Compared to the values from the alternative strictly frequentist approximation, these values appear to have a better frequentist performance (in terms of both power and distribution under the null) (Wood, 2006ab).

Interaction models

A more general and original modeling can be obtained by adopting interaction models (Ruppert *et*

[4] Because the GCV might present a tendency to over fitting, we have increased the amount of smoothing by correcting the GCV score by a factor $\delta = 1.4$ that can correct the over fitting without compromising model fit (Kim and Gu, 2004).

al., 2003). To the best of our knowledge this paper represents the first attempt to remove the additivity assumption in the analysis of the determinants of specialization.

We first consider a *"factor-by-continuous interaction model"* that allows the factor variable D_{EUit} to interact with the continuous covariates *per capita* income and size of the market:

$$SPEC_{it} = f_{1D_{EUit}}\left(GDP_{it}\right) + f_{2D_{EUit}}\left(MARKET_{it}\right) + \alpha_i + \varepsilon_{it} \qquad (2)$$

This model specifies a factor-by-curve interaction and introduces three distinct nonparametric effects for both income and size on specialization, one for each value of D_{EUit}. Because the level of development and the competition of the single market can be considered as two outcomes of the process of economic integration, this simple semiparametric interaction model is useful for identifying the joint effect of two different outcomes of integration on specialization.

We then relax the assumption that the effect of GDP is separable from the effect of $MARKET$, that is

$$SPEC_{it} = f\left(GDP_{it}, MARKET_{it}\right) + \gamma D_{EUit} + \alpha_i + \varepsilon_{it}, \qquad (3)$$

which is also called a *"continuous-by-continuous interaction"*. We use scale-invariant tensor product smooths proposed by Wood (2006c) (see also Wood, 2006a; Augustin *et al.*, 2009) to represent the two dimensional term f. Indeed, while single penalty smooths of multiple covariates are problematic if the covariates are not naturally on the same scale, tensor product smooths with separates penalties associated to each covariate can provide smooths which are invariant to the linear rescaling of covariates and, as in our case, are good for smooth variables measured in different units. This has long been recognized in the literature (e.g. Gu, 2002). Another reason why multiple penalties are preferable to single penalty is that they have relatively low rank while single penalty smooths suffer of rank deficiency which renders the penalization useless. The other key feature of multiple penalties tensor product smooths proposed by Wood (2006c) is that they can be generated from any marginal basis. We in particular specify a tensor product smooth *f* of the two covariates *GDP* and *MARKET* constructed from marginal thin plate regression splines bases.

Finally, by combining the *"factor-by-continuous interaction"* (2) with the *"continuous-by-continuous interaction"* (3) we have

$$SPEC_{it} = f_{D_{EUit}}\left(GDP_{it}, MARKET_{it}\right) + \alpha_i + \varepsilon_{it} \tag{4}$$

which introduces three distinct two dimensional smooths, $f\left(GDP_{it}, MARKET_{it}\right)$, one for each value of D_{EUit}.

4. Results

4.1. Description of the main variables

The creation of the single market and of the single currency zone in Europe might have led to substantial upheavals in regional specialization. The ongoing changes of the 'European center', composed of previously independent national centers that have merged in an homogenous economic space, have been shown to be the *main specificity* of the process of integration, and the issue to tackle when trying to grasp the evolution of the economic landscape in Europe.

As indicated previously, two variables have to be considered to grasp such changes: the *within* (*GINI* index) and the *between* ($KRUGMAN$ index) specializations (see Tables a1 and a2 in the Appendix). Their time series evolution and their kernel density estimates are given in Figure 1.

FIGURE 1 APPROXIMATELY HERE

The *GINI* specialization index increased, while the *KRUGMAN* dissimilarity index decreased nonlinearly over time, with widening (resp. narrowing) ranges. Figure 1 first indicates some of the complex dynamics surrounding the generally increasing (resp. decreasing) trends. It then depicts the kernel density estimates for both the $GINI$ and $KRUGMAN$ indexes. The evolution of the densities over time indicates that the curves shift towards higher $GINI$ and lower $KRUGMAN$ and that some movements of convergence are at work. For each variable, three densities are finally provided, one for each modality of the variable D_{EUit}. Interestingly, the densities suggest that the more the cities are involved in the process of economic integration, then the more they are specialized (higher $GINI$) and the less they are different from the average terms of the sectoral structure (lower $KRUGMAN$). The density estimates switch from bimodality outside European Union to unimodality in the other cases. This apparent trend towards more specialization and similarity of the sectoral structures of the 35 metropolitan areas over the process of European integration is pivotal[5].

4.2. Benchmark results

The benchmark specification expressed in Equation (1) is first estimated for both the *GINI* and *KRUGMAN* indexes. Figure 2 indicates the estimated nonparametric functions f_1 and f_2 (panel A: *GINI* ; panel B: *KRUGMAN*). The component smooths are shown with confidence intervals that include the uncertainty about the overall mean (Marra and Wood, 2012). All the smooths are overall highly significant while detailed approximate significance of the smooth terms available upon request.

The results regarding *within* specialization indicates that there is a *positive nonlinear but monotonic relation* between *GINI* and *per capita* income. This result provides empirical support to the prediction of increasing specialization over the development path, which is adopted by all of the theories and is sometimes studied at higher levels of territorial aggregation (Imbs and Wacziarg, 2003; Aiginer and Rossi-Hansberg, 2006;Cutrini, 2010) but not yet empirically documented at the level of metropolitan areas. This is one of the primary facts established in this paper.

The relationship between GINI and the size of the local market (*MARKET*) is found to be positive. However, the relationship has a clear threshold for medium sized cities. Primarily, the threshold is for southern metropolitan areas (Spain, Italy), where integration does not appear to have triggered major structural changes. The relationship is positive for smaller cities, and primarily northern specialized areas and larger cities, such as Paris and London. Larger cities host larger shares of Financial Services and Other Market Services, which are two sectors that include most of the higher advanced business and producer services and which turn more and more specialized.

Another relevant conclusion is that there is a positive relationship between the categorical variable about the status of the metropolitan areas regarding European integration. D_{EUit} and *GINI* . Indeed, while the coefficient associated with the adhesion to the single market ($D_{EUit} = 1$) is not significant with a p-value at about 0.5 ($D_{EUit} = 0$ is taken as reference), the coefficient associated with the inclusion in the Euro zone ($D_{EUit} = 2$) is positive (0.014) and highly significant (p-value=0.002). The deepening of the integration process fosters the dynamics of specialization.

FIGURE 2 APPROXIMATELY HERE

[5] More detailed descriptive statistics opening the "black box" of the Gini and Krugman indexes and taking a closer look at the economic structure of cities and their evolution over time are available upon request.

The estimation of the model explaining the $KRUGMAN$ dissimilarity index also provides interesting insights. Figure 2 indicates a U–type relationship between the $KRUGMAN$ index and the *per capita* GDP. There is a clear negative relationship along the low levels of *per capita* GDP towards a threshold. Finally, there is a small upward bending of the curve caused by just a few observations, such as Swiss cities overspecializing in financial services.

The effect of the size of the local market on the $KRUGMAN$ index is found to be positive, monotonic, and nonlinear. Particularly, small sized metropolitan areas (which have an active population less than 1 million) demonstrate a more positive $KRUGMAN - MARKET$ relationship than the other cities. The curve reveals that some home market effects are at work, as larger metropolitan areas appear to specialize at a higher pace.

Finally, the results clearly indicate that the deepening of the integration process decreased sectoral dissimilarity (lower $KRUGMAN$). Indeed, the coefficients associated with both $D_{EUit} = 1$ and $D_{EUit} = 2$ are negative, with the former (-0.009) being almost significant at 10%, whereas the latter (-0.02) is highly significant (p-value=0.003).

The deepening of the processes of economic development and integration is thus going with more similarity of the sectoral structure of the areas considered. This result runs against some conclusions too hastily drawn from the NEG models.

4.3. Interaction models

Figure 3 reports the estimated functions from the *"factor-by-continuous interaction model"* described in Equation (2). It clearly indicates that there is a joint effect of development and integration on specialization. More precisely, when considering first the $GINI$ index, the nonparametric GDP effect for $D_{EUit} = 0$ is linear and not globally significant at the standard levels (p-value=0.18). On the contrary, the nonparametric GDP effects for $D_{EUit} = 1$ and for $D_{EUit} = 2$ are increasing monotonic nonlinear functions of GDP and are highly significant.

The interaction between integration and market size also appears, to a lesser extent, to be important. In this case, the nonparametric effect of $MARKET$ on $GINI$ for $D_{EUit} = 0$ is much more flat than when considering higher levels of integration ($D_{EUit} = 1$ and $D_{EUit} = 2$), but all the three nonparametric effects are significant.

Similar results appear when looking at the $KRUGMAN$ index. In this case, when compared to those obtained for higher levels of integration, the estimated curves for both GDP and $MARKET$ are also much more flat when $D_{EUit} = 0$.

The deepening of the integration process goes with increasing *GINI* and decreasing *KRUGMAN* indexes. The lack of change in the metropolitan areas located outside the European Union contrasts with the large and significant effects at work in the areas that belong to the European Union. With the deepening of the Union, these effects confirm the expected results regarding *within* specialization, but they somewhat contradict the expected emergence of large specialized 'districts' as suggested by the NEG. The changes are highly effective *within* the member states, but not yet *between* the member states, thus resulting in decreasing dissimilarities between the main European metropolitan areas.

FIGURE 3 APPROXIMATELY HERE

The assumption that the effect of GDP is separable from the effect of $MARKET$ is then relaxed in the model in Equation (3) *"continuous-by-continuous interaction"*, which makes use of bivariate smoothing. The resulting Figure 4 first indicates that an interaction between GDP and $MARKET$ is clearly found for $GINI$. Indeed, while the effect of $MARKET$ on $GINI$ is monotonic positive regardless of the value of GDP, the effect of GDP on $GINI$ varies for different levels of $MARKET$. For low levels of $MARKET$, the relationship is flat (or even slightly an inverted U), while the relationship becomes positive for higher levels of $MARKET$.

Some interesting insights can also be drawn when analyzing the *KRUGMAN* index. Indeed, while the $KRUGMAN - GDP$ relationship is broadly U–shaped for all values of MARKET, the $KRUGMAN - MARKET$ relationship varies significantly for different levels of GDP. For low levels of GDP, the effect is monotonic positive, while for higher levels of income it is inverted U–shaped.

FIGURE 4 APPROXIMATELY HERE

Finally, the plots resulting from the estimation of the more general specification in Equation (4) are given in Figure 5 below. It can be noted that the estimated bivariate smoothing varies according to the value of D_{EUit}. While for $D_{EUit} = 1$ and $D_{EUit} = 2$, they broadly replicate the plots in Figure 4 discussed above, this is not the case for $D_{EUit} = 0$. In this case, the $GINI - GDP$ relationship is still flat for low levels of MARKET. However, the relationship becomes negative for high levels of

MARKET .

FIGURE 5 APPROXIMATELY HERE

Summing up, the specification of interaction models indicates that: (i) as opposed to cases with no integration (such as $D_{EUit} = 0$) the relations *specialization* (both *GINI* and *KRUGMAN*) – *GDP* and *specialization* – *MARKET* are more sloping for higher levels of integration ($D_{EUit} = 1$ and $D_{EUit} = 2$) . (ii) There is a relevant interactive $(GDP, MARKET)$ effect on *specialization*. Indeed, the effect of GDP on $GINI$ is positive only for large cities (high $MARKET$), while the effect of $MARKET$ on $KRUGMAN$ varies with GDP because for low levels of *per capita* income it is monotonic positive, while for high levels of income it is inverted U–shaped. (iii) The bivariate smoothing $f(GDP, MARKET)$ varies also with the value of D_{EUit} . As a relevant example, a local (notably for high levels of $MARKET$) negative $GINI - GDP$ relationship is only obtained for $D_{EUit} = 0$.

5. Concluding remarks and some comments on European policy

Specialization patterns of metropolitan areas are of crucial importance in characterizing the effects of economic integration in Europe. This paper aims to model such patterns and estimates an econometric model that explains both sectoral specialization and sectoral dissimilarity. The sectoral specialization and dissimilarity for 35 European metropolitan areas over the period 1980-2005 are measured with the *GINI* and *KRUGMAN* indexes, respectively. The paper adopts a semiparametric setting that relaxes most of the restrictive assumptions underlying standard parametric specifications. The semiparametric setting we adopt is based on the generalized additive models (GAMs) approach and allows both controlling for unobserved heterogeneity and that multiple explanatory variables affect nonlinearly and additively the dependent variable. A more general and original modeling is provided by adopting interaction models aiming at removing the additivity assumption. We consider both *“factor-by-continuous”* interaction and *"continuous-by-continuous”* interactions, finally combining them and scale-invariant tensor product smooths are adopted.

The proposed model allows us to answer some relevant questions, such as “do the processes of economic integration and development make metropolitan areas more specialized?”, “do these processes make metropolitan areas more similar in terms of sectoral structure?” and “do economic development and integration interact, and, if so, how?”.

One of the primary findings in this study is that the deepening of the processes of development and integration that occurred in the last decades increased both the specialization and similarity of the sectoral metropolitan structure. This finding thus supports a *"specializing alike hypothesis"*. Some of the identified empirical facts indicate that specialization has followed unexpected trends, which underlies the fact that the integration process has, despite its deepening, not yet reached according the words of Krugman and Venables (1996) the "sufficient level" that can trigger these dynamics. Nor has the integration process reached the "necessary level" (Krugman and Venables, 1996) that *must* trigger the *within and between* specialization.

The specification of interaction models that remove additivity also provides interesting results. Particularly, maybe the most relevant one is that there is a joint effect of development and integration on specialization: the positive effect of development on specialization is higher for higher level of integration.

This process of structural change, mainly driven by economic development and European integration, has finally resulted in metropolitan areas “specializing alike” in ‘financial services’ and ‘other market services’, i.e. services that gather most of the knowledge based intensive activities. This process has not occurred in a policy vacuum, but the regional policy implemented through the structural funds has been unable to balance the autonomous path followed by the metropolitan areas. The reform implemented in 2007 with the definition of a Competitiveness Objective covering all the European Union aims at reinforcing the knowledge based services specialization of the metropolitan areas. Our results thus complement Imbs et al. (2012) who also find that economic integration is a main determinant of structural change and suggest that specialization is *“achieved through domestic integration rather than through the heavy hand of …/… policy, with well known drawbacks”*. The basic debate refers to the relevant level of European integration to be achieved.

The paper provides a robust analysis of the related main consequences of the interactions between European integration, economic development and the size of the local market on the metropolitan areas specialization dynamics which should highlight the debate.

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APPENDIX : Cities and sectors covered

Table a. Cities.

City (Country)	City (Country)
Amsterdam (Netherlands)	Lille (France)
Athina (Greece)	Lisboa (Portugal)
Barcelona (Spain)	London (UK)
Birmingham (UK)	Lyon (France)
Bologna (Italy)	Madrid (Spain)
Bordeaux (France)	Manchester (UK)
Bruxelles (Belgium)	Marseille (France)
Cardiff (UK)	Milano (Italy)
Den Haag (Netherlands)	Munchen (Germany)
Dublin (Ireland)	Paris (France)
Dusseldorf (Germany)	Roma (Italy)
Edinburgh (UK)	Rotterdam (Netherlands)
Frankfurt (Germany)	Stockholm (Sweden)
Glasgow (UK)	Stuttgart (Germany)
Hamburg (Germany)	Torino (Italy)
Helsinki (Finland)	Utrecht (Netherlands)
Kobenhavn (Denmark)	Wien (Austria)
Koln (Germany)	

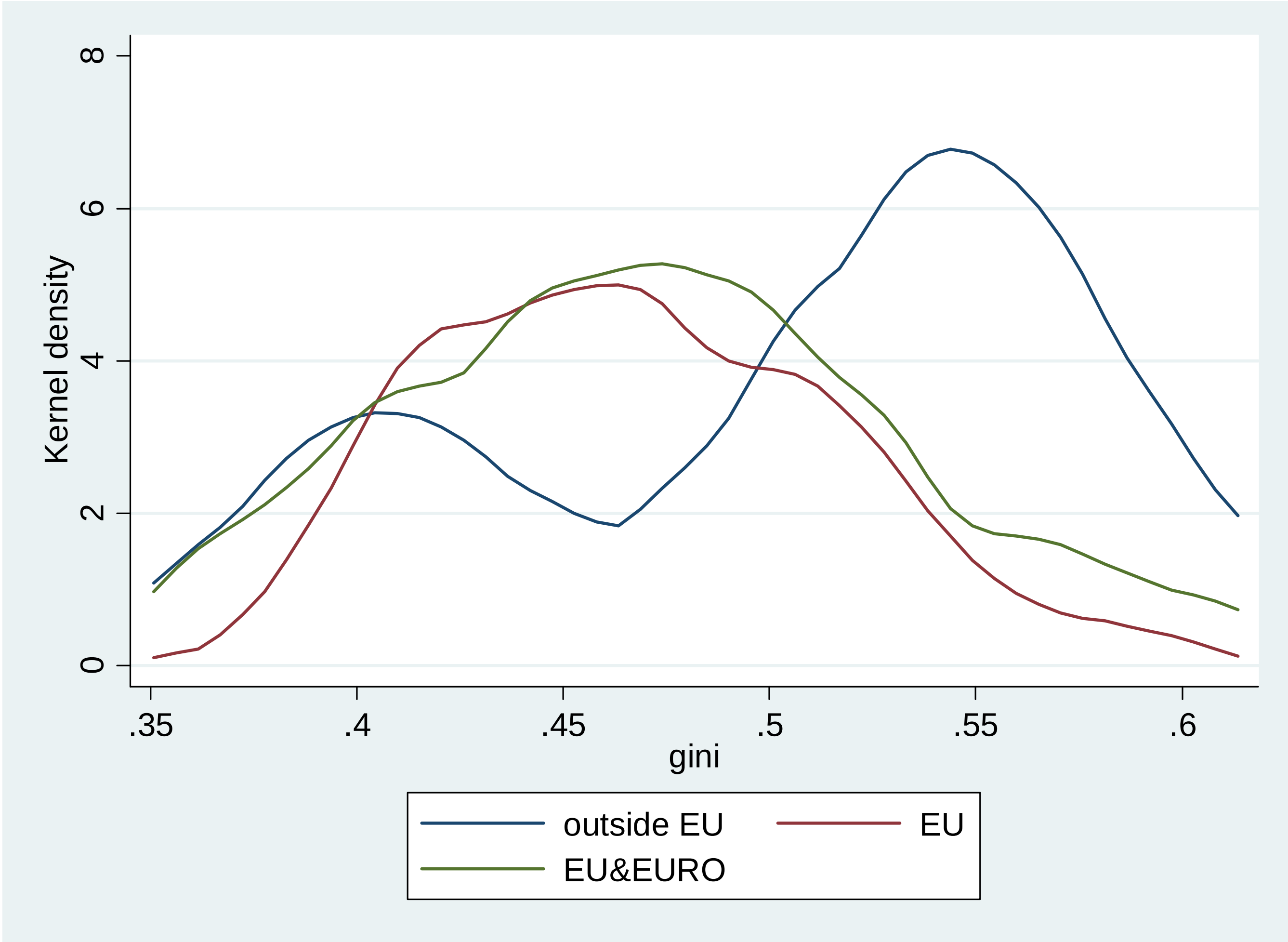
Table b. Sectors. Nomenclatures and codes

	Sector		Sector
1	Agriculture, Forestry and Fishing	8	Other Manufacturing
2	Mining and Energy Supply	9	Construction
3	Food, Beverages and Tobacco	10	Wholesale and Retail
4	Textiles and Clothing	11	Hotels and Restaurants
5	Fuels, Chemicals, Rubber and Plastic Products	12	Transport and Communications
6	Electronics	13	Financial Services
7	Transport Equipment	14	Other Market Services* *Including:real estate, renting and business activites (computer and related activities Research and Development, legal, accounting, book-keeping and auditing activities; tax consultancy; market research and public opinion polling; business and management consultancy; holdings)*

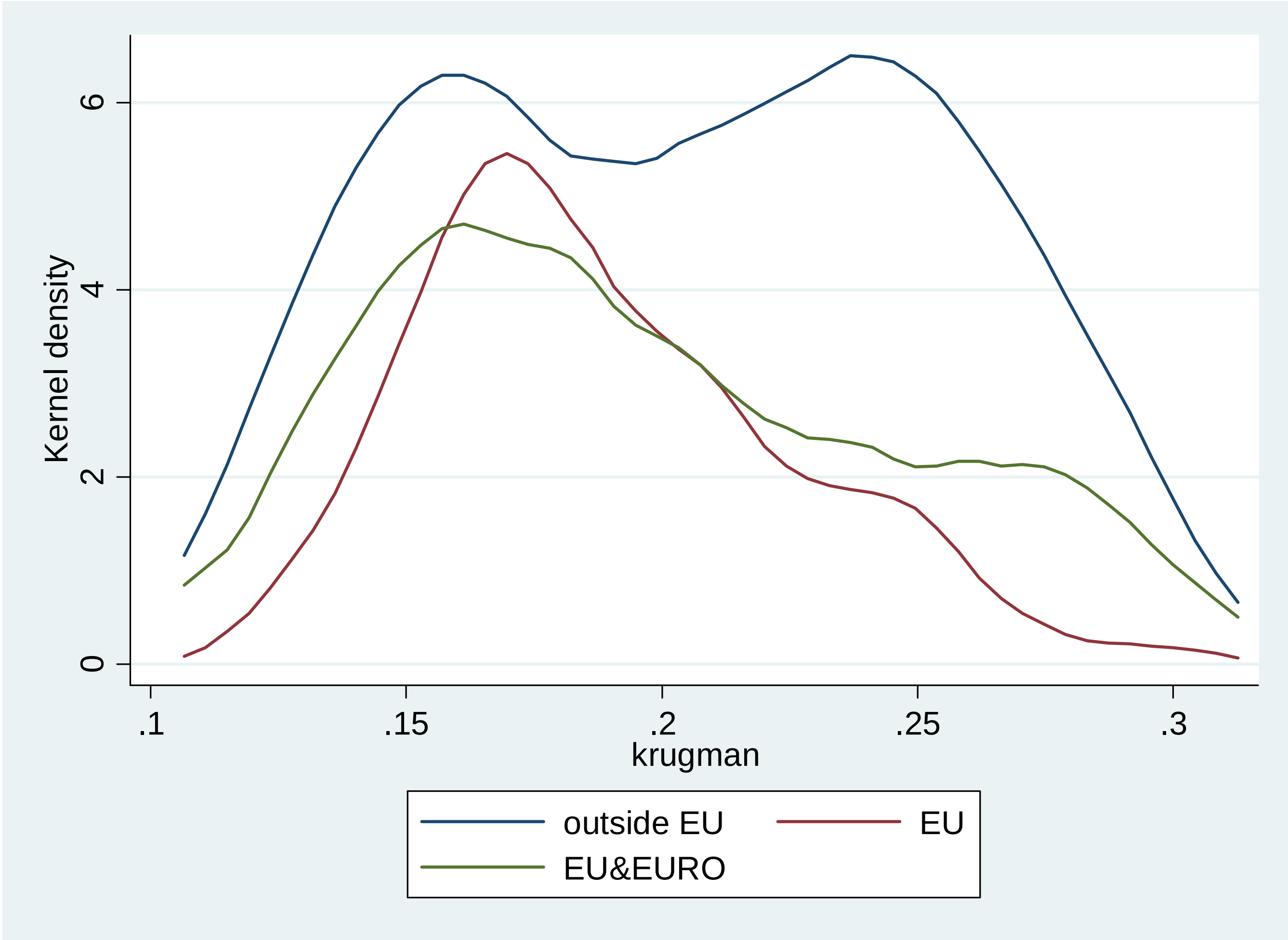
FIGURES

FIGURE 1. Gini and Krugman indexes : trends over time and density estimation by D_{EUit} ,


Amsterdam
Athina
Barcelona
Birmingham
Bologna
Bordeaux
Bruxelles
Cardiff
Den Haag
Dublin
Dusseldorf
Edinburgh
Frankfurt
Glasgow
Hamburg
Helsinki
Kobenhavn
Koln
Lille
Lisboa
London
Lyon
Madrid
Manchester
Marseille
Milano
Munchen
Paris
Roma
Rotterdam
Stockholm
Stuttgart
Torino
Utrecht
Wien
krugman
year
Graphs by city



Kernel density
0
2
4
6
8
.35
.4
.45
.5
.55
.6
gini
outside EU
EU
EU&EURO


Kernel density
0
2
4
6
.1
.15
.2
.25
.3
krugman
outside EU
EU
EU&EURO

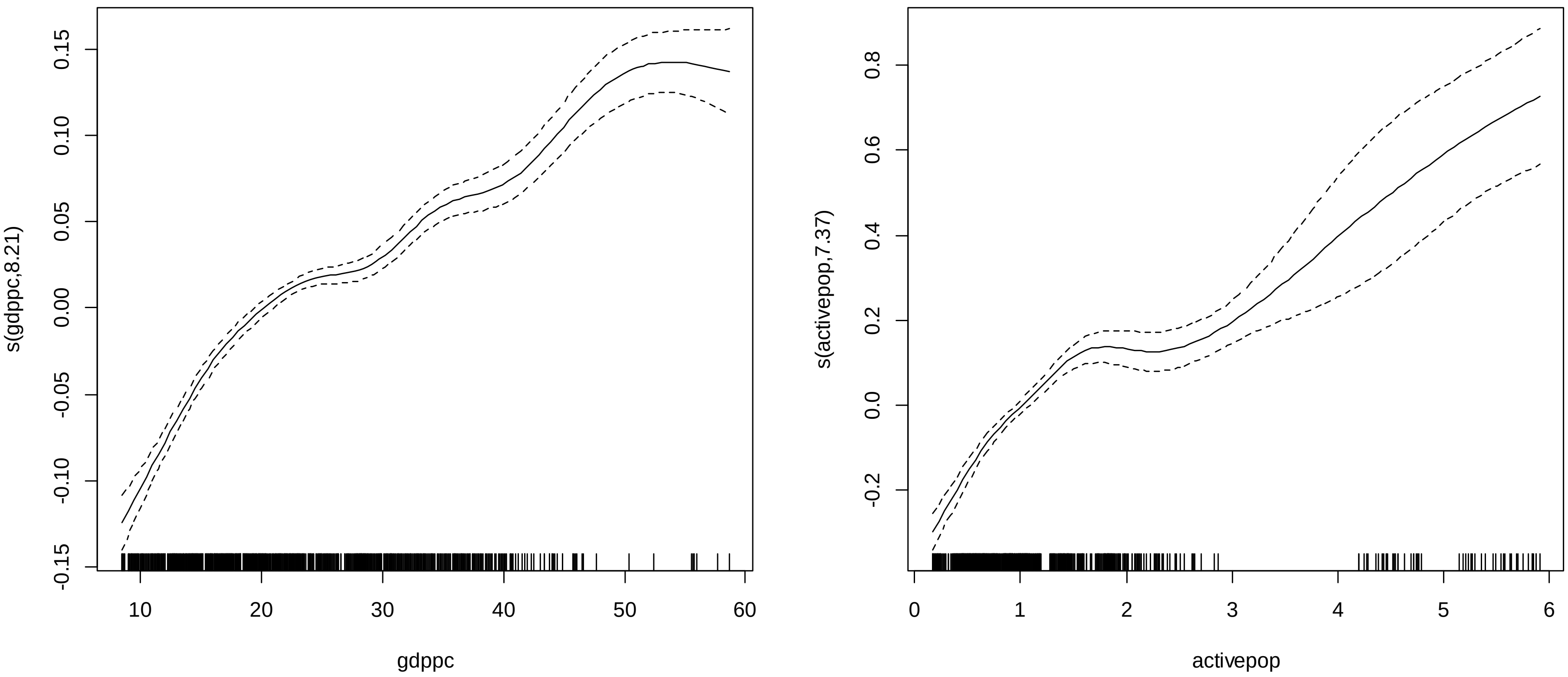


FIGURE 2a. Benchmark specification (eq. (1)). Dep. Var.: GINI.

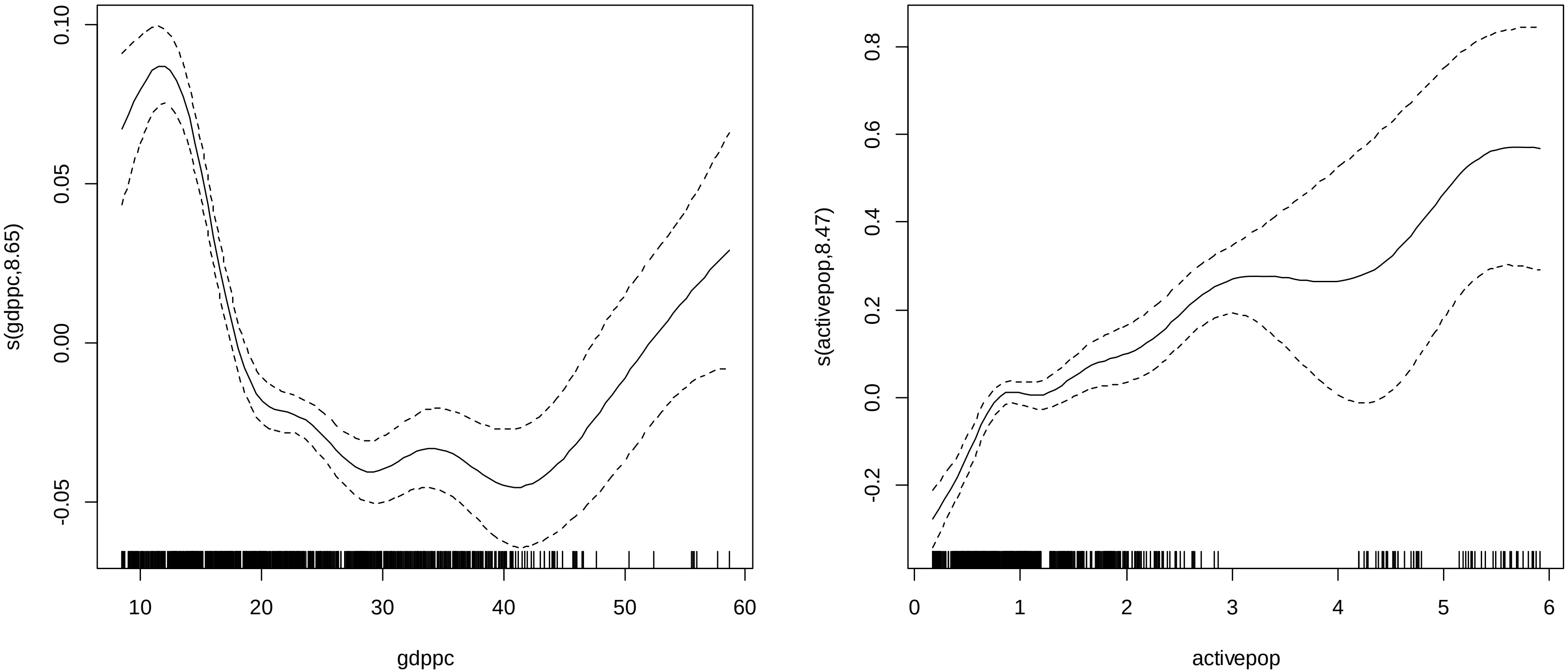


Figure 2b. Benchmark specification (eq. (1)). Dep. Var.: KRUGMAN.

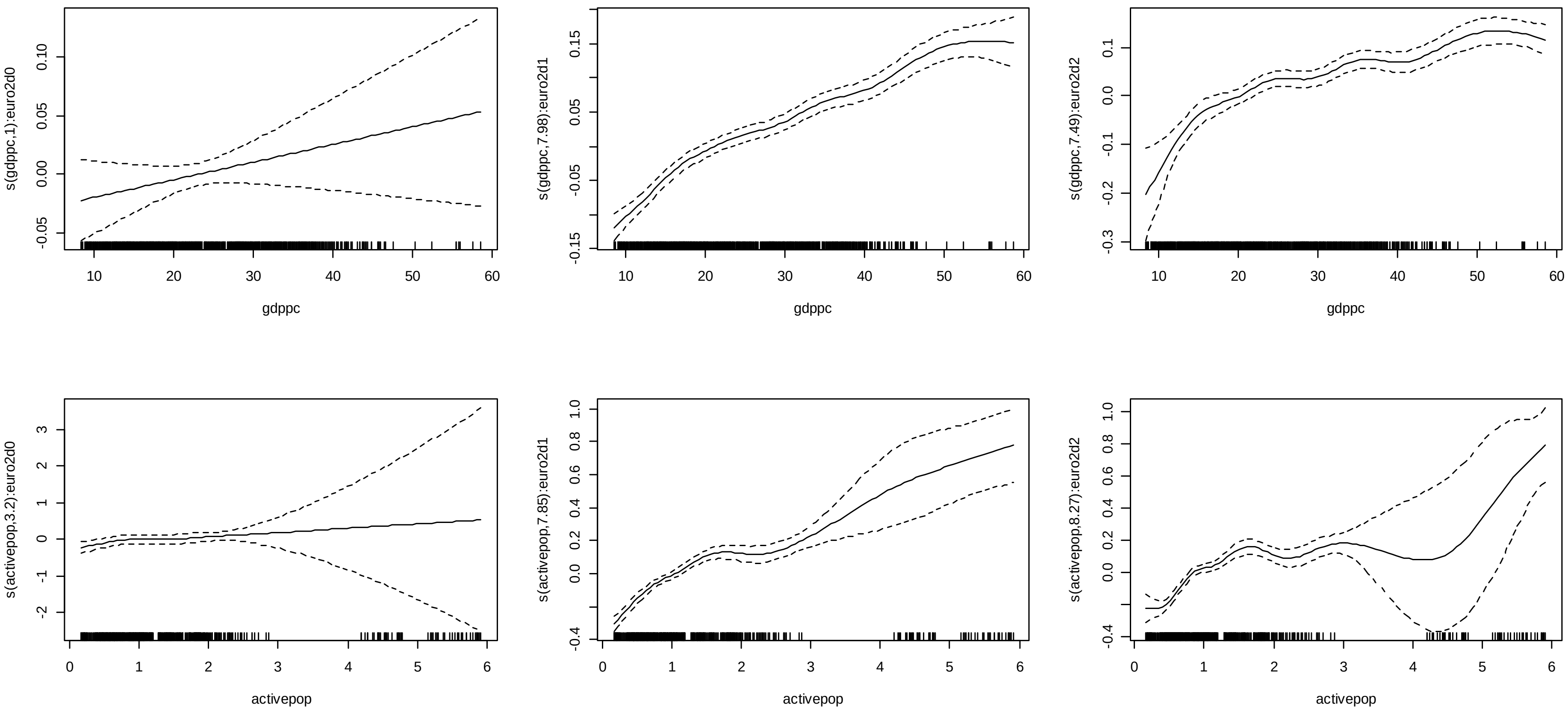


FIGURE 3a. Factor-by-continuous interaction (eq. (2)). Dep. Var.: GINI.

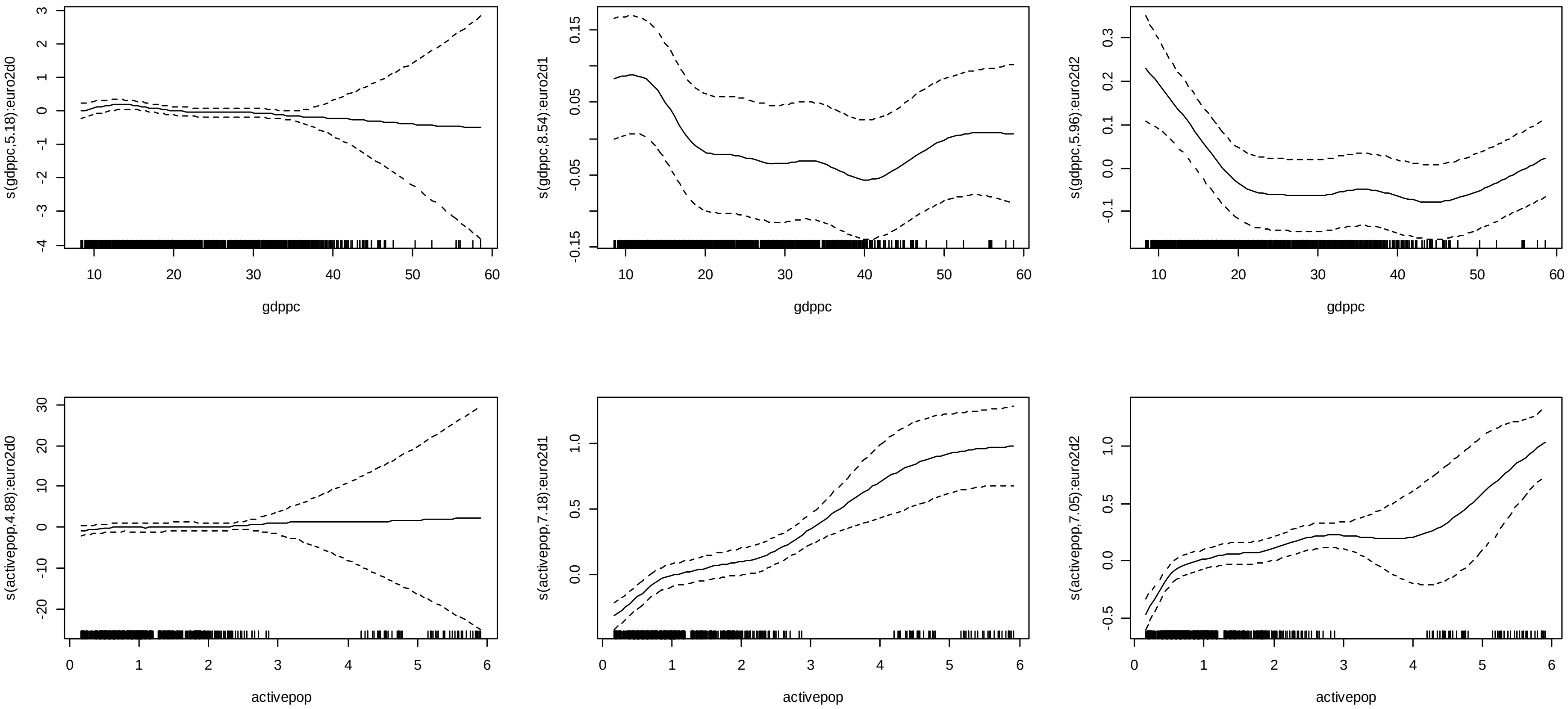


FIGURE 3b. Factor-by-continuous interaction (eq. (2)). Dep. Var.: KRUGMAN.

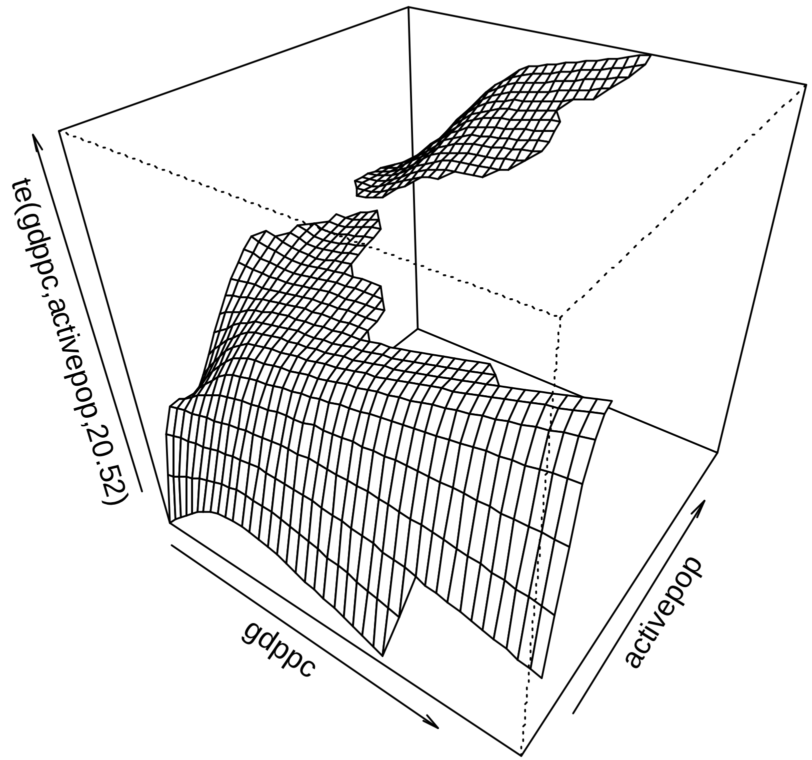


Figure 4a. Continuous-by-continuous interaction (eq. (3)). Dep. Var.: GINI.

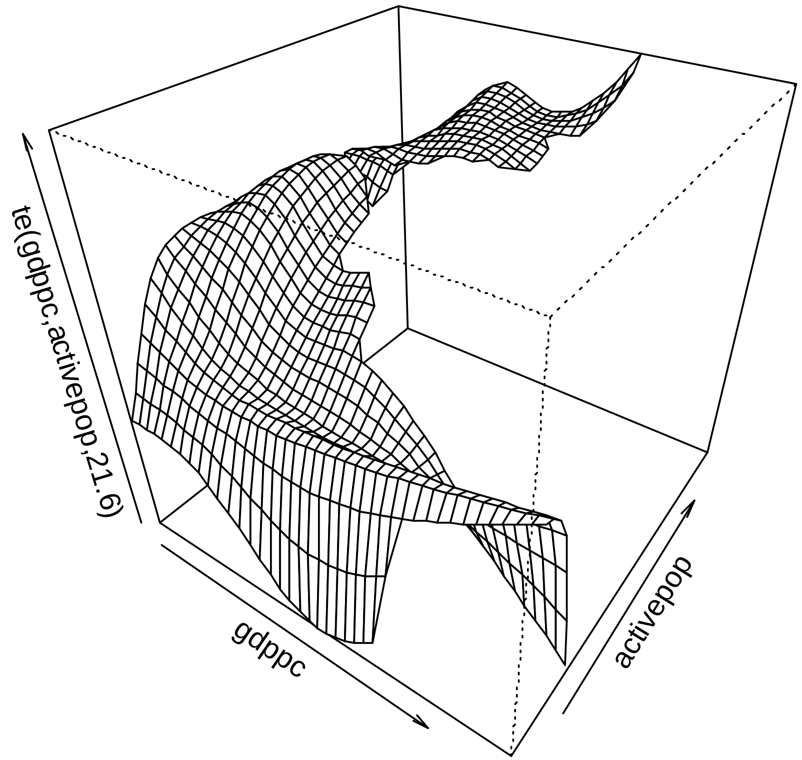
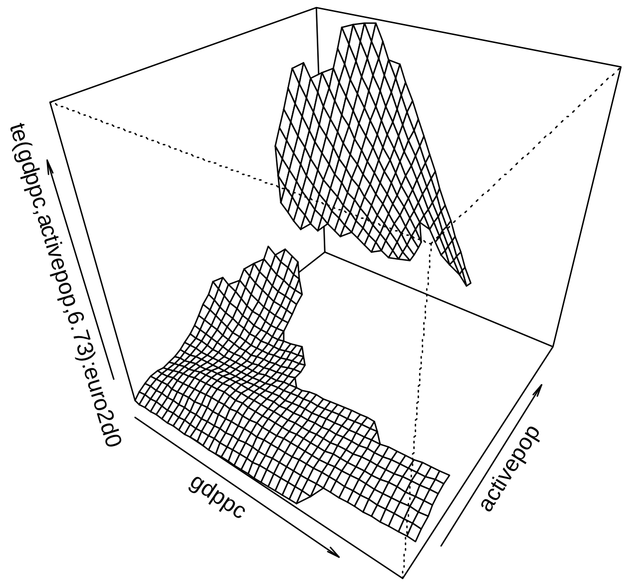


Figure 4b. Continuous-by-continuous interaction (eq. (3)). Dep. Var.: KRUGMAN.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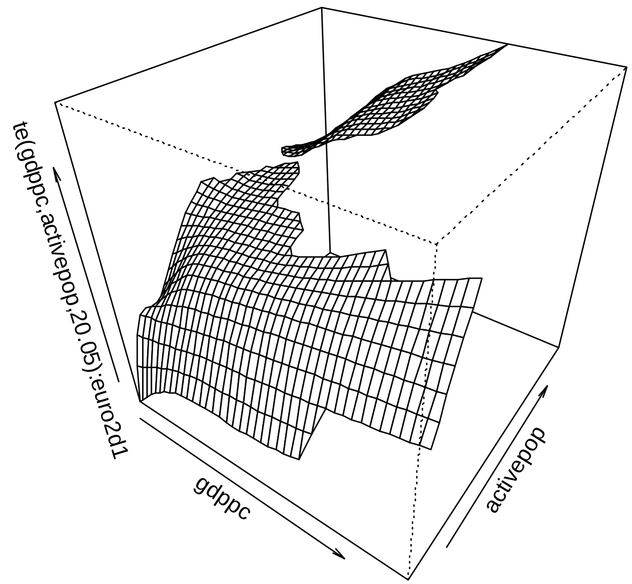
activepop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activepop

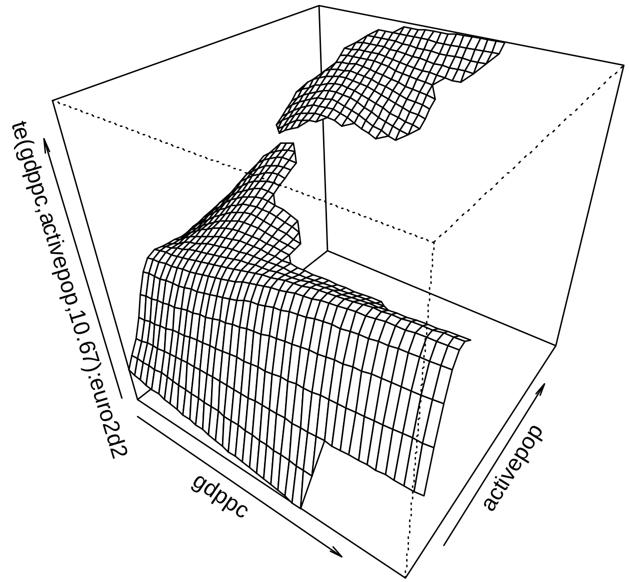
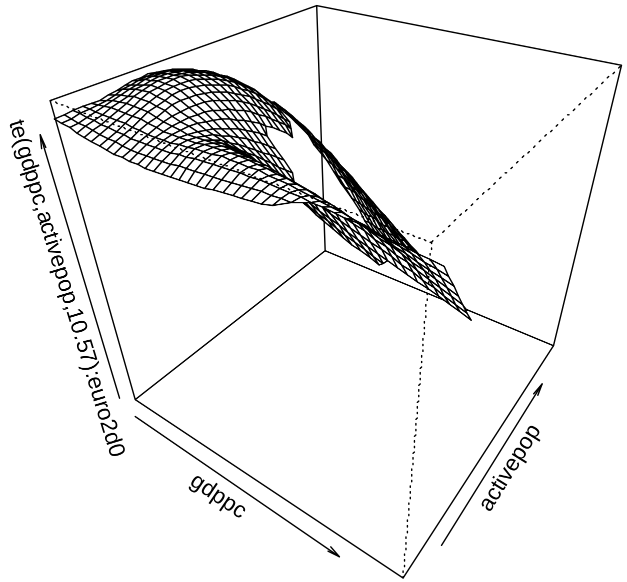


Figure 5a. "General" specification (eq. (4)). Dep. Var.: GINI. From left to right: outside EU, EU, EU&EURO.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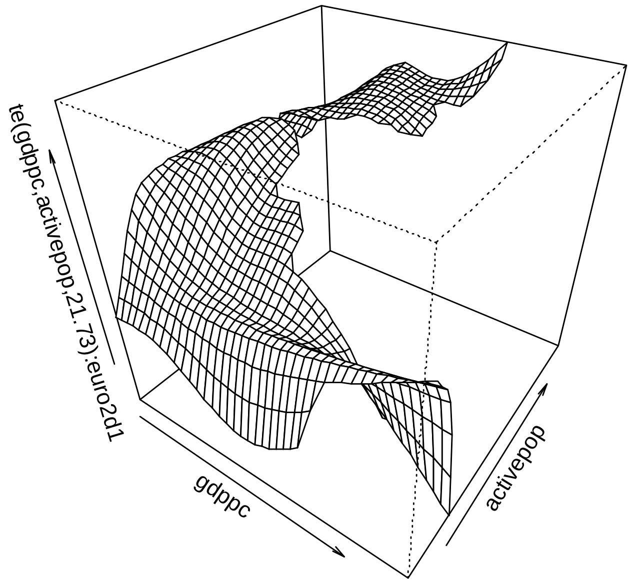
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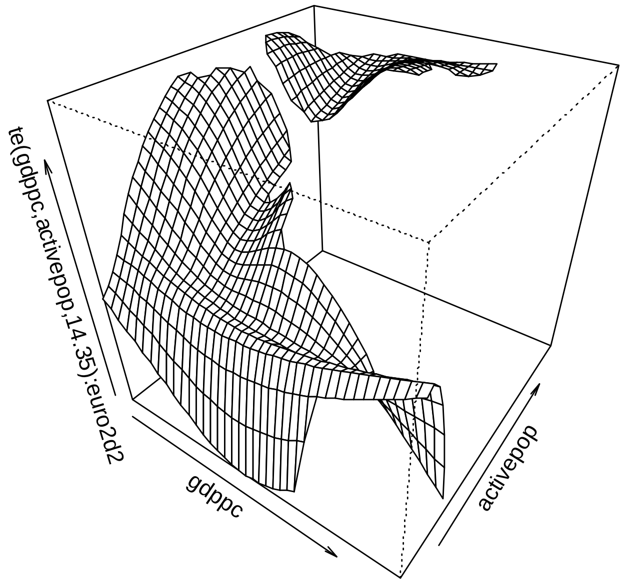

Figure 5b. "General" specification (eq. (4)). Dep. Var.: KRUGMAN. From left to right: outside EU, EU, EU&EURO.