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Lumpy Countries, Urbanization, and Trade

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Abstract

Lumpiness of production factors within a country might overturn the predictions for the structure of trade by the factor-abundance (HO) model. Trade patterns, as predicted by this model, can both be magnified or reversed by uneven concentration of production factors within a country. Cities are the most characteristic manifestation of lumpiness of production factors and as a consequence different patterns of urbanization between countries might cause trade patterns to differ from HO predictions on the basis of the overall availability of production factors. We argue that urbanization indeed affects trade patterns. The consequence of this result is that urbanization should be included in empirical trade analysis; urbanization could, e.g. to the understanding of the 'missing trade' puzzle.

JEL-Code: F110, F150, R120.

Keywords: Heckscher-Ohlin, factor endowments, agglomeration, geographical economics.

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1 Introduction

Empirical tests of the factor-abundance or Heckscher-Ohlin (HO) model are not very successful. Ever since Leontief (1956) discussed the paradox that bears his name it has been demonstrated time and again that empirical tests of the HO model are only marginally better than the toss of a coin (see Leamer, 1984, for a survey of the early literature). This state of affairs led to the conclusion that the HO model "does poorly, but we do not have anything that does better", see Bowen et al. (1987, p. 805). With the availability of better and more detailed data, the 1990s witnessed a revival of empirical work on the HO model. Trefler's (1995) 'mystery of missing trade', for example, has been particularly influential in this literature.[2]

The empirical literature has stressed two extensions of the basic model to increase the explanatory power of the HO model. First, one can allow for productivity differences between various countries. Second, consumption might not be homothetic.[3] The mystery of missing trade, for example, can to a large extent be explained by allowing for differences in technology between countries (Davis and Weinstein, 2001; see for surveys Feenstra, 2004, or Baldwin, 2008). A possible third explanation of the standard model that might add to the understanding of the empirical puzzles that the trade data present us, and which is traditionally disregarded in the literature, is lumpiness of production factors within a country. Within the HO framework, lumpiness, or the uneven distribution of production factors within a country, can affect the structure of trade flows in complex ways (Courant and Deardorff, 1992 and 1993). The indeterminateness of trade patterns, and the difficulty to find factor endowment data and trade flows on a disaggregated level within countries are the main reasons for the neglect of this explanation. This, however, does not imply that lumpiness is not an issue.

[2] The 'missing trade puzzle refers to the fact that the predicted factor content of net exports is smaller than the actual factor content, hence trade is 'missing'. In addition, two groups of countries could be identified: developing and developed countries. For poor countries the difference between actual and predicted factor content of net exports is negative, while for rich countries this is positive. This implies that poor countries are abundant in most factors of production, whereas rich countries are scarce in most factors of production.

[3] In the standard HO model countries have access to identical technology, and consume commodities in the same proportion.

The most apparent manifestation of regional clustering is the concentration of production factors in cities. If mobile factors of production are clustered in urban areas, the resulting international trade could magnify net trade beyond what is expected on the basis of the overall factor endowments within a country. A similar magnification is possible because of technological differences.[4] This paper addresses this issue in a modest way. It is mainly concerned to answer the empirical question if lumpiness could affect international trade flows. Evidence on lumpiness is relatively scarce. Some earlier studies show that lumpiness, using the so-called lens condition for regional data, is not a concern for Japan, the UK, and India (Debaere, 2004). Furthermore, Debaere and Demiroglu (2003) show that for the group of OECD countries the lens condition is not violated. For Mexico, regional lumpiness might be important (Bernard et al., 2010). A limitation of data availability concentrates the analysis on regions, but we argue that this is not the most natural spatial unit to measure lumpiness. Instead, local interaction mostly takes place in cities or between cities, and urban agglomerations are more natural units of measurement than regions (see also the remarks in the concluding section of Bernard et al., 2010). We therefore focus on urbanization as a reflection of lumpiness of production factors by using the lens condition, and compare these results to NUTS 1 and NUTS 2 regional aggregation levels. We find evidence that at the city level the lens condition is violated for all countries under consideration. At NUTS 1 and NUTS 2 we find violations for the Netherlands and to a lesser extent for France. These violations point towards an additional explanation of HO related empirical puzzles in international trade studies.

Section 2 discusses the theoretical links between the uneven distribution of factors of production (lumpiness) and international trade flows. Section 3 discusses the data used in our study for a selection of OECD countries. Section 4 presents the lens condition graphically for NUTS 1 and NUTS 2 levels of aggregation. Section 5 presents the data for the lens condition on an urban scale. We evaluate the results in section 6, and conclude in section 7.

[4] And as such both extensions of the standard HO model might add to our understanding of the missing trade puzzle.

2 Lumpiness and trade[5]

The relationships between urbanization and the potential effects on trade flows can best be explained by an Edgeworth-box (see Figure 1). We assume that the country under consideration is small, such that world prices are given. The figure – made popular by Dixit and Norman (1980) – depicts a perfectly integrated country, in which there are no distortions, two factors of production – skilled labor *S* and labor *L* - and two goods, *X* and *Y*, produced under constant returns to scale. The country consists of two regions, I and II. Moreover, consumer preferences are identical and homothetic. The (given) amount of labor is depicted on the horizontal axis, and the (given) amount of skilled labor along the vertical axis, where the use of endowments in area I is measured from the *O* origin and the use of endowments in area II is measured (upside down) from the O^* origin. If the endowments are distributed over the two areas, given world prices determine the production levels of goods *X* and *Y*, the country's income level, the demand for goods *X* and *Y*, and thus its internal trade flows (all welfare maximizing under standard circumstances).

Figure 1 The integrated equilibrium and lumpiness

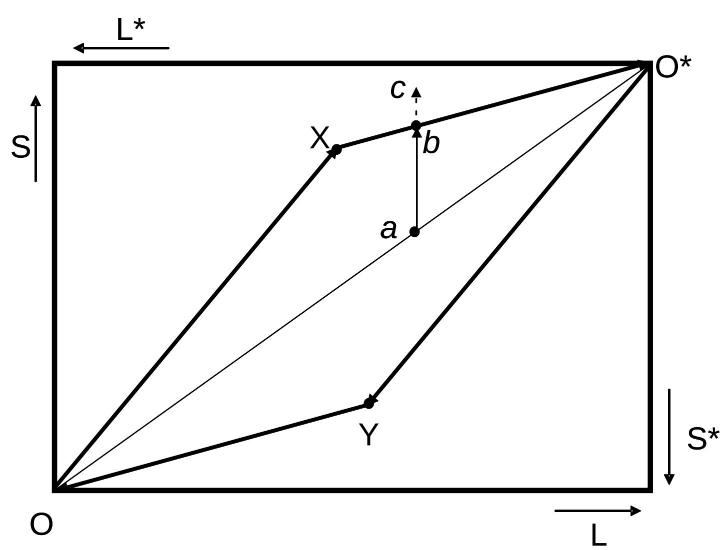


Figure 1 depicts the integrated equilibrium. Total supply in the integrated equilibrium is characterized by *OX* of good *X* and *OY* of good *Y* (with an appropriate unit of

[5] This section is based on Courant and Deardorff, 1992.

measurement). The slope of the vectors indicates that we have assumed that the production of good *X* is relatively skilled labor intensive. If we perform a vector summation on *OX* and *OY*, total factor use in both sectors is exactly equal to the total amount of available factors of production, *L* for labor, and *S* for skilled labor.

A question that can be answered using Figure 1 is: can the welfare maximizing integrated equilibrium be reproduced once the country is split into two separate regions with given factor endowments? The answer is: 'yes', as long as the distribution of production factors in a country is not too different, that is, within the factor price equalization (FPE) set; OXO*Y. For spatial distributions outside the FPE set the answer is 'no' (see Dixit and Norman, 1980 for a detailed explanation). Courant and Deardorff (1992) explicitly apply this analysis to lumpiness of production factors within a single country. Assume that the - autarkic - country in Figure I consists of two areas, *I* and *II*. Activity from area *I* is measured from *O*, and for area *II* from *O**. In *a* the two areas have identical relative endowments of skilled and unskilled labor, and total production of *X* and *Y* is simply divided over the two areas in the ratio *Oa/aO**, which indicates the size of area *I* relative to the size of area *II*. If we redistribute skilled and unskilled labor such that we follow the arrow starting in point *a*, production of *X* increases and *Y* decrease in area *I*, and the production of *X* decreases and *Y* increases in area *II*. These are standard Rybczynski effects in both areas. Along the arrow *ab* the integrated (within country) equilibrium can be reproduced and the redistribution of skilled and unskilled labor has no effect on the trade flows of this country with the outside world. The two areas within the country do trade with each other; the capital abundant area exporting the capital intensive good, and the labor abundant area exporting the labor intensive good. This is possible until one or both areas are completely specialized. As drawn, at point *b* area *I* still produces both *X* and *Y*, but area II is completely specialized in *Y*. The total amounts of both *X* and *Y* correspond to the integrated equilibrium. If we follow the arrow from the point of complete specialization, say, from *b* to *c*, the amount of *X* in *I* increases, but without the accompanying decrease of *X* in *II*. The amount of *Y* decreases in both countries. This is caused by the Rybczynski effect in *I* (given good prices), and a further reduction of the production of *Y* in *II,* which is specialized in *Y*. This unambiguously raises the supply of

X, and reduces that of *Y*. Independently of the initial export position of the country as a whole, this provides an incentive to export good *X* and import good *Y*, thus influencing the country's trade patterns. So, outside the FPE parallelogram *OXO*Y* the country's trade pattern is effected by the lumpy distribution of factors of production. Note that outside the FPE set trade patterns are difficult to establish. If we, for example move horizontally instead of vertically from *a* and apply similar reasoning as above, we create a tendency to start exporting good *Y*. These examples show that partial equilibrium reasoning already makes predictions about trade patterns complicated. Introducing a second country, in which lumpiness also matters, makes it even more difficult. The combination of lumpiness in both countries might strengthen predictions by the HO model or might go in the opposite direction if the relatively scarce factors are the lumpy factors.[6]

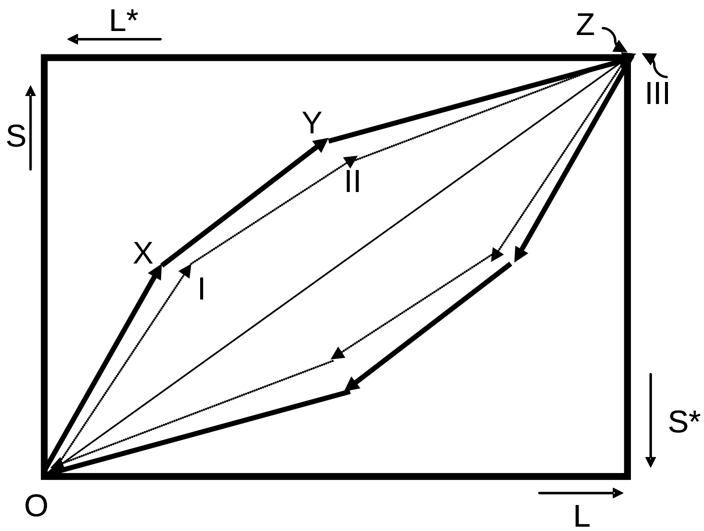
It is relatively easy to generalize Figure 1 into a country with many areas, and many goods/sectors in a two production factor world, giving rise to the so-called *lens condition* (Deardorff 1994, Debeare, 2004, Debeare and Demiroglu, 2003). We can rank factor intensities of all sectors according to decreasing skilled-labor/labor intensities above the diagonal (and vice versa below the diagonal) and concatenate the corresponding vectors of factor intensity. Following a similar procedure we can concatenate the vectors of relative factor endowments in each area. If the line of relative factor intensities in the sectors encloses the line of relative regional factor endowments, the integrated equilibrium can be reproduced. This is called the lens condition because if we introduce a large number of goods and areas the two lines look like lenses.[7] Figure 2, illustrates the condition for a three goods (*X*, *Y*, and *Z*) three region (*I*, *II*, and *III*) example. In panel 2a the *lens condition is satisfied*: the area of the *factor endowment lens* is a *subset* of the (factor use) *goods lens*, indicating that the empirical distribution of the factors of production across the various areas within the country does not influence the country's overall trading position. In panel 2b the *lens condition is violated*: the area of the factor

[6] Combinations are also possible. In cases where the two autarkic and lumpy countries have an excess supply in the same good, the relative excess supply determines the trade pattern (see Courant and Deardorff, 1992, for an extensive discussion).

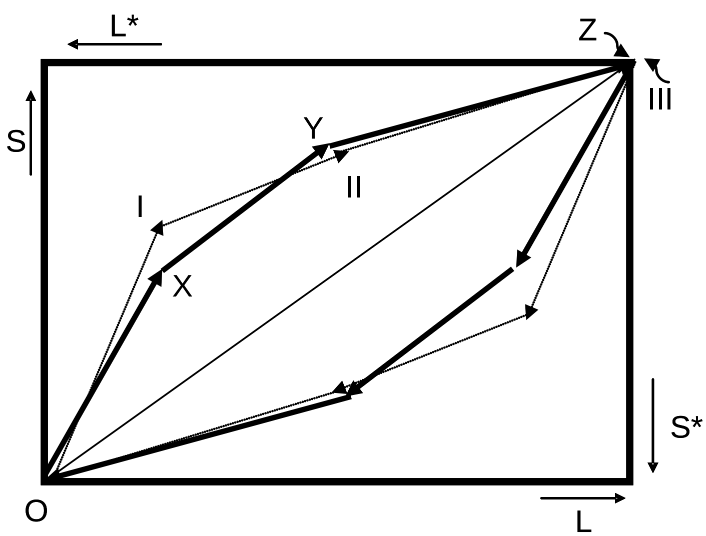
[7] See Debeare and Demiroglu, (2003) for a more detailed discussion of the lens condition.

endowment lens is *not* a subset of the goods lens, indicating that the empirical distribution of the factors of production across the various areas within the country *does* influence the country's overall trading position.

Figure 2 The lens condition



2a lens condition satisfied



2b lens condition violated

Empirical evidence provided by Debaere (2004), who uses the lens condition on regional data for India, Japan, and the UK, indicates that lumpiness is not an issue at the regional level as the lens condition is not violated. Bernard et al. (2005), however, criticize the lens condition for being subject to aggregation problems.[8] Central in their argument is that the size of both the goods lens and the factor endowment lens is sensitive to the level of aggregation. Lenses that are constructed using more disaggregate data are larger than lenses with more aggregate data. This is immediately clear by inspecting Figure 2. Suppose, for example, that the goods vector *OX* is further disaggregated into two commodities that together use *OX*, one of these will use more skill intensive production methods, whereas the other uses less skill intensive production methods compared to *OX*.[9] This implies that the goods lens in the more disaggregate cases will enclose the aggregate cases. The same holds for the factor endowment lens. Because theory does not guide us with regard to the optimal level of (dis)aggregation of both goods and regions, tests of the lens condition are subject to these biases.[10]

To date, empirical evidence regarding the lens condition uses the *region* as the relevant geographical scale. Regions, however, are often the result of *ad hoc* spatial differentiations that are made for administrative and not necessarily economic reasons. Also, regions themselves consist of (smaller) areas with different factor endowment densities. They are home to both highly dense agglomerations like cities, or rural areas with very different (relative) factor endowments. Using regions as the smallest unit of observation implies that within-region differences in production factor lumpiness are smoothed and that potential violations of the lens condition (which affect trade patterns) are not revealed in the analyses. Debaere (2004, p. 498), however, notes that a too disaggregated level of analysis, for example at the county level, might result in spurious violations of the lens condition. This discussion, on the most relevant unit of observation, refers to the so-called modifiable areal unit problem or MAUP. The problem is relevant because a unit of observation should reflect economic appropriate concentrations of production factors. As, for example, is noted by ESPON (2006) standard spatial aggregation levels such as NUTS 1-3, produce 'noise' in the sense that these spatial

[8] The criticism refers to, for example, Wong and Yun (2003).
[9] In the – unlikely – case that both disaggregated goods use the same factor intensities as the combined vector *OX*, the lens is exactly the same.
[10] The skilled wage rates across Mexican regions are negatively correlated with the distribution of relative factor endowments – lumpiness of production factors across Mexico thus affects the trade outcome relative to the implied trade caused by the overall distribution of production factors; see Bernard et al (2010).

measures do not reflect homogeneous levels of activity and ‘produce confusion and errors of interpretation because of scale confusion (p. 134); different geographical objects are sometimes mixed in the same territorial units and sometimes isolated in separate units.’ In our case lumpiness should reflect economic relevant concentrations of production factors – such as urban agglomerations – and not units of observation that smooth these potentially important differences (see also Briant et al., 2008). In *Reshaping Economic Geography* The World Bank (2009) stresses the importance of cities in economic development, and shows that density in cities and proximity is beneficial to both firms and consumers. In early stages of development the rural-urban development (income) gap is large, whereas in more advanced stages of developments the rural-urban disparities narrow (World Bank, 2009, p. 62-64). What is also highlighted and summarized in the World Bank report are the differences in specialization between urban and rural areas within countries: most migration of capital and labor take place within a country leading to large (urban) agglomerations. Also continues measures, rather than administrative definitions of agglomerations also show that urban concentration is related to urbanization (see, for example, empirical results in Duranton and Overman, 2005). The urban-rural divide is more telling for an economy than differences that take the region as a unit of measurement. So, urban agglomerations versus non-urban areas provide a more meaningful unit of measurement of lumpiness than factor differences between regions. The relevance of urban agglomerations as opposed to regions as relevant units of observations is also pointed out by Bernard et al. (2010) in the concluding section of the Mexico study, but to our knowledge has not been performed.

Urbanization is one of the more obvious determinants of production factor lumpiness (World Bank, 2009). In Courant and Deardorff (1993), the link between urbanization and lumpiness is explicitly analyzed. Within countries one might assume that factor mobility is larger than between countries resulting in factor price equalization. Still, also in this setting the analysis of lumpiness is only valid outside the FPE set. The question then becomes what causes prolonged factor price differences in situations with (some) factor mobility between areas within a country. One reason, noted by Courant and Deardorff (1993) and illustrated by the World Bank (2009), is related to differences in the level of amenities between locations, which may lead to differences in factor prices. Factor mobility equates utilities between locations, and not necessarily factor incomes. So, factor rewards of specific mobile factors of production can be lower in certain areas compared to others, because they are compensated by local amenities.

Given the discussion so far we can proceed in two different directions. First, the importance of lumpiness can be shown by linking (urban) agglomerations of production factors to (urban) trade patterns, most importantly including within country trade flows (see figure 2). However, trade flows at this level of disaggregation are not available. Second, we can try to find evidence of lumpiness and analyze violations of the lens condition using urban data (in contrast to regional data). If the lens condition is violated lumpiness is a concern for observed trade flows.[11] Given data availability we focus on this second, more modest, contribution. We include both regional lenses as well as lenses that correspond to urbanization. This enables us to confront the findings in the earlier literature, that uses regional data, with our data on cities.

3 Data

In order to construct the lenses we need data on factor intensities for goods or sectors, and factor endowment data for the spatial units we distinguish. To put the city lens condition into perspective we first use two regional datasets for NUTS1 and NUTS2 for the six countries under consideration: France, Italy, Netherlands, Portugal, Sweden, and Germany. Table 1a and 1b give the normalized skill endowments for NUTS1 and NUTS2, respectively, and table 2 for cities.

[11] The implication for trade patterns is: the more a mobile production factor is concentrated, the more likely it becomes that a country exports the good that relatively intensely uses this production factor. Note, that it is relative lumpiness that matters. The country with the most lumpy distribution will export this particular commodity (Courant and Deardorff, 1992).

Table 1a. NUTS 1 regional labor skill endowments (total endowment = 1)

	Labor skills	
Germany	High	Other
Baden-Württemberg	0.145	0.125
Bayern	0.160	0.151
Berlin	0.060	0.039
Brandenburg	0.037	0.030
Bremen	0.007	0.008
Hamburg	0.025	0.022
Hessen	0.077	0.074
Mecklenburg-Vorpommern	0.021	0.021
Niedersachsen	0.078	0.100
Nordrhein-Westfalen	0.189	0.226
Rheinland-Pfalz	0.043	0.051
Saarland	0.009	0.014
Sachsen	0.062	0.047
Sachsen-Anhalt	0.027	0.030
Schleswig-Holstein	0.029	0.035
Thüringen	0.030	0.028
Sweden	High	Other
Östra Sverige	0.437	0.367
Södra Sverige	0.413	0.439
Norra Sverige	0.149	0.194

	Labor skills	
France	High	Other
Île de France	0.271	0.165
Bassin Parisien	0.133	0.185
Nord - Pas-de-Calais	0.055	0.067
Est (FR)	0.075	0.091
Ouest (FR)	0.121	0.138
Sud-Ouest (FR)	0.114	0.106
Centre-Est (FR)	0.119	0.120
Méditerranée	0.112	0.127
Italy	High	Other
Nord-Ovest	0.283	0.266
Nord-Est	0.191	0.194
Centro (IT)	0.231	0.192
Sud	0.202	0.236
Isole	0.093	0.113
Netherlands	High	Other
Noord-Nederland	0.084	0.110
Oost-Nederland	0.193	0.217
West-Nederland	0.529	0.445
Zuid-Nederland	0.194	0.228
Portugal	High	Other
Continente	1.000	1.000

Table 1b. NUTS 2 regional labor skill endowments (total endowment = 1)

France	Labor skills	
	High	Other
Île de France	0.271	0.165
Champagne-Ardenne	0.015	0.024
Picardie	0.023	0.034
Haute-Normandie	0.020	0.033
Centre (FR)	0.034	0.043
Basse-Normandie	0.020	0.024
Bourgogne	0.022	0.028
Nord - Pas-de-Calais	0.055	0.067
Lorraine	0.029	0.042
Alsace	0.031	0.030
Franche-Comté	0.015	0.020
Pays de la Loire	0.051	0.057
Bretagne	0.049	0.050
Poitou-Charentes	0.020	0.031
Aquitaine	0.049	0.052
Midi-Pyrénées	0.055	0.042
Limousin	0.011	0.012
Rhône-Alpes	0.098	0.098
Auvergne	0.021	0.022
Languedoc-Roussillon	0.037	0.042
Prov.-Alpes-Côte d'Azur	0.072	0.079
Corse	0.003	0.006

Netherlands	High	Other
Groningen	0.032	0.035
Friesland (NL)	0.030	0.042
Drenthe	0.022	0.033
Overijssel	0.057	0.071
Gelderland	0.116	0.121
Flevoland	0.020	0.025
Utrecht	0.096	0.062
Noord-Holland	0.200	0.148
Zuid-Holland	0.215	0.210
Zeeland	0.017	0.025
Noord-Brabant	0.137	0.154
Limburg (NL)	0.057	0.074

Italy	Labor skills	
	High	Other
Piemonte	0.070	0.075
Valle d'Aosta/Vallée d'Aoste	0.002	0.002
Liguria	0.034	0.025
Lombardia	0.177	0.164
Pr Aut Bolzano/Bozen	0.006	0.008
Provincia Autonoma Trento	0.009	0.009
Veneto	0.075	0.085
Friuli-Venezia Giulia	0.018	0.021
Emilia-Romagna	0.082	0.071
Toscana	0.063	0.062
Umbria	0.016	0.014
Marche	0.027	0.026
Lazio	0.125	0.090
Abruzzo	0.025	0.022
Molise	0.005	0.005
Campania	0.081	0.097
Puglia	0.052	0.069
Basilicata	0.008	0.010
Calabria	0.031	0.033
Sicilia	0.070	0.083
Sardegna	0.023	0.030

Portugal	High	Other
Norte	0.318	0.385
Algarve	0.040	0.042
Centro (PT)	0.174	0.239
Lisboa	0.411	0.260
Alentejo	0.057	0.074

Sweden	High	Other
Stockholm	0.286	0.196
Östra Mellansverige	0.151	0.171
Småland med öarna	0.067	0.092
Sydsverige	0.155	0.143
Västsverige	0.192	0.203
Norra Mellansverige	0.066	0.097
Mellersta Norrland	0.034	0.041
Övre Norrland	0.049	0.056

Table 1b. continued

Germany	Labor skills High	Other	*Germany*	Labor skills High	Other
Stuttgart	0.056	0.046	Mecklenburg-Vorpommern	0.021	0.021
Karlsruhe	0.037	0.032	Braunschweig	0.016	0.021
Freiburg	0.027	0.026	Hannover	0.024	0.026
Tübingen	0.024	0.021	Lüneburg	0.016	0.022
Oberbayern	0.068	0.049	Weser-Ems	0.023	0.031
Niederbayern	0.012	0.015	Düsseldorf	0.055	0.066
Oberpfalz	0.011	0.014	Köln	0.056	0.053
Oberfranken	0.012	0.013	Münster	0.025	0.033
Mittelfranken	0.021	0.021	Detmold	0.019	0.026
Unterfranken	0.016	0.016	Arnsberg	0.034	0.048
Schwaben	0.019	0.022	Koblenz	0.013	0.019
Berlin	0.060	0.039	Trier	0.006	0.006
Brandenburg - Nordost	0.016	0.014	Rheinhessen-Pfalz	0.024	0.025
Brandenburg - Südwest	0.021	0.016	Saarland	0.009	0.014
Bremen	0.007	0.008	Chemnitz	0.021	0.018
Hamburg	0.025	0.022	Dresden	0.025	0.018
Darmstadt	0.052	0.046	Leipzig	0.016	0.011
Gießen	0.012	0.013	Sachsen-Anhalt	0.027	0.030
Kassel	0.013	0.015	Schleswig-Holstein	0.029	0.035
			Thüringen	0.030	0.028

Source: European Commission - Eurostat - Regions and cities - Regional statistics - data – database, accessed; September 2011.[12]

Urbanization data are also extracted from the Eurostat key indicators (6 August 2010); high-skilled labor refers to ISCED 5 or 6; non-high skilled labor is taken to be ISCED 1 or 2 plus other labor. Selected countries are based on (urban) data availability. Total factor availability is normalized to one (if 2003-2007 data is missing, 1999-2002 data is used instead). Factors not allocated to a specific city are aggregated to a residual 'regional' category.[13] Table 2 provides an overview of the factor endowments for six European countries and their (urban) areas, namely Germany (40 areas), Italy (28 areas), France (24 areas), The Netherlands (16 areas), Portugal (10 areas), and Sweden (9 areas).

[12] See, http://epp.eurostat.ec.europa.eu/portal/page/portal/region_cities/regional_statistics/data/database

[13] The residual area consists of –potentially- many cities, hence the term 'region'. For data description see: http://epp.eurostat.ec.europa.eu/portal/page/portal/region_cities/introduction

The Groningen Growth and Development Center database provides international comparisons of inputs, outputs, and productivity at the sector level, see Inklaar and Timmer (2008).[14] This source distinguishes between high-skilled labor and non-high skilled labor for sectors at different levels of aggregation. For our purposes, the highest level of disaggregation is 18 different sectors. At higher levels of disaggregation the database uses the factor intensity ratios at lower levels of disaggregation to create the ratios at lower levels (missing observations are corrected in this way). This implies that at lower levels, some sectors have the same high-skilled labor versus other labor intensity as the more aggregated sectors, see Appendix I.[15] Table 3 provides an overview of the sector factor use in the six countries under consideration. It is important to note that we use the highest level of disaggregation for sectors; this enlarges the good lens, making violations of the lens condition more challenging.

[14] See for a detailed description of the data: http://www.ggdc.nl/databases/levels.htm We used the 1997 benchmark estimates as they are more reliable than the updated version.

[15] More disaggregation detail is provided in some other dimensions, such as capital compensation.

Table 2 Urban and regional labor skill endowments (total endowment =1)

	Labor skills			Labor skills	
France	High	Other	*Italy*	High	Other
FRA-region	0.745	0.841	ITA-region	0.711	0.829
Lens - Liévin	0.002	0.004	Cagliari	0.005	0.003
Marseille	0.017	0.016	Sassari	0.003	0.002
Aix-en-Provence	0.008	0.005	Reggio di Calabria	0.004	0.003
Tours	0.005	0.004	Catanzaro	0.002	0.002
Toulon	0.006	0.006	Potenza	0.002	0.001
Cayenne	0.001	0.002	Taranto	0.003	0.004
Fort-de-France	0.002	0.003	Caserta	0.003	0.001
Pointe-a-Pitre	0.001	0.001	Campobasso	0.001	0.001
Saint Denis	0.002	0.003	Pescara	0.004	0.002
Ajaccio	0.001	0.001	L'Aquila	0.002	0.001
Besançon	0.004	0.003	Ancona	0.003	0.002
Limoges	0.004	0.003	Perugia	0.005	0.002
Orléans	0.005	0.004	Trieste	0.005	0.003
Reims	0.004	0.003	Trento	0.003	0.002
Nancy	0.006	0.004	Cremona	0.002	0.001
Le Havre	0.003	0.004	Verona	0.006	0.004
Saint-Etienne	0.005	0.006	Venezia	0.006	0.004
Lille	0.021	0.017	Catania	0.006	0.005
Nantes	0.013	0.009	Bologna	0.013	0.005
Bordeaux	0.016	0.010	Bari	0.008	0.005
Toulouse	0.019	0.009	Firenze	0.011	0.005
Lyon	0.028	0.017	Genova	0.014	0.009
Paris	0.081	0.023	Palermo	0.013	0.012
Portugal	High	Other	Torino	0.020	0.014
PRT-REGION	0.476	0.742	Napoli	0.022	0.017
Faro	0.009	0.006	Milano	0.045	0.019
Aveiro	0.012	0.007	Roma	0.078	0.041
Ponta Delgada	0.007	0.007	*Netherlands*	High	Other
Setúbal	0.016	0.012	NLD-region	0.688	0.781
Coimbra	0.033	0.013	Leeuwarden	0.006	0.006
Funchal	0.013	0.010	Apeldoorn	0.009	0.010
Braga	0.025	0.017	Nijmegen	0.016	0.008
porto	0.054	0.021	Breda	0.013	0.009
Kernel Lisboa	0.354	0.166	Almere	0.010	0.011
Sweden	High	Other	Heerlen	0.004	0.006
SWE-REGION	0.492	0.682	Arnhem	0.011	0.009
Örebro	0.018	0.015	Enschede	0.009	0.010
Linköping	0.025	0.015	Groningen	0.018	0.010
Uppsala	0.040	0.019	Tilburg	0.013	0.012
Umeå	0.023	0.012	Eindhoven	0.016	0.012
Jönköping	0.015	0.014	Utrecht	0.032	0.013
Malmö	0.040	0.032	Rotterdam	0.036	0.038
Göteborg	0.086	0.055	Amsterdam	0.083	0.038
Kernel Stockholm	0.261	0.156	s' Gravenhage	0.035	0.027

Table 2 continued

	Labor skills			Labor skills	
Germany	High	Other		High	Other
DEU-region	0.737	0.788	Göttingen	0.001	0.002
Koblenz	0.001	0.001	Wiesbaden	0.004	0.003
Potsdam	0.003	0.002	Magdeburg	0.004	0.003
Saarbrucken	0.001	0.002	Halle an der Saale	0.004	0.003
Kiel	0.003	0.003	Bielefeld	0.004	0.004
Mainz	0.003	0.002	Bochum	0.004	0.005
Mönchengladbach	0.003	0.003	Nürnberg	0.006	0.006
Karlsruhe	0.005	0.003	Hannover	0.008	0.006
Bonn	0.005	0.004	Bremen	0.006	0.007
Augsburg	0.003	0.003	Düsseldorf	0.008	0.007
Erfurt	0.004	0.002	Dortmund	0.005	0.008
Schwerin	0.002	0.001	Dresden	0.011	0.005
Weimar	0.001	0.001	Leipzig	0.010	0.005
Frankfurt (Oder)	0.001	0.001	Stuttgart	0.009	0.007
Regensburg	0.002	0.002	Essen	0.006	0.007
Freiburg im Breisgau	0.003	0.003	Frankfurt am Main	0.011	0.008
Trier	0.001	0.001	Köln	0.013	0.012
Darmstadt	0.003	0.002	München	0.022	0.015
Moers	0.001	0.001	Hamburg	0.021	0.022
Mülheim a.d. Ruhr	0.002	0.002	Berlin	0.060	0.040

Two issues need attention before we present the analysis. First, we focus on two factors of production: high-skilled labor and 'other' labor. Obviously, more factors of production can be distinguished in reality. What does this restriction to two factors of production (based on data limitations) imply if we find support or violations of the lens condition? Demiroglu and Yun (1999), show that the lens condition for two factors of production is a necessary, but not a sufficient condition for FPE. A violation of the lens condition – for any combination of two factors of production – therefore indicates that FPE does not hold. In contrast, when the lens condition is satisfied, we cannot yet conclude that FPE holds in a multi-sector world. Second, how does the level of aggregation affect the analysis? As discussed above and noted by Bernard et al (2005), higher levels of disaggregation (either along the goods dimension or along the urban dimension) increases the size of the lenses, which raises the question what the appropriate level of disaggregation is. As argued above, we opt for the urban level (to the extent available) coupled with the most detailed level of sector disaggregation available. This makes the goods lens as large as possible, which *a priori* reduces the likelihood of lens violations.

Table 3 Sector factor use (total endowment =1)

High skilled labor	ESP	FRA	GER	ITA	NLD	PRT	SWE
Electrical and optical equipment	0.016	0.026	0.050	0.027	0.019	0.012	0.040
Post and telecommunications	0.023	0.013	0.016	0.012	0.012	0.018	0.011
Consumer manufacturing	0.048	0.033	0.027	0.058	0.037	0.067	0.033
Intermediate manufacturing	0.092	0.085	0.122	0.106	0.066	0.061	0.102
Investment goods, excluding hightech	0.038	0.042	0.097	0.052	0.025	0.019	0.074
Mining and quarrying	0.004	0.002	0.006	0.001	0.002	0.003	0.002
Electricity, gas and water supply	0.010	0.012	0.015	0.007	0.005	0.010	0.008
Construction	0.101	0.047	0.093	0.077	0.079	0.136	0.059
Agriculture, hunting, forestry & fishing	0.024	0.028	0.019	0.023	0.030	0.014	0.021
Trade	0.090	0.116	0.106	0.121	0.148	0.117	0.129
Transport and storage	0.034	0.034	0.032	0.045	0.069	0.041	0.047
Financial intermediation	0.046	0.054	0.039	0.046	0.044	0.065	0.048
Renting and other business activities	0.119	0.198	0.113	0.125	0.134	0.098	0.138
Hotels and restaurants	0.063	0.028	0.019	0.034	0.024	0.028	0.019
Other community, soc. & pers. services	0.028	0.026	0.037	0.035	0.048	0.013	0.043
Private househ. with employed persons	0.013	0.007	0.004	0.015	0.007	0.006	0.000
Public admin, education and health	0.237	0.234	0.193	0.208	0.239	0.284	0.203
Real estate activities	0.016	0.015	0.014	0.007	0.011	0.008	0.023
Other labor	ESP	FRA	GER	ITA	NLD	PRT	SWE
Electrical and optical equipment	0.016	0.021	0.037	0.022	0.018	0.015	0.028
Post and telecommunications	0.016	0.022	0.017	0.017	0.015	0.018	0.019
Consumer manufacturing	0.059	0.042	0.041	0.071	0.047	0.080	0.032
Intermediate manufacturing	0.093	0.076	0.105	0.091	0.075	0.073	0.093
Investment goods, excluding hightech	0.038	0.034	0.072	0.042	0.023	0.022	0.052
Mining and quarrying	0.005	0.002	0.006	0.002	0.003	0.004	0.003
Electricity, gas and water supply	0.011	0.012	0.014	0.012	0.008	0.012	0.010
Construction	0.085	0.062	0.070	0.055	0.068	0.066	0.056
Agriculture, hunting, forestry & fishing	0.040	0.043	0.019	0.041	0.040	0.090	0.029
Trade	0.124	0.120	0.146	0.153	0.148	0.147	0.127
Transport and storage	0.044	0.047	0.041	0.063	0.046	0.041	0.057
Financial intermediation	0.046	0.045	0.047	0.050	0.055	0.051	0.026
Renting of and other business activities	0.063	0.114	0.071	0.068	0.147	0.047	0.085
Hotels and restaurants	0.087	0.029	0.026	0.043	0.024	0.035	0.018
Other community, soc. & pers. services	0.035	0.031	0.043	0.031	0.043	0.030	0.056
Private househ. with employed persons	0.016	0.008	0.005	0.014	0.006	0.013	0.000
Public admin, education and health	0.213	0.283	0.231	0.222	0.220	0.252	0.294
Real estate activities	0.008	0.009	0.009	0.004	0.012	0.004	0.014

4 Region Lens condition

Based on the data presented in section 3 we can construct the lenses. We focus on a selection of OECD countries (France, Germany, Italy, Netherlands, Portugal, Spain, and Sweden) using regional data (and city data in section 5). We focus on these countries as Debaere and Demiroglu (2003) show that the OECD countries as a group are in the same cone of diversification at the country level of aggregation. The OECD group of countries is homogeneous in this respect; factor endowments are not too different to interfere with lumpiness (see also the discussion in Debaere, 2004, p. 496). The construction is carried out as follows. For the goods (sector) lens we need factor intensity data for each sector, both for high-skilled and other labor. The summation across factors, and across cities equals the total amount of that particular factor in a country. In order to facilitate comparison between countries we normalize factors. Next, we rank sectors, and cities according to their factor use (decreasing order of high-skilled / other labor) and concatenate the resulting vectors.

At both levels we find violations for France and the Netherlands: in figure 3a for NUTS1 and in Figure 3b for NUTS2. The other countries satisfy the lens condition for these factors of production. Closer inspection of the data reveals that for France the *Ile de France* (essentially Paris) and for The Netherlands the so-called *Randstad* (essentially the three large cities in the western part of The Netherlands) are responsible for these violations. This illustrates that regions are an ambiguous concept as far as lumpiness is concerned. We know from Demiroglu and Yun (1999) that for Germany, Italy, Portugal and Sweden we cannot conclude that the lens condition is satisfied because in a multi-factor world we have to check for all possible combinations of factor uses; Figure 3 is necessary but not sufficient for these four countries. The NUTS 1 and NUTS 2 violations for France and The Netherlands are caused by special regions whose spatial definitions are already close to cities. We now turn to city evidence.

Figure 3a Lens condition at NUTS 1 level; violated for France and Netherlands

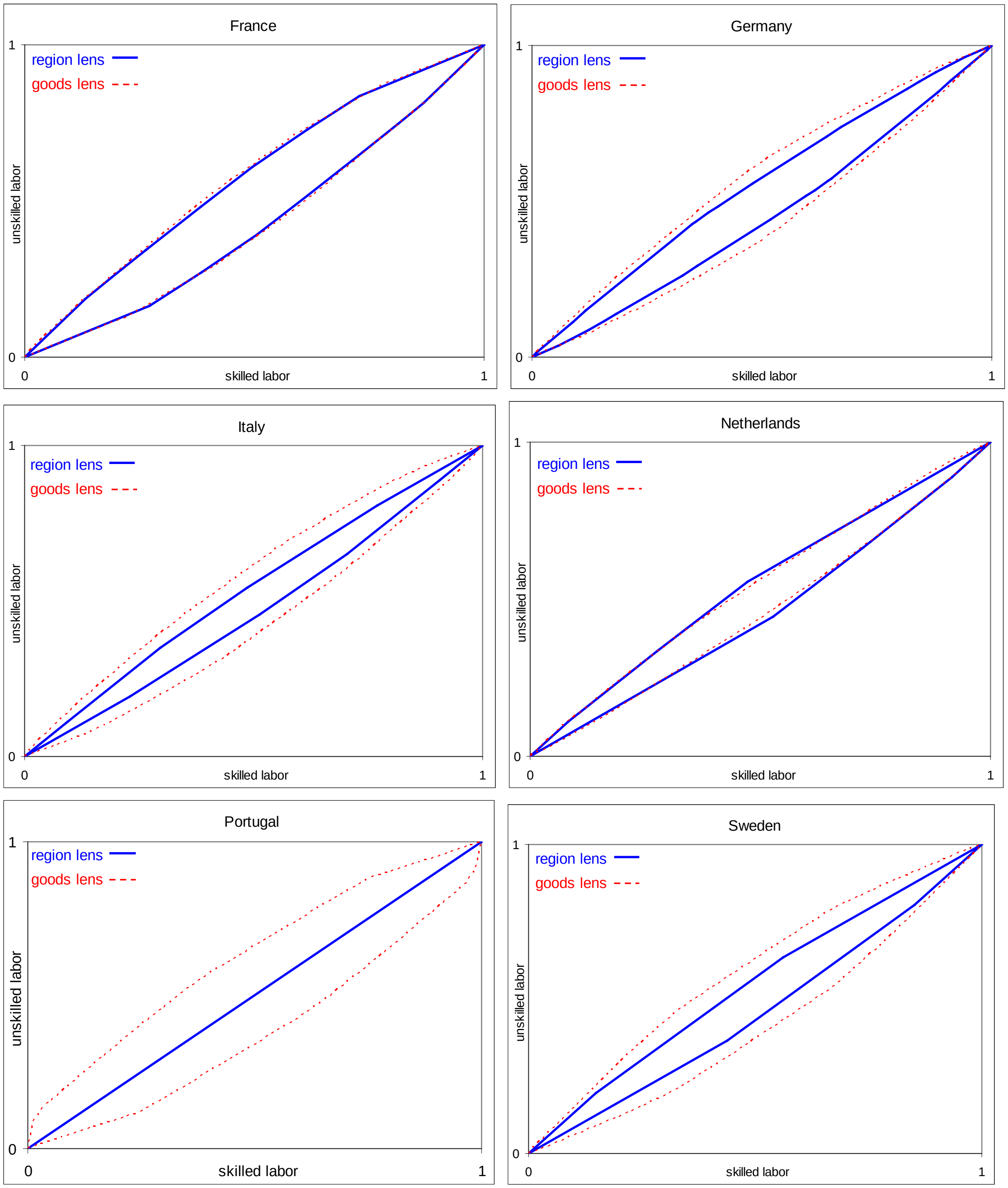
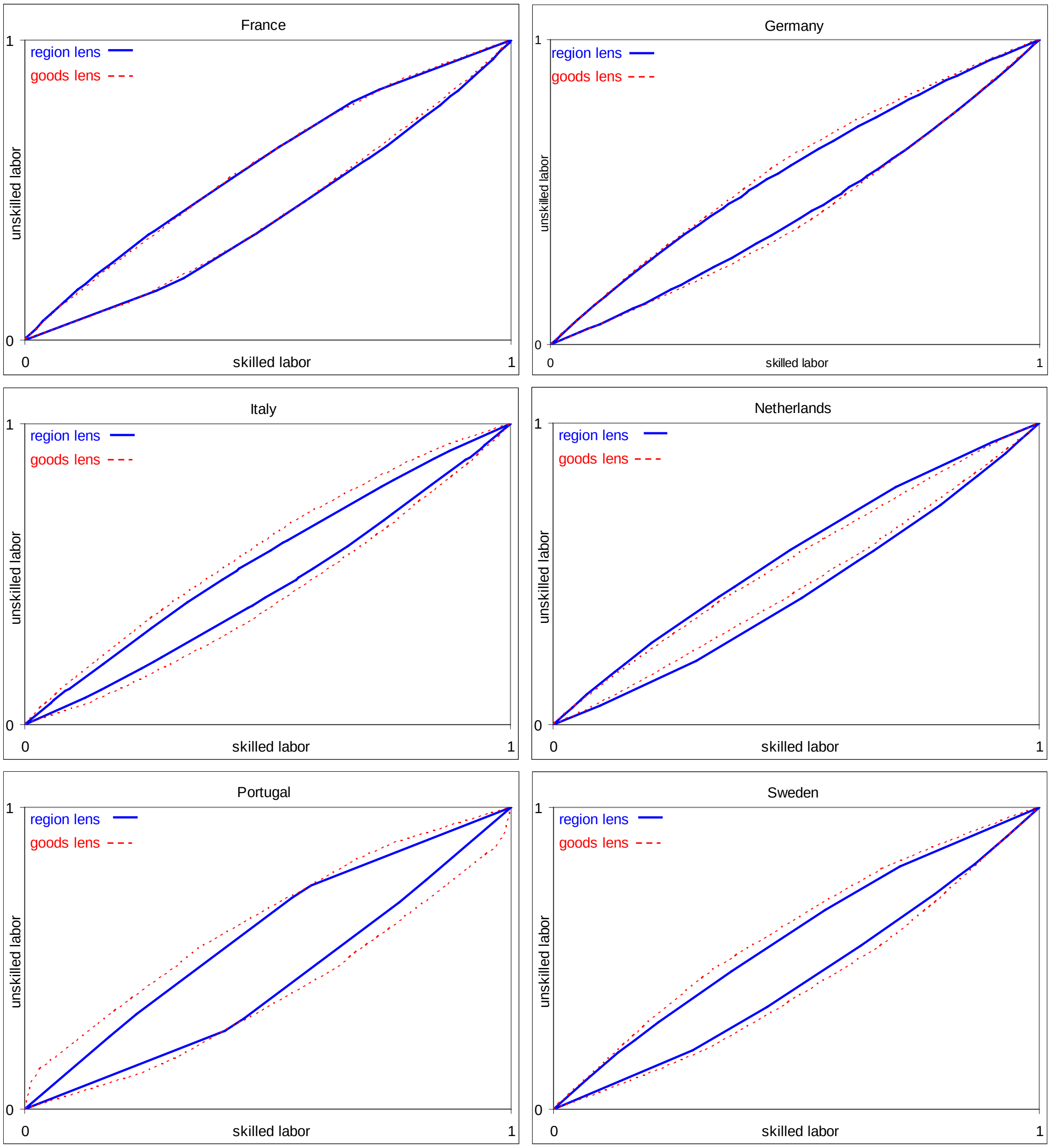


Figure 3b Lens condition at NUTS 2 level; violated for France and Netherlands



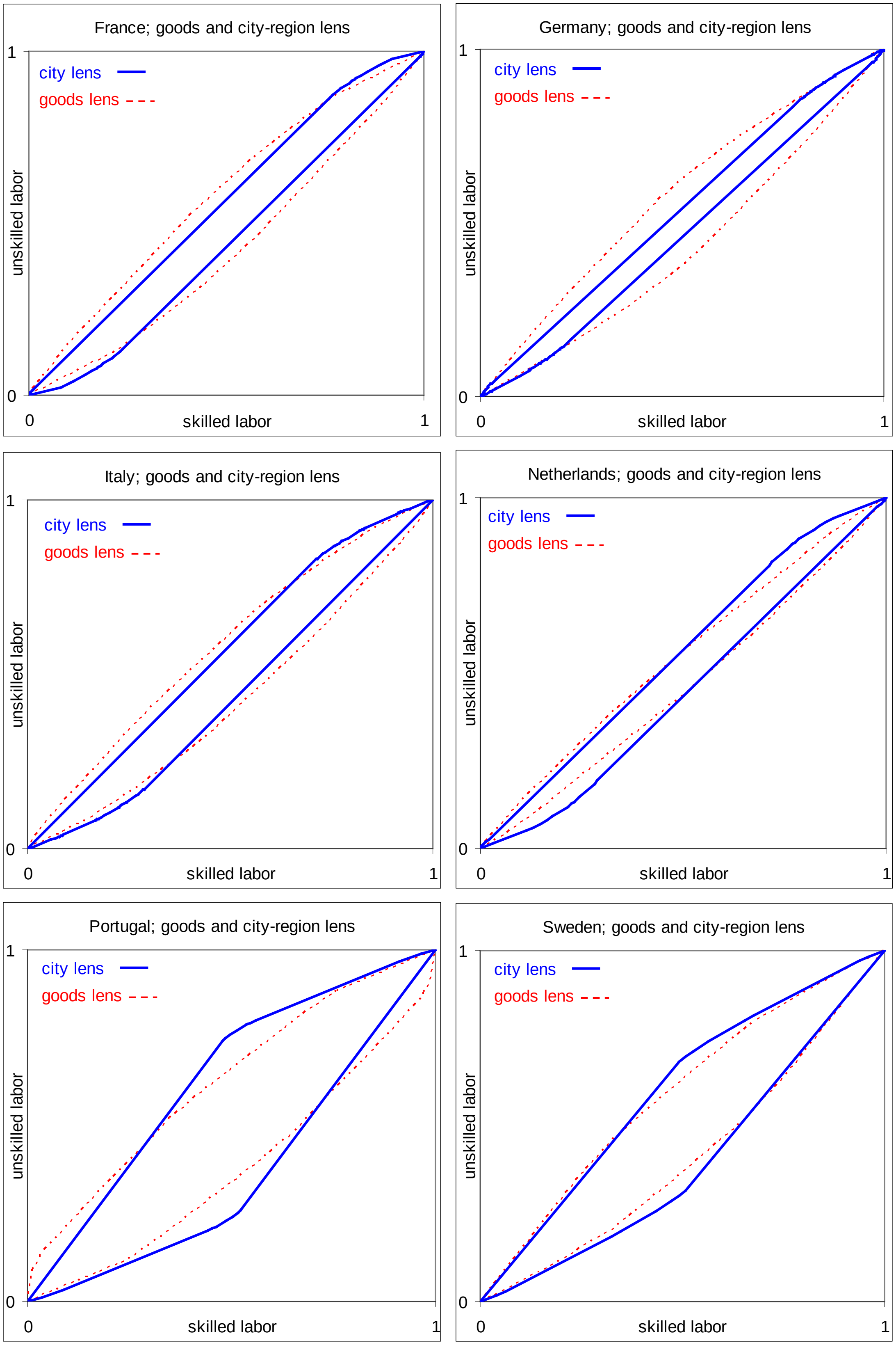
5 City Lenses

Figure 4 depicts the city lens and goods lens for the most disaggregated level (18 sectors). Appendix I, Figure A1, shows how the goods lens expands as the level of disaggregation increases. The striking feature of Figure 4 is that *none* of the city lenses is a subset of the respective goods lenses, such that the *lens condition is violated* for all countries.[16] As

[16] This also holds for Germany, although it may not be immediately evident from the figure.

such, a necessary condition for FPE is not fulfilled, which implies that the lumpy distribution of high-skilled and other workers across space influences the international trade flows for *each* of the six countries. The same conclusion holds, obviously, for lower levels of disaggregation from a goods perspective (see Figure A.1 in appendix I). If more detailed information of factor use for different sectors were available, however, the lens condition might potentially not be violated (as argued by Bernard et al, 2005). For readers so inclined, we point out the limitations of Eurostat's urban audit data collection system, on which our city lenses are based. According to the State of European Cities report (2007, p. 4), the selection of cities was "undertaken through collaboration between EUROSTAT, national statistical offices and local authorities. The selection took into account geographical spread, as well as size and both large and medium-sized cities were chosen. The combined population of the 258 cities in 2001 was 107 million inhabitants, accounting for more than 20% of the EU-27 population." When compared to the share of the European population living in cities (about 80%), this implies that the level of urban detail is very limited indeed (which accounts for the large straight lines in Figure 3, based on the large share of the miscellaneous 'region' categories in Table 1). With the limited information we have we already find overwhelming evidence in support of lumpiness. More detailed information expands the city lens and strengthens this conclusion.

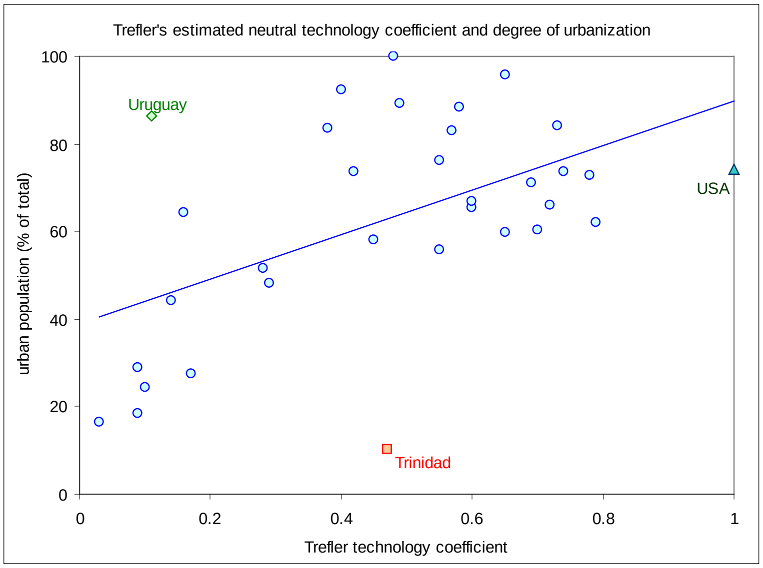
Figure 4 City lens condition violated for all countries



6. Evaluation

The significance of our findings is that specialization, and as a consequence international trade, is not necessarily determined at the country level, but is likely to have an urban component, and as such affect trade patterns. In this sense the implications are different from Debaere (2004), who observes no violations of the lens condition at the regional level. It is tempting to relate lens condition violations to Trefler's (1995) missing trade puzzle. The general consensus in the literature is that the puzzle can to a large extent be solved by introducing technological differences between countries. A first indication that lumpiness could contribute to our understanding of the Trefler's findings is provided by a simple correlation between his estimated neutral technology parameters and the observed degree of urbanization, see Figure 5.[17] In general, the higher the degree of urbanization, hence the higher the degree of lumpiness, the higher the estimated technology level to explain the missing trade puzzle. The most obvious outliers are Uruguay (with a low estimated technology coefficient and a high degree of urbanization) and Trinidad (with a medium estimated technology coefficient and a low degree of urbanization).

Figure 5 Technology differences and urbanization



[17] Data on the missing trade puzzle are from Treflers' website: http://homes.chass.utoronto.ca/~trefler/ . The degree of urbanization (per cent of total) used for the Trefler lumpiness calculations is based on the World Bank Development Indicators, interpolated for 1983 using the observations for 1980 and 1985.
For Yugoslavia, we calculated a population-weighted average degree of urbanization based on the separate parts of Serbia, Croatia, Bosnia Herzegovina, Macedonia, Slovenia, and Montenegro.

The correlation shown in Figure 4 is interesting as it raises the age-old question if urbanization causes technological progress, or the other way around. Evidence in regional and urban economics indicates that density or agglomeration (city formation) is the cause of higher productivity and wages. The most advanced economies are also the most urbanized economies. The evidence indicates that the causality (weakly) runs from cities (agglomeration) towards productivity, so urbanization could be an ultimate cause of productivity, see Rosenthal and Strange (2004) and Duranton et al (2009) for recent overviews.

An alternative method to find evidence for lumpiness can be obtained using the methodology introduced by Bernard et al. (2005). Cost minimization of a standard (Cobb-Douglas or CES) production functions for an industry yields unit cost functions. Production factors in different regions and industries are corrected for (unobserved) quality differences. Under the null-hypothesis – that is, the absence of lumpiness – the relative wages between different locations and industries only differ because of (unobserved) quality differences. Unfortunately we lack the necessary labour market data on a city level in order to perform this alternative test of lumpiness.

6 Conclusions

Courant and Deardorff (1992, 1993) show that the lumpy distribution of factors of production across space in a particular country may affect this country's international trade flows. Using the lens condition and regional data for Japan, the UK, and India, Debaere (2004) argues that lumpiness does not appear to be an issue in the international trade flows of those countries. Although the lens condition is a necessary *and* sufficient condition in the two-factor case (see Qi, 1998, and Xiang, 2001) it is only a necessary, but *not* sufficient condition in the multi-factor case (Demiroglu and Yun, 1999). Consequently, Debaere's (2004) conclusions on the irrelevance of lumpiness for trade flows might not hold in a multi-factor setting. We argue that the relevant spatial scale to measure the degree of lumpiness is at the urban level, not the regional level. Using urban data for six European countries on the distribution and use of high-skilled workers and other workers we show that the necessary lens condition is violated for all six countries.

This leads us to conclude that the lumpy distribution of factors of production *does* affect international trade flows. It is tempting to relate lumpiness to the missing trade puzzle, in view of the systematic nature of these deviations urbanization might add to our understanding of trade flows.

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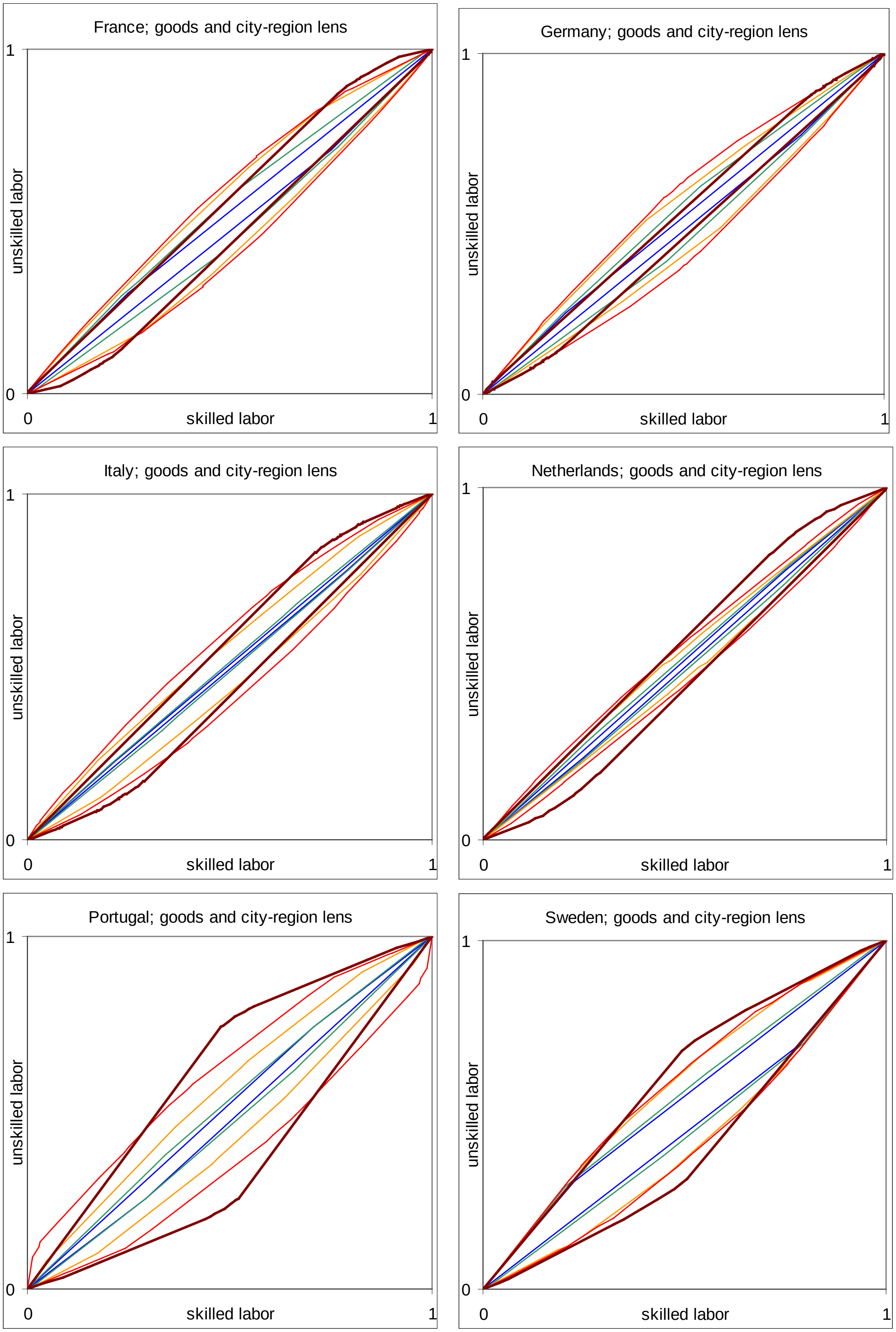
Appendix I

GGDC sectors with the same high-skilled versus other labor intensities:

MARKET ECONOMY	
ELECTRICAL MACHINERY, POST AND COMMUNICATION SERVICES	
Electrical and optical equipment	
Post and telecommunications	
GOODS PRODUCING, EXCLUDING ELECTRICAL MACHINERY	
TOTAL MANUFACTURING, EXCLUDING ELECTRICAL	
Consumer manufacturing	
Food products, beverages and tobacco	same intensity
Textiles, textile products, leather and footwear	same intensity
Manufacturing nec; recycling	same intensity
Intermediate manufacturing	
Wood and products of wood and cork	same intensity
Pulp, paper, paper products, printing and publishing	same intensity
Coke, refined petroleum products and nuclear fuel	same intensity
Chemicals and chemical products	same intensity
Rubber and plastics products	same intensity
Other non-metallic mineral products	same intensity
Basic metals and fabricated metal products	
Investment goods, excluding hightech	
Machinery, nec	same intensity
Transport equipment	same intensity
OTHER PRODUCTION	
Mining and quarrying	same intensity
Electricity, gas and water supply	same intensity
Construction	
Agriculture, hunting, forestry and fishing	
MARKET SERVICES, EXCLUDING POST AND TELECOMMUNICATIONS	
MARKET SERVICES EXCL P AND T CORRECTED	
DISTRIBUTION	
Trade	
Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel	
Wholesale trade and commission trade, except of motor vehicles and motorcycles	
Retail trade, except of motor vehicles and motorcycles; repair of household goods	
Transport and storage	
FINANCE AND BUSINESS, EXCEPT REAL ESTATE	
Financial intermediation	
Renting of m&eq and other business activities	
PERSONAL SERVICES	
Hotels and restaurants	
Other community, social and personal services	same intensity
Private households with employed persons	same intensity
NON-MARKET SERVICES	
Public admin, education and health	
Public admin and defence; compulsory social security	
Education	
Health and social work	
Real estate activities	

Figure A.1 Lumpiness, in various countries



Bold solid line: city lens - thin lines (from inside to out): 2, 5, 9, and 18 sector lenses.