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# Effective area as a measure of land factor

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## Abstract

Empirical studies use the total area as a measure of land factor. This measure is flawed as it ignores the effectiveness of that total area. We develop an estimator of effective area based on spatial population distribution. The empirical application for the OECD countries highlights the advantages of the United States in land factor and shows that Eastern European countries have the highest proportion of effective area. The estimation also supports Helpman's view: if population density increases, population disperses.

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# 1. Introduction

In addition to capital and labour, land is an important factor that influences economic activity. Indeed, land (or land factor) provides natural resources, as well as space for production and living. Empirical literature in geographical, international, or development economics uses total area (or total surface area) as a measure (or proxy) of land (Brülhart and Sbergami, 2009; Escobar Gamboa, 2010; Henderson et al., 2011). This measure is however flawed since the total area may not be usable because of climatic or geographic conditions. For example, Australia is 70% arid land and Japan is 71% mountain terrain. We propose an alternative measure of land that we call *effective area*. Effective area refers to an area that is directly useful for production - agriculture, industry, or service - and living at the date under consideration.

According to the neo-classical theory (Heckscher-Ohlin-Samuelson), natural conditions (or first-nature) such as resource endowment, landform, sea access, or climate are important factors for people to consider settling in a region. In some countries like the Netherlands, these factors are similar across the total area and allow an equal distribution of the population. In other countries like Sweden, only a small part of the total area benefits from friendly landscape; population concentrate in this part. Following the new economic geography (Krugman, 1991; Helpman, 1998), in addition to natural conditions, human location and human activity (or second-nature) influence the attractiveness of a region according to agglomeration and dispersion effects. Indeed, people and firms tend to seek out areas with already established people and firms (Krugman, 1991; Helpman, 1998). In an agglomeration, people benefit from more employment opportunities and lower product prices, while firms benefit from larger employment area and better market access, reflecting an agglomeration effect. But not all people and firms agglomerate into a single region since since the regions' total area is an immobile amenity. Its price increases with population and economic activity, reflecting a dispersion effect (Helpman, 1998).

The first contribution of the article is the development of the effective area estimator. The effectiveness of an area is linked to its spatial population distribution. More precisely, if any part of an area is effective, the population is uniformly distributed. Similarly, if some part of an area is not effective, nobody lives in this part. We assume that the spatial population distribution captures both natural conditions and human activities. Hence, we can omit detailed data on the underlying characteristics of land such as climate, altitude, coastline, or ground quality. To estimate the effective area of any type of territory - a country or a region - we only need data on population and area for the territory's subdivisions. This is much less information and computational need than Burchfield et al. (2006) method which uses fine-resolution data. The effective area estimator is based on the Gini coefficient and is similar to Sen's welfare index (Sen, 1976). As such, it is a synthetic indicator with an easy calculation and an appealing interpretation. The second contribution is the estimation of the effective area for the OECD countries. The United States have from far the largest effective area and Mexico is the second country in terms of effective area. The formerly communist countries have the largest proportion of effective area. Finally, in line with Helpman (1998), effective area increases with density.

# 2. Effective area estimator

The Lorenz curve in Figure 1 represents the distribution of population within an area. It links the cumulative population share to the cumulative area share. It is similar to the classical Lorenz (1905) curve - a representation of the distribution of wealth within population - which links the cumulative wealth share to the cumulative population share.

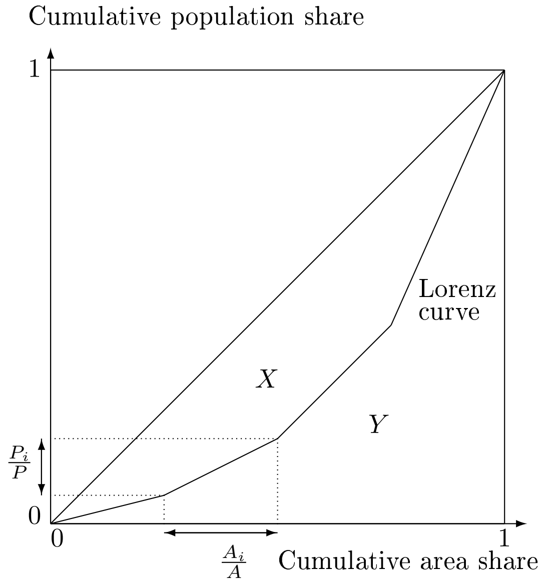
A country is composed of $n$ regions indexed by $i \in [1, n]$ ordered by density (or population density). Let the total Area of the country be $A$ and the total Area of region $i$ be $A_i$. Let the Population of the country be $P$ and the Population of region $i$ be $P_i$. The surface $X \in [0, 1/2[$ measures the area between the bisectrix and the Lorenz curve. The coefficient $G = 2X$ measures the population distribution among the regions. $G$ is then similar to the classical Gini coefficient. The surface $Y \in ]0, 1/2]$ under the Lorenz curve measures how close is the Lorenz curve to the bisectrix. We have:

$$Y = \sum_{i=1}^{n} \frac{A_i}{A} \frac{P_{i-1} + P_i}{2P}, \text{ with } P_0 = 0. \tag{1}$$

The proportion of effective area is $1 - G$, with:

$$1 - G = 2Y. \tag{2}$$

Figure 1. Population distribution among regions




If the Lorenz curve is the furthest from the bisectrix - the uniform distribution line - then only a small part of the country's area is effective, and the population concentrate in this part; $X$ tends to 1/2, $Y$ tends to 0, and the proportion of effective area $1-G$ tends to 0. Alternatively, if the Lorenz curve merges with the bisectrix, then all the country's area is effective, and the population is uniformly distributed; $X$ equals 0, $Y$ equals 1/2, and the proportion of effective area $1-G$ equals 1.

The Effective Area $EA$ is:

$$EA = A(1-G). \tag{3}$$

Substituting (1) in (2) and the result in (3) gives:

$$EA = \sum_{i=1}^{n} A_i \frac{P_{i-1} + P_i}{P}, \text{ with } P_0 = 0. \tag{4}$$

From (4), if the population is concentrated within region $i$ ($P_i = P$), the effective area is region $i$'s total area ($EA = A_i$). Alternatively, if the population is uniformly distributed between the regions ($\frac{P_i}{A_i} = \frac{P_{i+1}}{A_{i+1}}$), the effective area is the country's total area ($EA = A$). Thus, the effective area has the property of being equivalent to the total area of an equally distributed population. It is similar to Sen's (1976) welfare index, which measures the mean equally distributed income. As Sen's index, the effective area estimator does not have the additive property. In the general case, the sum of the effective area of several countries is not the effective area of these countries as a whole.

## 3. Effective area estimation for the OECD countries

We estimate the effective area for the OECD countries[1]. The OECD (2011) provides area and population data for micro-regions at Territorial Level 3 belonging to the member countries for the period 2005-2009. While 50.4% of the total area of small and temperate Switzerland is effective, only 6.7% of large and arid Australia is effective (Table I). Comparing the countries' ranking of total area versus the countries' ranking of effective area, half of the countries have, at least, a difference of two ranks. Although the total area of Mexico is four times smaller than the total area of the United States, Canada, or Australia, Mexico is the second-highest country in terms of effective area behind the United States.

The United States, Canada, and Australia have similar total area (9.1, 9.0, and 7.7 million $km^2$). While the United States is relatively temperate, most of Canada is cold desert and most of Australia

[1] Datasets and commands are available on the authors' website in Stata format.

Table I. Effective area for the OECD countries in 2008

| Country | Regions | Density | Area | Rank | % Eff. Area | Rank | Eff. Area | Rank |
|---|---|---|---|---|---|---|---|---|
| United States | 179 | 33 | 9 161 924 | 1 | 33.1% | 27 | 3 030 769 | 1 |
| Mexico | 209 | 54 | 1 959 248 | 4 | 27.8% | 28 | 544 748 | 2 |
| Australia | 60 | 3 | 7 702 250 | 3 | 6.7% | 31 | 515 552 | 3 |
| Canada | 288 | 4 | 9 017 699 | 2 | 5.5% | 32 | 498 139 | 4 |
| Turkey | 81 | 92 | 769 604 | 5 | 51.7% | 15 | 397 764 | 5 |
| France | 96 | 114 | 543 965 | 7 | 52.6% | 14 | 286 339 | 6 |
| Germany | 96 | 230 | 357 089 | 11 | 58.3% | 11 | 208 113 | 7 |
| Spain | 59 | 89 | 501 757 | 8 | 41.1% | 20 | 206 323 | 8 |
| Poland | 66 | 122 | 312 679 | 12 | 61.2% | 9 | 191 229 | 9 |
| Italy | 107 | 200 | 295 212 | 15 | 56.3% | 12 | 166 150 | 10 |
| Japan | 47 | 342 | 373 530 | 10 | 39.3% | 22 | 146 763 | 11 |
| Chile | 53 | 22 | 754 937 | 6 | 18.4% | 30 | 138 830 | 12 |
| Sweden | 21 | 22 | 410 312 | 9 | 33.6% | 25 | 137 834 | 13 |
| Norway | 19 | 15 | 304 280 | 14 | 42.6% | 19 | 129 573 | 14 |
| Finland | 20 | 17 | 304 473 | 13 | 40.7% | 21 | 123 817 | 15 |
| New Zealand | 14 | 16 | 263 357 | 16 | 42.6% | 18 | 112 223 | 16 |
| United Kingdom | 133 | 250 | 243 154 | 17 | 33.4% | 26 | 81 284 | 17 |
| Greece | 13 | 85 | 130 714 | 18 | 53.0% | 13 | 69 272 | 18 |
| Hungary | 20 | 108 | 93 030 | 21 | 69.8% | 4 | 64 945 | 19 |
| Czech Republic | 14 | 133 | 77 263 | 24 | 71.2% | 3 | 54 994 | 20 |
| Ireland | 8 | 63 | 68 395 | 25 | 63.1% | 7 | 43 137 | 21 |
| Austria | 35 | 100 | 82 450 | 23 | 50.1% | 17 | 41 316 | 22 |
| Slovak Republic | 8 | 110 | 49 034 | 26 | 82.6% | 1 | 40 504 | 23 |
| Korea | 16 | 487 | 99 461 | 20 | 35.7% | 23 | 35 495 | 24 |
| Portugal | 30 | 115 | 92 119 | 22 | 34.4% | 24 | 31 704 | 25 |
| Denmark | 11 | 126 | 43 098 | 28 | 61.8% | 8 | 26 613 | 26 |
| Iceland | 8 | 3 | 102 696 | 19 | 25.5% | 29 | 26 136 | 27 |
| Estonia | 5 | 31 | 43 432 | 27 | 60.1% | 10 | 26 098 | 28 |
| Netherlands | 12 | 484 | 33 782 | 30 | 66.3% | 5 | 22 386 | 29 |
| Belgium-Lux | 12 | 336 | 32 914 | 31 | 64.0% | 6 | 21 054 | 30 |
| Switzerland | 26 | 188 | 39 999 | 29 | 50.4% | 16 | 20 147 | 31 |
| Slovenia | 12 | 100 | 20 141 | 32 | 72.2% | 2 | 14 541 | 32 |
| Average | 56 | 35 | 1 071 375 | | 21.7% | | 232 931 | |

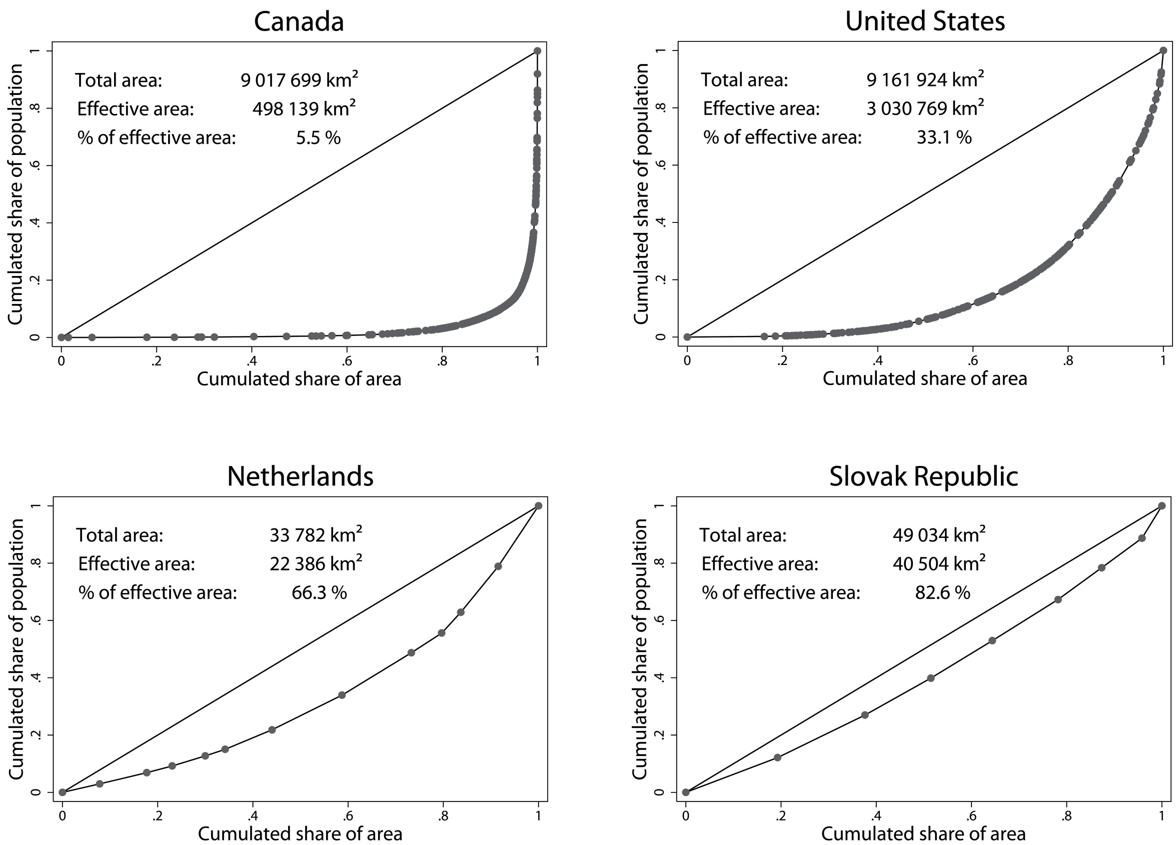
Notes. Data source: OECD (2011) for the year 2008. The surfaces are in $km^2$. Regions refer to the number of micro-regions in the country and Density refers to population density. Given that Luxembourg has only a region and shares a border with Belgium, we consider Luxembourg and Belgium as one country.

is arid desert. Hence, the proportions of effective area differ among these countries (33.1%, 5.5%, and 6.7%); the effective area of the United States is six times larger than the effective area of Canada or Australia (3.0, 0.5, and 0.5 million $km^2$). These results highlight the United States' advantages in terms of land factor and capture the desert area in Canada and Australia.

Eastern European countries, formerly controlled by the Soviet Union, show the most uniform distribution of population; Hungary, the Czech Republic, Slovenia, and the Slovak Republic are the four countries with the highest proportion of effective area (69.8%, 71.2%, 72.2%, and 82.6%). The uniform distribution of population is a direct consequence of Soviet policies. The Soviet policies dictated, for reasons of military defence and population control, the city size. That is why city size differences among Eastern Europe reduced between 1959 and 1979 (Clayton and Richardson, 1989).

According to Figure 2, the relative shapes of the Lorenz curves are coherent to the relative proportions of effective area: 5.5% for Canada, 33.1% for the United States, 66.3% for the Netherlands, and 82.6% for the Slovak Republic. More specifically, 92% of the population in Canada live in the last total area

Figure 2. Lorenz curve and effective area for selected countries in 2008




Notes. For each country, the number of segments is the number of regions. The relative size of each segment is the relative total area of each region.

decile (or the 10% of the total area with highest density). Similarly, in the last total area decile live 50% of the population in the United States, 22% of the population in the Netherlands, and 18% of the population in the Slovak Republic. The relative proportions of effective area make sense since Canada is large and cold; the United States is large and temperate; the Netherlands is small and temperate; the Slovak Republic was controlled by the Soviet Union. We would obtain similar results if we had taken into account the underlying characteristics of these countries such as climate, altitude, terrain variability, or access to the sea.

The effective area estimator is based on spatial population distribution, hence a change in population distribution influences its value. In other words, the effective area estimator does not consider land as a fixed factor. The quantity of land directly useful shifts with variations in natural conditions and human activities. Unless natural disasters, social conflicts, or other exogenous shock, we do not expect variations in the proportion of effective area in the short run. Table II shows the evolution of proportion of effective area for the OECD countries between 2005 and 2009. Excepting Turkey, where there was an exogenous shock - the creation of the Turkish Statistical Institute in 2005 modified the method of population census - the proportion of effective area for OECD countries is stable over four years.

Table III illustrates the sensitiveness of the proportion of effective area to the density, the number of regions, the population, and the total area. A high density in a country appears to lead to a greater proportion of effective area, while the number of regions has no significant impact. These results hold for different forms of controls. Because of multicollinearity issues, we do not regress for density, population and total area at the same time. The first column (control for population) and the second column (control for total area) show that a 10 percentage-points increase in density increases the proportion of effective area by about 3.2 and 2.3 percentage-points. This supports Helpman's (1998) claim that, when density increases, the distribution of population is more uniform because of the increase in housing prices in agglomerations. In the third column, as we control for population and total area, we must omit density. The third column verifies that population has a positive impact and that total area has a

Table II. Proportion of effective area for the OECD countries for 2005-2009

| Year | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|
| Canada | 5.6% | 5.6% | 5.6% | 5.5% | 5.5% |
| Australia | 6.7% | 6.7% | 6.7% | 6.7% | - |
| Chile | 18.4% | 18.4% | 18.4% | 18.4% | 18.4% |
| Iceland | 27.5% | 27.3% | 26.2% | 25.5% | - |
| Mexico | 27.8% | 27.8% | 27.8% | 27.8% | - |
| United States | 32.9% | 33.0% | 33.0% | 33.1% | 33.1% |
| United Kingdom | 33.4% | 33.4% | 33.4% | 33.4% | 33.3% |
| Sweden | 34.1% | 33.9% | 33.8% | 33.6% | 33.4% |
| Portugal | 34.8% | 34.7% | 34.6% | 34.4% | 34.3% |
| Korea | 36.2% | 36.1% | 35.9% | 35.7% | 35.5% |
| Japan | 39.8% | 39.6% | 39.5% | 39.3% | 39.2% |
| Finland | 41.0% | 40.9% | 40.8% | 40.7% | 40.5% |
| Spain | 41.6% | 41.4% | 41.3% | 41.1% | - |
| New Zealand | 43.1% | 42.9% | 42.8% | 42.6% | 42.5% |
| Norway | 43.4% | 43.2% | 42.9% | 42.6% | 42.3% |
| Switzerland | 50.5% | 50.5% | 50.4% | 50.4% | 50.3% |
| Austria | 50.7% | 50.5% | 50.3% | 50.1% | 49.9% |
| France | 52.7% | 52.6% | 52.6% | 52.6% | 52.6% |
| Greece | 53.5% | 53.3% | 53.2% | 53.0% | 52.8% |
| Turkey | 55.3% | 53.8% | 52.0% | 51.7% | 51.4% |
| Italy | 56.5% | 56.5% | 56.3% | 56.3% | 56.3% |
| Germany | 58.7% | 58.5% | 58.4% | 58.3% | 58.2% |
| Estonia | 60.3% | 60.3% | 60.2% | 60.1% | 60.0% |
| Poland | 61.2% | 61.2% | 61.2% | 61.2% | 61.2% |
| Denmark | 61.9% | 61.8% | 61.8% | 61.8% | 61.6% |
| Ireland | 63.0% | 63.0% | 62.9% | 63.1% | 63.3% |
| Belgium | 64.0% | 64.0% | 64.0% | 64.0% | 63.9% |
| Netherlands | 66.2% | 66.2% | 66.3% | 66.3% | 66.2% |
| Hungary | 70.6% | 70.4% | 70.2% | 69.8% | 69.4% |
| Czech Republic | 71.0% | 71.1% | 71.2% | 71.2% | 71.3% |
| Slovenia | 72.8% | 72.7% | 72.7% | 72.2% | 72.0% |
| Slovak Republic | 82.9% | 82.8% | 82.7% | 82.6% | 82.5% |

Notes. Constructed by the authors using data from OECD (2011). For some countries, data for the year 2009 are not available. Given that Luxembourg has only a region and shares a border with Belgium, we consider Luxembourg and Belgium as one country.

negative impact on the proportion of effective area. The number of micro-regions is an administrative decision that depends on population and total area. Thus, the point estimate for the number of regions is a proxy of country size. According to the three columns, the point estimate for the number of regions is negative, though not statistically significant. The proportion of effective area estimator is robust to the number of regions. As a conclusion from Table III, density increases the proportion of effective area and the number of regions, an administrative decision, has no impact on the effective area.

Since a potential application of the effective area is the computation of *effective density* (population/effective area), we analyse the link between the effective density and the Ciccone and Hall (1996) density index. For each country, the Ciccone and Hall (1996) density index is:

$$D(\gamma) = \frac{\sum_i P_i^{\gamma} A_i^{-(\gamma-1)}}{P}. \tag{5}$$

were $\gamma$ is a coefficient that captures both agglomeration and dispersion effects. If $\gamma > 1$, the agglomeration effect dominates the dispersion effect. If $\gamma < 1$ the dispersion effect dominates the agglomeration effect.

Table III. OLS estimates of the effect of density and number of regions on the proportion of effective area

| Dependent variable: log of % of effective surface | (1) | (2) | (3) |
|---|---|---|---|
| Density | 0.324** | 0.226* | |
| | (0.079) | (0.101) | |
| Number of regions | -0.143 | -0.143 | -0.143 |
| | (0.161) | (0.161) | (0.161) |
| Population | -0.099 | | 0.226* |
| | (0.130) | | (0.101) |
| Total area | | -0.099 | -0.324** |
| | | (0.130) | (0.079) |
| Observations | 156 | 156 | 156 |
| $R^2$ | 0.68 | 0.68 | 0.68 |

Notes. * significant at 5%, ** significant at 1%. All variables are expressed in log form. Standard errors robust to serial correlation and heteroskedasticity are in parentheses. Each regression includes a constant and four time dummies not reported here.

Table IV. Estimates of density and effective density on Ciccone and Hall (1996) density index

| Dependent variable: log of Cicconne and Hall (1996) density index | OLS | OLS | F-E | F-E |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Density | 0.022** | | 0.034** | |
| | (0.005) | | (0.012) | |
| Effective density | | 0.034** | | 0.039** |
| | | (0.003) | | (0.004) |
| Observations | 156 | 156 | 156 | 156 |
| $R^2$ | 0.63 | 0.92 | 0.71 | 0.94 |
| RMSE | 0.0228 | 0.0107 | 0.0004 | 0.0002 |
| Time F-test | 5.46** | 0.98 | 6.13** | 0.91 |

Notes. * significant at 5%, ** significant at 1%. All variables are expressed in log form. Standard errors robust to serial correlation and heteroskedasticity are in parentheses. Each regression includes a constant and four time dummies not reported here. Time F-test indicates the F-test of joint significance for the time dummy variables.

We set $\gamma = 1.04$ which corresponds to Ciccone and Hall (1996) findings for the United States for which the agglomeration effect dominates.

Table IV illustrates the differences between density and effective density as proxies of Ciccone and Hall (1996) density index. Although estimates of both variables are significant at 1% level, R-squared and root mean square error (RMSE) values show that effective density performs much better as a proxy of Ciccone and Hall (1996) density index. Moreover, the effective density also better captures time variations in the Ciccone and Hall (1996) density index. Indeed, the F-test of joint significance for time dummies is significant with density and is not significant with effective density. In conclusion, the effective area allows to easier compute more robust density indexes for physical capital, human capital, or industrial activity.

## 4. Conclusion

Land factor is hard to measure; empirical literature uses total area as its measure. The total area biases the results since land characteristics are unequal within countries of same total area. We propose a measure of land factor called effective area. We suppose that population settle in regions with better land characteristics and that population presence influences the attractiveness of those regions. Land characteristics differences across the regions of a country lead to different population distribution within this country. Hence, we use the spatial distribution of population to estimate the effective area of a country. The effective area estimator summarises detailed data that are time consuming to find. The effective area is also easy to calculate and uses data usually available in the public domain.

We illustrate the effective area estimator with the OECD countries. In average, the effective area of the OECD countries is less than a quarter of their total area. The United States are by far the country with the largest effective area. These results would be similar if we had taken into account the climatic and geographic features of the countries. In addition, the estimator of effective area is coherent with Helpman's (1998) view according to which the distribution of population is more uniform when the density increases. The effective area also captures the evolution of natural conditions and human activity over time. The effective area is a robust proxy for the Ciccone and Hall (1996) density index. As such, it can be used to estimate effective density index for other variables such as physical capital, human capital, or industrial activity. Finally, the effective area is useful in all fields as geographical, international, or development economics that need a measure for land factor.

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