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David, Martín-Barroso and Juan Andres, Nuñez and Francisco J., Velazquez

Universidad Complutense de Madrid, Universidad Autonoma de Madrid, Group for Research on Innovation, Productivity and Competitiveness

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THE EFFECT ON FIRMS' PRODUCTIVITY OF ACCESSIBILITY. THE SPANISH MANUFACTURING SECTOR

David Martín-Barroso (2) (3)
Juan A. Núñez (1) (3)
Francisco J. Velázquez (2) (3)

(1) Universidad Autónoma de Madrid
(2) Universidad Complutense de Madrid
(3) Group for Research on Innovation, Productivity and Competitiveness (GRIPICO)

ABSTRACT:

This paper evaluates the impact of accessibility on the productivity of Spanish manufacturing firms. We suggest the use of accessibility indicators to workers and commodities, integrating transport, land use, and individual components in their measurement, and computing real distances or travelling times using the Spanish full road network. The estimation is carried out in two steps. In the first one we estimate almost a hundred production functions using a panel of 155,937 firms along the 1999-2009 period from *SABI* database, applying Levinsohn and Petrin technique. From these estimations we derive the Total Factor Productivity function for year 2009, which is then explained in the second estimation step as a function of the accessibility indicators and additional control variables. Results evidence the crucial role of the accessibility to commodities, and a lesser but significant effect of workers' accessibility on firms' productivity.

KEYWORDS: Accessibility, Firm Productivity, Transport Infrastructures.

JEL: D24, R12, R40

David Martín Barroso
Despacho 1.07b-Pab. Segundo
Dept. Economía Aplicada II
Facultad CC. Económicas y EE.
Univ. Complutense de Madrid
Campus de Somosaguas, s/n
28223 POZUELO DE ALARCÓN (MADRID)
dmartin@ccee.ucm.es

Juan A. Núñez Serrano
Despacho E-XII-301
Dept. Economía Aplicada
Facultad CC. Económicas y EE.
Univ. Autónoma de Madrid
Avda. Francisco Tomás y Valiente, 5
28049 MADRID
juanandres.nunnez@uam.es

Francisco J. Velázquez Angona
Despacho 1.06-Pab. Segundo
Dept. de Economía Aplicada II
Facultad CC Económicas y EE.
Univ. Complutense de Madrid
Campus de Somosaguas, s/n
28223 POZUELO DE ALARCÓN (MADRID)
javel@ccee.ucm.es

1. Introduction

From the 1990s, the positive effects of transport infrastructures on economic growth are well documented, although some controversy exists with regards to the magnitude of these effects[1]. However, only along last decade, papers have focused attention over the channels through which transport infrastructures affect firms' decisions (Banister and Berechman, 2001; Oosterhaven and Knaap, 2003; Anderson and Lakshmanan, 2007). The effects of infrastructures may be just temporary or permanent. The permanent ones last over the life span of the infrastructure, and can be classified in three types. (i) Direct (derived from the immediate improvement of transport conditions), (ii) externalities (noise, pollutant emissions and other environmental perturbations), and (iii) indirect, which take place over longer terms and affect the production and location decisions of firms and people, and condition the economic environment and thus the future generation of people's income and jobs (Rietveld and Nijkamp, 2000)[2].

The consequences directly derived from these effects can result, as pointed out by Prud'homme (2002), in firm location changes motivated by a reduction in logistic costs (Aschauer, 1992), allowing consideration of new forms of firm production, as the "just in time" one (Gillen, 2001)[3]. Furthermore, as firms' fields of actions are broadened (Limão and Venables, 2001; Vickerman et al. 1999; amongst others), the rising of specialisation and economies of scale is more likely to occur (Weisbrod and Treyz, 1998), which in turn provokes increases in competition pressure (Garrison and Souleyrette, 1996) and technological diffusion. All these effects generate in one hand, a reduction in firms' costs and thus productivity gains, and in the other, an

[1] To this respect one may refer to the literature revision on the impact of transport infrastructures on economic growth in Gillen (1996), Boarnet (1997), Jiang (2001), and more recently, the meta-analysis of Nuñez (2012) and Melo et al. (2012).

[2] When transport infrastructure investment policies pursue associated indirect effects, they are often referred as "active infrastructure policies", which are mainly oriented towards the induction of private investment.

[3] For instance, a new loading terminal may allow for inter-modality connections between trucks and railways, improving "just in time" production and diminishing maintenance costs of stock producers (Berechman, 2002). Furthermore, Gillen (2001) points out that this kind of organisational innovations may turn in additional product and process innovations.

increase in geographic concentration leading to the productivity effects associated to the economics of agglomeration (Berechman, 2002).

However, the expansion of geographical concentration of economic activity may also generate some undesired effects on firms' performance, in the form of diseconomies of agglomeration. This is, as property and labour demand increases, so they do rents and wages. Similarly, road traffic growth may turn in network congestion and thus augment transport costs. In turn, a need for new transport infrastructures surges initiating again the mentioned effects sequence (Anderson and Lakshmanan, 2007).

Consequently, transport infrastructures modify the importance of agglomeration economies (Venables, 2007 and Graham, 2007a), which at the same time, reinforce the benefit of these type of infrastructures. Precisely, some authors following the literature on the effects of agglomeration on productivity have recently incorporated the role of infrastructures in spatial location decision theory. This is how the concept of accessibility gains relevance in both, the literature on agglomeration and that in infrastructure networks. The new challenges of this field of research have to do with the availability of information and the way measurement can be carried out.

From the macro perspective, several papers have shown a positive effect of agglomeration on productivity, using density of economic activity measures and different geographical areas as units of analysis (Melo et al., 2009). In some cases, the potential market is introduced as a proxy for economic agglomeration, as Combes et al. (2010), who analyse the impact over wages in French employment areas. In some other cases, the effect of accessibility on territories is studied, as Forslund and Johansson (1995) in Swedish municipalities, and Weisbrod and Treyz (1998) for Michigan districts.

Firm or plant level studies are only recent. Andersson and Lööf (2011) analyse the effect of agglomeration on Swedish firms' productivity. Grahan (2007a, 2007b) and Graham and Kim (2008) highlight the positive impact of potential markets in British firms, using the inverse of the Euclidean distance to compute the impedance function or disutility associated to distance. Graham (2007b) and Holl (2012) [4] measure road distances[5] although they use the same

[4] In this case, the study is carried out for the Spanish firms.

kind of impedance function. Lall et al. (2004), when analysing Indian firms, goes a step further by introducing a more complex function (negative exponential) in order to adjust for the observed utility loss. Nevertheless, to the extent of our knowledge, these kinds of studies have not considered the individual features of economic agents in accessibility measures.

An additional relevant issue in this line of Research, is that many papers emphasise the role of accessibility to commodities, and only marginally, the studies consider workers' accessibility, and usually restricting the analysis to an aggregate level (Gibbons et al., 2010 and Melo et al., 2013).

To this respect, the present paper evaluates the effect of accessibility on the productivity of Spanish manufacturing firms using the System for Analysis of Iberian Balances (SABI) database, from the family of AMADEUS databases. Accessibility is measured for two components, workers and commodities, the first study in doing it jointly to the best of our knowledge. Accessibility measures are obtained according to Núñez (2012), and incorporate the specific locations of firms at the municipality level. The impedance function considers effective times and distances of travelling across the complete Spanish road infrastructure network (urban and intercity), and not just along the high capacity network as it is usually the case. When estimating the loss in utility associated to travelling, the specific features of economic agents (workers and firms) are taken into account, as suggested by the available accessibility literature, which in turn constitutes a radical and important contribution of the present paper.

The paper is organised as follows. The next Section presents and examines employed accessibility indicators to workers and commodities. The third Section is dedicated to the formulation of estimated empirical models. We then describe followed measurement procedures for productivity, accessibility and remaining control variables. Section 5 offers and discusses obtained results and concluding remarks and policy recommendations are presented in Section 6.

[5] In fact, Graham's (2007b) approximation to the generalized cost of travelling is basically a time measure.

2. Accessibility Indicators

The economic literature offers a wide variety of accessibility measures[6]. Although the definition of the concept is sometimes controversial, there is no disagreement on the components that these indicators should include: transport, land use, individual, and temporal (Geurs and Van Eck, 2001). The first component considers the availability and configuration of transport infrastructure networks, as well as the loss in utility associated to travelling. The land use dimension reflects the distribution of opportunities along the geographical territory and thus, the geographic concentration of economic activities. The individual component identifies economic agent characteristics to take advantages of available opportunities and make use of transport infrastructures. Lastly, the temporal dimension analyses changes in opportunities and in capacity or use of transport infrastructures along the different moments in time (e.g. morning, afternoon, night, summer, winter…).

The simplest measures of accessibility consider only partially the first mentioned component (for instance, considering the distance from the firm to the nearest transport infrastructure —Lutter et al., 1992—). The improvement in the design of these indicators has been oriented to the full inclusion of the land use dimension, as it is the case of the potential measures of accessibility. Often, with regards to the transport component, these measures contemplate disutility associated to travelling (i.e. market potential identified through geodesic distance measures —Grahan, 2007a; Graham and Kim, 2008; amongst others—). More recent refinements evaluate travel distances or times along main road networks (Lall et al., 2004; Holl, 2012; Melo et al., 2013; amongst others). Only a few examples incorporate the individual component (for instance, workers' accessibility to jobs as a function of worker's qualification -Van Ham, et al., 2001 and Korsu and Wenglenski, 2010-). With the exception of very specific applications, the temporal component is usually omitted (Kwan, 1998).

[6] See for instance Bhat et al. (2000), Geurs and Van Eck (2001), Baradaran and Ramjerdi (2001), and Scheurer and Curtis (2007) amongst others, for a detailed analysis of these accessibility measures.

Therefore, this paper measures manufacturing firms' accessibility to the most relevant factors determining their costs and thus their productivity, (i) the accessibility to workers, and (ii) the accessibility to commodities.

Accessibility measures in labour markets often cover insufficient or relatively small geographic areas of influence. In fact, most of the papers treating this aspect are based on the labour supply side, focusing attention on limited geographical areas such as municipalities, functional areas, industrial districts, local labour markets, etc. (Kawabata, 2003 from the perspective of demand and Gibbons et al., 2010; Melo et al., 2013 from supply; amongst others). However, these geographical limits unnecessarily impose fictitious impediments to objective measurement. For this reason, we select an accessibility measure from the competition typology, based on Shen (1998 and 2001) proposal, which takes the form of expression (1).

$$\mathrm{ACC}_{\mathrm{ij}}^{\mathrm{T}} = \sum_{\mathrm{k}} \frac{\mathrm{W_k} f_L(\mathrm{d_{jk}}, \mathrm{i}, \mathrm{t_k}, \mathrm{j}, \mathrm{k})}{\sum_{\mathrm{p}} \mathrm{E_p}\, f_L(\mathrm{d_{kp}}, \mathrm{i_p}, \mathrm{t_k}, \mathrm{k}, \mathrm{p})} \qquad (1)$$

Where $\mathrm{ACC}_{\mathrm{ij}}^{\mathrm{T}}$ is the accessibility indicator to workers of firm *i* located in municipality *j*. W_k registers the number of potential workers (labour supply) living in a generic municipality *k* located in the neighbourhood of municipality *j* (this neighbourhood also contains the reference municipality *j*). $f_L(\mathrm{d_{jk}}, \mathrm{i}, \mathrm{t_k}, \mathrm{j}, \mathrm{k})$ is the impedance function that accounts for the cost or disutility associated to travelling from *j* to *k*[7], and it depends on the travelling time or distance between *j* and *k* (d_{kp}), the characteristics of both municipalities (*j* and *k*), the features of the potential workers living in *k* (t_k), and the firm *i*.

The point realisation of this impedance function can be interpreted as the probability a potential worker living in municipality *k* has to work in firm *i*. By symmetry, this measure can be also understood as the probability of firm *i* hiring this worker residing in municipality *k*. Therefore, the numerator of this indicator shows firm *i* expectations about hiring workers from the municipality where it is

[7] Impedance functions generally reflect the costs of transport. In this current case, these transport costs are measured in terms of the distance between *j* and *k* along the road network, measured either in Kilometres or time units, taking into account specific characteristics of involved municipalities (size, excess labour supply, etc.), as well as workers' features (sex, qualifications, etc.) and firms' attributes (type of labour demanded, size, etc.).

located and associated neighbourhood (opportunities)[8]. The denominator expresses firms' labour demand over workers residing in a given municipality. Its construction is identical to that of the numerator. To this respect, workers' expectations on competition are measured by adding up the crossed product of labour demand over municipalities located across attraction radius of workers living in *k* —denoted here by *p*— and the probability that firms located in these municipalities *p* choose those available workers in *k*.

In order to successfully apply expression (1), it is absolutely necessary to have all required information at the municipality level, as well as having access to the impedance functions or the equivalent probability realisations between each firm and its associated municipalities. The indicator must be equal or greater than zero, and although it is not bounded from above, it does not usually take values greater than one.

With regards to accessibility for commodities, competition for available opportunities is not as relevant as in the labour market. Thus in this case the potential accessibility indicator is based on the economic activity and considers three different types of commodity flows, (i) intermediate consumption of goods by firms, (ii) intermediate uses, and (iii) final uses of firms' production.

Potential accessibility indicators, in contrast to potential market ones, consider as well as the spatial distribution of economic activity the individual component in the form of product required or obtained by firms. To this respect, firm's accessibility to intermediate consumption is defined as the ease with which the firm has access to available or potential production for intermediate use. The indicator takes the form of expression (2)

$$ACC_{ij}^{IC} = \frac{\sum_g IU_g \, f_M\left(d_{jg}, j, g, IC_i\right) SI_{ig}^{IC,IU}}{\sum_g IU_g} \qquad (2)$$

where ACC_{ij}^{IC} is firm's *i* (located in *j*) accessibility indicator to intermediate consumption. *g* denotes each one of all possible municipalities where production is originated. *IU* registers manufacturing production available for

[8] If municipality *k* is far enough from municipality *j*, then, $f_L\left(\mathrm{d_{jk}}, \mathrm{i}, \mathrm{t_k}, \mathrm{j}, \mathrm{k}\right) = 0$, implying that municipality *j* is beyond the attraction or influence radius of firm *i*.

intermediate use in each municipality. $f_M(d_{jg}, j, g, IC_i)$ represents the impedance function, which depends on distance, specific characteristics of the municipalities of origin and destination, as well as other features of firm's *i* intermediate consumption, mainly related to the type of required product. Once again, the interpretation of this function has to do with the probability that firm *i* is provided with commodities for intermediate use that have been produced by the firms located in *g*. In contrast to previous applications where this function is basically an inverse function of distance (Graham, 2007a; Holl, 2012; amongst others) or simply a parameter affecting distance in gravity functions, the proposed function is not determined *ad-hoc* but derived from available information. *SI* is a similarity index between commodities produced in *g* for intermediate uses and the intermediate consumption required by firm *i*. Thus the similarity index SI_{ig} reflects the potential intensity of flows between municipality *g* and firm *i*[9]. The flow is zero when production differs substantially, and increases as similarities in production arise. The intermediate consumption required by firm *i* can be obtained from all possible manufacturing locations, including the municipality where the firm is located, as these manufacturing units are often bound to use their production as intermediate uses of their final production.

Analogously, accessibility to firm's final production from the perspective of remaining firms demanding intermediate consumption is defined by expression (3).

$$ACC_{ij}^{IU} = \frac{\sum_g IC_g \, f_M(d_{jg}, j, g, Y_i) SI_{ig}^{IU,IC}}{\sum_g IC_g} \qquad (3)$$

Where $\mathrm{ACC}_{\mathrm{ij}}^{IS}$ is the accessibility indicator to firm's *i* production that is demanded for the intermediate uses of other firms. In this case, the impedance function depends on the characteristics of final production.

Somewhat different is the accessibility indicator to final uses of firm's production destined to final consumers. Homogeneity in tastes across locations

[9] The specific definition of this similarity index is $SI_{ig} = 1 - 0{,}5 \sum_j |S_{ij}^{IC} - S_{gj}^{IU}| = \sum_j Min(S_{ij}^{IC}; S_{gj}^{IU})$, where $S_{.j}$ is the share of commodity *j* in corresponding total production.

is assumed, and accessibility depends solely on markets' size, which in turn is affected by population and purchasing power. The indicator is defined in expression (4).

$$ACC_{ij}^{FU} = \frac{\sum_g R_g \, f_M\left(d_{jg}, j, g, Y_i\right)}{\sum_g R_g} \qquad (4)$$

Where ACC_{ij}^{FU} is the accessibility indicator to the production of firm *i* located in *j*, destined to meet final demand, and *R* denotes the income of municipality *g*. The accessibility indicators to commodities are normalised according to country totals and hence, they are defined in the closed interval [0,1].

The global accessibility indicator in expression (5) is therefore defined as the firm-level weighted average of the accessibility indicators to each type of commodity flow.

$$ACC_{ij}^{M} = \alpha_{1i}A_{ij}^{IC} + \alpha_{2i}A_{ij}^{IU} + \alpha_{3i}A_{ij}^{FU}; \quad \sum_{z=1}^{3} \alpha_{zi} = 1 \qquad (5)$$

3. The empirical model

In order to analyse the effect on manufacturing firms' productivity of the degree of accessibility, we assume that technology can be described by the Cobb-Douglas production function with two factor inputs[10] of expression (6).

$$Y_{it} = A_{it} L_{it}^{\beta_l} K_{it}^{\beta_k} \qquad (6)$$

Where Y_{it} is firm's *i* value added in period *t*, *L* and *K* are labour and capital, respectively, and *A* is the efficiency level or total factor productivity (TFP) of the firm. Taking logarithms in expression (6) we have the linear function in (7).

[10] We choose a value added function instead of a production function, which would require intermediate consumption as an additional production factor. Sims (1969) and Arrow (1972) point out that the elasticities obtained from this specification are equivalent to those in which the dependent variable is production, whenever underlying gross production is weakly separable in value added and intermediate consumption, and efficiency only affects value added.

$$y_{it} = \beta_0 + \beta_l l_{it} + \beta_k k_{it} + v_i + \varepsilon_{it} \qquad (7)$$

Where β_0 is an estimate of the average level of firms' efficiency in corresponding sector, v_i is the individual component of firm *i* and captures differences in efficiency between each firms' averages and the average level in the sector. Finally, ε_{it} registers efficiency differences by year with respect to industry average. Thus each firm's TFP can be estimated according to expression (8).

$$\ln(A_{it}) = \beta_0 + v_i + \varepsilon_{\mathrm{it}} = y_{it} - \beta_l l_{it} + \beta_k k_{it} \qquad (8)$$

A two-step approach is followed in order to evaluate the impact of accessibility on firms' productivity. The individual component can be explained from specific firms' characteristics or the strategies they follow. One of these characteristics may well be the degree of accessibility the firm benefits from. Barro and Sala-i-Martin (1995) and Berndt and Hansson (2002), argue that infrastructure endowments enhance productive efficiency, since for a given combination of private factor inputs, a higher level of potential production may be attained. Meade (1952) refers to these type of public factors as "the creation of the atmosphere", which are beyond control of individual firms, suggesting the two-step estimation process described by expressions (7) and (8). Nonetheless, Arrow and Kurz (1970) suggest that these elements contributing to firms' production should be included in the production function as an additional factor input, as they show features of a private good. However, Núñez (2012) shows through a meta-analysis of almost 2000 results provided by nearly 150 different papers, that there are no statistical significant differences from the results derived from either of the two mentioned procedures, as theory predicts for the Cobb-Douglas production function.

The two-step estimation has nevertheless some practical advantages due to data availability. The time horizon, for which data on factor inputs and infrastructure endowments and thus accessibility is available, does not usually coincide, especially if considering the complete road network and not just the high capacity one. Whilst firms' panel data is available for a large time horizon, the information on transport infrastructure endowments is only recent. Additionally, the cost associated to this kind of geodatabases often obliges to use only a cross-section[11]. Consequently, the TFP function is specified as described by expression (9).

$$\ln(A_i) = \alpha_0 + \sum_j \gamma_j lnACC_i^j + \gamma_Z Z_i \qquad (9)$$

Where ACC_i^j refers to each of the used accessibility measures and $\mathrm{Z_i}$ is a vector of control variables identifying those firms' characteristics or strategies that affect their productivity levels.

A first group of control variables recognises firms' internationalisation strategies. International trade strategies (exports and/or imports) have been shown to be related to larger productivity levels (Fariñas and Martín-Marcos, 2007; Andersson et al., 2008; Vogel and Wagner, 2012; Aw et al., 2011; amongst others). The same occurs with foreign investment (Damijan et al., 2007; Tomiura, 2007; Yeaple, 2009; to mention some recent ones) and foreign capital participation on firms' social capital, which positively affect productive efficiency (Harris and Robinson, 2003; Weche, 2012). Additionally, the inclusion of a variable indicating the presence of firms' subsidiaries in the country, may capture a positive relation with productivity, as it may identify internal reorganisation of production in relation to outsourcing strategies.

A second group of control variables identifies state features of firms, such as age, market exit and human capital. The variable age captures knowledge accumulation and learning by doing processes (e.g. Audretsch, 1995; Huergo and Jaumandreu, 2004). In order to detect the relationship indicated by Jovanovic (1982) and Hopenhayn (1992), i.e. exiting firms exhibit lower productivity levels just before abandoning activity, we introduce a variable to reveal market exit. In fact, Fariñas and Ruano (2005) show for the Spanish manufacturing sector that firms exiting the market return lower productivity scores. Finally, the introduction of human capital enables to recognise the fact that higher human capital endowments are usually associated to higher levels

[11] In the case of Spain, the complete road network is only available for year 2006 and is especially dear.

of innovations in management, processes and product, and thus productivity (Bartelsman and Doms, 2000).

4. Data

In order to fulfil the defined two-step estimation strategy, we must estimate first the production function from a firm panel data and derive TFP, and then, using estimated TFP and accessibility data, we need to identify the productivity function. For the first step, we use the information available in *SABI* database, System for Analysis of Iberian Balances, elaborated by Informa and Bureau Van Dijk, and belonging to the group of European firms databases integrated in AMADEUS. An unbalanced panel along the period 1999-2009 is available, with a total of 155,937 manufacturing firms[12]. The second step estimation, i.e. the productivity function, is restricted to 2009 cross-section, due to the lack of a panel of geodatabases with Spanish full road network. The firm information required for control variables in the productivity function, is also derived from *SABI* database.

A. TFP calculation

Although the origin of TFP calculation is due to Solow's (1956) seminal paper, many empirical and theoretical studies have risen along past few decades, proposing statistical techniques to improve the estimation processes for newly available firm databases[13].

The ordinary least squares estimation, OLS, in (7) requires that firms' efficiency levels must be independent of factor inputs. In this sense, if firms know their level of efficiency at the moment when they decide upon their factor input endowments, then simultaneity occurs between input factors and production (Olley y Pakes, 1996; Ackerberg, et al, 2007)[14]. A solution to this

[12] The analysis is constrained to continental Spain, excluding the Canary Islands, the Balearic Islands, Ceuta and Melilla. SABI coverage for the manufacturing sector amounts to 30% in terms of firms and 66.7% in terms of employment. An intense process of data depuration is previously required, detailed information on it can be found in Martín et al. (2011).

[13] See Van Beveren (2012) for a more detailed explanation.

[14] A positive productivity shock leads to a lesser utilisation of firm inputs in the short term, and this introduces upward bias in coefficients (De Loecker, 2007).

problem may consist of within-group estimation procedures (Pavcnik, 2002; Levinsohn and Petrin, 2003). However, these methodologies result in extremely low values for the income elasticity of capital, and impose strict exogeneity of factor inputs conditioned to firm heterogeneity, therefore implying that the election of factor inputs does not react to productivity shocks (Wooldridge, 2009).

An alternative procedure to guarantee consistency in the production function parameter estimates is through instrumental variables techniques (Griliches y Mairesse, 1995), although finding appropriate instruments may be somehow problematic[15]. Other possibility is General Method of Moments, GMM, procedures (Wooldridge, 2009), although factor input quantities are often too persistent in time and hence, they provide weak endogeneity corrections. Blundell and Bond (1999) propose an extended GMM estimator (system-GMM) that uses lagged values of first finite differences as instruments in levels' equations, and vice versa, also incorporating both in estimations, and thus attaining more reasonable results.

A preferred substitute for previously described methods corresponds to semi-parametric estimation procedures, which offer consistent and better behaved estimators (Van Beveren, 2012). Olley and Pakes (1996) are pioneers in using an algorithm that solves the simultaneity problem, and takes also into account firm dynamics. They use firms' investment decisions as a proxy for unobservable productivity shocks and they also control for firm exit. Nonetheless, this procedure does only generate consistent estimations if and only if there exists a strict monotonic relationship between the proxy and the output.

However, very often, there are no available variables measuring firms' investment. For this reason, Levinsohn and Petrin (2003) offer a similar estimation procedure that uses intermediate inputs (raw materials and energy) instead of investment as a proxy for unobservable productivity shocks, as they are usually available in most databases, they tend to achieve the monotonicity

[15] If markets were perfectly competitive, prices could be appropriate instruments (Ackerberg, et al, 2007). Nevertheless, firms often operate in imperfect markets and exhibit certain market power, and thus prices cannot be valid instruments.

condition more often, and they provide very similar results (Levinsohn et al. 2004).

The information required to estimate the production functions using Levinsohn and Petrin methodology—production, employment, net tangible fixed assets (as a proxy for capital), raw materials, main activity of the firm to 4 digits (NACE rev. 1.1)— is obtained from *SABI* database. Production is deflated using the Index for Industrial Prices available at the Spanish National Institute of Statistics (INE)[16]. Intermediate consumption and capital are deflated according to the different intermediate goods and capital goods, respectively, available in the Index for Industrial Prices. Value added is deflated applying a double deflation criterion. As the panel is unbalanced, upward biases in TFP estimations associated to the exclusion of firms exiting the market are attenuated (Jovanovic, 1982 and Hopenhayn, 1992). In order to estimate the production functions by type of productive activity, each firm is assigned to its sector of primary activity defined at 4 digits, with a final total of 93 different activities[17].

B. Accessibility

Impedance functions are required to compute accessibility indicators. These functions can be approximated through a collection of probability functions[18]. In the case of workers, they adopt the form of expression (10).

$$D_{ij}(T) = \alpha_0 + \beta X_i + \gamma X_I + \delta X_j + \theta X_J \quad (10)$$

Where $D_{ij}(T)$ refers to the commutation probability of worker *i* over the interval *T* (where *T* is measured either on time or distance units), worker *i* living in municipality *I* and commuting to municipality *J* where firm *j* is located. X_i incorporates worker's subjective characteristics, X_I refers to the features of the

[16] This Index for Industrial Prices is available to 3 digits NACE rev. 1.1.

[17] When there are less than 2000 observations along the complete time horizon (firms and years) in one of the primary activities, available information is assigned to the most closely related activity, in terms of technology, chosen from the secondary activities declared by the firms.

[18] A brief summary on the calculation of accessibility indicators and impedance functions is presented here. For a detailed explanation on adopted procedures refer to Núñez (2012).

municipality where the worker resides, X_j includes the attributes of the hiring firm, and X_J describes the municipality where the firm is located.

The information needed to estimate the probabilities for each *T* (time intervals dedicated to commutation) comes from a 5% sample extracted from the microdata of the Spanish Population Census for year 2001 and published by *INE*. Individuals not working, those classified as freelancers, and workers employed either in more than one municipality or abroad are excluded from the sample, as they have no associated commuting times. Additionally, workers living or employed outside the Spanish Peninsula are also excluded.

Commuting information is grouped in five different time intervals, (i) less than 10 minutes, (ii) between 10 and 20 minutes, (iii) 20 to 30 minutes, (iv) 30 to 45 minutes, and (v) more than 45 minutes. This last time interval is nonetheless excluded as it comprises anomalous information[19]. The final sample covers about 600,000 commuting observations.

The probability of travelling along each time interval required to estimate the equations of expression (10) is computed as follows. (i) All individuals are able to travel along the minimum time interval (up to 10 minutes), i.e. the probability here is degenerated. (ii) Individuals prepared to commute along a given time interval would do it as well along the previous ones. (iii) The probability of commuting over a 45 minutes time interval is zero. (v) Estimations include all individuals commuting, though assigned probabilities vary according to the estimated probability function[20].

Information on the characteristics of firms, municipalities and individuals is also due to the available Census microdata. In relation to workers, subjective characteristics include sex, age and education level. With respect to the municipality where the worker inhabits, we consider the province, size (measured in intervals), and municipality's unemployment rate. In terms of the firm hiring the worker, we reflect the sector of economic activity, size interval[21], and qualification level of employed workers. Lastly, regarding to the municipality

[19] In fact, only 9.4% of individuals commute over the 45 minutes threshold.

[20] For instance, a worker commuting over the 20 to 30 minutes time interval would have a degenerated probability along this time interval and the previous one (i.e. 10 to 20 minutes), and a zero probability for the interval 30 to 45 minutes.

[21] This variable comes from *SABI* database for year 2001.

where the firm is located, the province, size, and municipality's unemployment rate are considered.

We estimate three probit functions, one for each of the commuting time intervals, 10-20 minutes, 20-30 minutes, and 30-45 minutes[22]. For known values of the probability function parameters, and incorporating the information for year 2009 obtained from the data sources detailed in Núñez (2012), the specific probabilities establishing connection between each firm and all Spanish municipalities can be computed.

Year 2009 distances and minimum commuting times between the Spanish municipalities across the urban and intercity road networks have been computed implementing Google Maps enquiries. Firms and workers are thus assumed to be located in municipalities' centroids[23]. The location of the firms is obtained from *SABI* database[24]. The information on resident labour force for each municipality is acquired from the Spanish Labour Force Survey and the municipal Census, whilst jobs are derived from affiliation statistics to the National Social Security Service.

From all this information workers' accessibility indicators can be computed for each firm, by substituting the impedance function by the probability value obtained for the corresponding commuting time interval in each of the available iterations between firms and municipalities, i.e. the one associated to real travelling time across centroids obtained from Google Maps enquiries.

The probability functions for commodity transport take a similar form, although the range of considered attributes is far less compared to the previous case due to the availability of information. They are calculated according to expression (11).

$$P_{ijg}(D) = \alpha_0 + \beta CAO_j + \gamma CAD_L + \sum_j \delta_j M_j \qquad (11)$$

[22] When travelling time is less than 10 minutes, a degenerated probability is assumed.
[23] Geographical coordinates for municipality centroids are obtained from the Spanish National Geographical Institute.
[24] *SABI* database offers information on manufacturing firms located in 4036 different municipalities, although workers and consumers are placed in 8112 Spanish municipalities along year 2009.

Where $P_{ijg}(D)$ is the probability that firm *i*, located in in *j*, moves its production to municipality *g*, located at a distance within the range *D*. CAO_j refers to Origin *Comunidad Autónoma* (i.e. the one where municipality *j* is located), CAD_g is the Destination *Comunidad Autónoma* (i.e. the one where municipality *g* is located) [25], and *M* contains several qualitative variables describing the type of transported commodity.

These probability functions are estimated using microdata from the Permanent Survey on Road Commodity Transport of the Ministry of Infrastructures along the time horizon 2002 to 2009. Transport of commodities being imported or exported are excluded from the sample, as well as those corresponding to trade between third party countries and the ones done by empty trucks. The sample is therefore constrained to the commodity transport in the interior market (80% of transported commodities) and only those made using the road network (94% of the total), amounting to 1,241,495 observations.

Expression (11) is estimated for ten different distance intervals, which are defined according to the observed distribution of transported commodities: less than 20 km, 20-40 km, 40-70 km, 70-100 km, 100-150 km, 150-200 km, 200-250 km, 250-350 km, 350-500 km, and more than 500 km. The initial assignation of probabilities (0 or 1) is carried out in a similar way to that applied for workers' commutations. The probability is degenerate in the case of less than 20 km long transportations, and firms transporting commodities to a given distance are also willing to do so in all inferior distance intervals. Additionally, probabilities are estimated applying weights which depend on the load transported in each journey.

Firms' intermediate consumption and production for year 2009 are obtained from *SABI* database. The composition and distribution of commodities in each intermediate consumption is assumed to be equal to the one revealed by the corresponding sector of economic activity, registered in the Destination of Production Table[26] of the Spanish National Accounts of year 2007. With

[25] Note that expression (11) refers to firm's *i* production. In the case of intermediate consumption, the Origen *Comunidad Autónoma* corresponds to that of municipality *g*, and the Destination one to the *Comunidad Autónoma* where firm *i* is located.

[26] The rows of the Destination of Production Table informs about the economic destination of each product, whilst the columns show the sector of economic activity where the good is destined. Thus the

respect to commodities' structure of final production, the procedure is identical, nonetheless, the distribution is computed from the Origin of Production Table[27] for year 2007. In order to quantify the proportion of each commodity dedicated to intermediate use (intermediate demand) or final use (final demand), we calculate the average of the shares in each of the producing sectors observed in year 2005 Symmetric Table, whilst the distribution in a given product is estimated from the year 2007 Destination of Production Table [28]. The classification of manufacturing activities in the Destination and Origin of Production Tables, as well as that of the Symmetric Table, has been aggregated to the 11 groups of homogenous commodities of the Revised Nomenclature for Transport Statistics (NST/R), used by the EPTMC and the National Classification of Products by Activity (*CNPA*-96) of National Accounts.

The intermediate consumption, the production, and associated commodities' distributions in each municipality are obtained by aggregation of the firms located in them, and applying the corresponding elevation coefficients.

The probability of each commodity's transportation between each firm and municipality is computed substituting the average distribution of firms' commodity flows (in terms of intermediate consumption and final production) and corresponding municipality. Municipalities' income is calculated multiplying the number of inhabitants declared by *INE*'s Municipality Census (year 2009) by the Province per capita income derived from *INE*'s Regional Accounts of the same year[29].

The accessibility indicators of expressions (2) to (4) are computed by substituting each firm-municipality iteration of the impedance function, by the previously estimated probability of commodities' transportation in the distance interval associated to the real distance between centroids of the corresponding firms and municipalities. These distances are calculated in the same manner as for workers' accessibility.

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columns give the distribution by products of the intermediate consumption in each sector of economic activity.

[27] The rows of the Origin of Production Table report the sectors of economic activity producing each good, and the columns, the products obtained by each sector. Thus each row offers the distribution by product of production.

[28] All deflated according to 2009 Index of Industrial Prices.

[29] Municipal income is only available for some *Comunidad Autónoma*. A common methodology for all municipalities is preferred.

C. Control variables in productivity function

The remaining variables included in the productivity functions are obtained from *SABI* database. In the case of firm's foreign trade activity the possibilities are four, (i) no foreign trade activity, (ii) firm exports, (iii) firm imports, and (iv) firm exports and imports. If the firm is associated with foreign owners controlling more than 50% of social capital (OECD control criterion), the firm is assumed to have foreign capital. If a firm participates in more than 50% of social capital of other Spanish or foreign firms, the firm is assumed to have Spanish and/or foreign affiliates, respectively. The age of the firm is calculated by subtracting from 2009 the year when the firm is first constituted. The firm exit variable is obtained from *SABI*'s State variable. If the firm state in year 2009 is different to active and related to an exit scenario, the firm is assumed to exit in year 2009. Lastly, firm's qualification level of workers is derived through a complex mechanism which compares firm's mean wage with that observed in the Province where the firm is located in the corresponding sector of economic activity[30].

5. The effect of accessibility on productivity

Table 1 presents the OLS results of expression (9), which relates firms' productivity with the different accessibility indicators and mentioned control variables. Additionally, all estimations include sector of economic activity (NACE-2 digits) indicators of firms' primary activity. The dependent variable corresponds to the logarithm of TFP estimated using Levinsohn and Petrin procedure. The first four columns of Table 1 refer to estimation results when accessibility indicators are introduced in an isolated manner, i.e. one by one. The fifth column registers results when only the aggregated accessibility to commodities is included. The sixth and final column reports estimation results when both accessibility indicators are considered, i.e. the aggregated accessibility indicator to commodities and the one to workers.

[30] The complete procedure is described in the Annex.

(Table 1 around here)

All of the accessibility indicators, both to workers and commodities, show a positive effect over the TFP, being far larger in the case of commodities. Additionally, results do not change drastically when both accessibility indicators are jointly introduced.

The observed effects over TFP of commodities' accessibility reveal that the accessibility to final consumers (.191) is more important than to intermediate uses (.097), probably due to the existence of previous contracts and business networks ensuring higher client fidelity than in the case of final consumers. Higher volatility with respect to consumers possibly generate larger logistic and distribution costs to firms, and hence, accessibility to final markets gains relevance in firms' performance. The observed elasticity for intermediate consumption is between the two already mentioned values (.122). These estimated values at least double in magnitude those recently available results in the literature analysing the effect of agglomeration or market potential on productivity (Combes et al., 2009; Melo et al., 2009; Puga, 2010; Combes et al., 2011; Holl, 2012; amongst others), and they are only slightly higher than those provided by Brülhart and Mathys (2008). Precisely, the nature of the accessibility indicators here computed can explain the differences in magnitude between provided and already available results. In one side, the inclusion of the individual component of accessibility provokes that certain firm's characteristics, as its size, affect not just productivity but the accessibility indicator itself. On the other, the substantial differences on variance's magnitude of delivered indicators in relation to those market potential ones grounded on inverse distance formulations of the impedance functions (Holl, 2012). Consideration of probabilities estimated from real travelling times or distances incorporates in the impedance function the highest propensity to supply larger markets even from those poorly communicated locations. This results in a relatively lower variance of our indicators and therefore higher elasticity levels.

In terms of workers' accessibility, a lower but statistically significant effect is obtained (.016-.024). Results in this dimension are less conclusive and comparison is not as straightforward, nonetheless they are in line with previous results highlighting a moderate impact over TFP (Gibbons et al., 2010 and Melo et al., 2013).

The differences on the results obtained for the two types of evaluated accessibility are somehow surprising, and they may be possibly caused by the degree of volatility of the accessibility indicators. In order to objectively evaluate the impact of accessibility over TFP, Table 2, based on the estimation registered in the last column of Table 1 (i.e. the results considered as definitive), evaluates the increase in productivity associated to changes in firm's accessibility calculated according to their year 2009 real locations. Moving from percentile 10 to 90 in terms of commodities' accessibility causes a 23.6% increase in productivity, and a 10.8% increase if the accessibility improvement is equivalent to a shift from percentile 25 to percentile 75. In terms of workers' accessibility, the increases in productivity are much more moderate although still relevant, a 5.1% and a 2.5% increase in productivity when accessibility improvements are identified with shifts from the percentiles 10 to 90, and 25 to 75, respectively.

(Table 2 around here)

The differences in obtained results can also be interpreted in terms of the cross-sectional and temporal variation. Although only the former dimension is exploited in the estimated regressions, it is important to notice that there has been a substantial improvement in Spanish urban and intercity infrastructure endowments along the recent years, which has led to notorious progress in everyday mobility. The efficiency gains associated to better infrastructures are already taken into account by firms' productivity, and therefore, cross-sectional variation in workers' accessibility has been reduced. However, commodities' accessibility is more influenced by agents' location and thus the structure and quality of the full road network, where there may still be important connexion problems in certain territories.

Additionally, high unemployment rates in Spanish labour markets erode workers' bargaining power, so labour commuting costs are often undertaken by workers and not shared by hiring firms. Conversely, commodities' transportation costs enter the costs function of the firm, directly affecting its productive efficiency.

Lastly, the productive structure of the Spanish economy may also help in understanding observed differences in estimated elasticities. Spanish manufacturing firms generally produce goods of medium-low technological content, thus the demand for qualified labour is relatively low. This provokes that firms' benefits associated to suitable matching between labour specialisation and required level of qualifications are rather limited. Additionally, labour intensive manufacturing activities will tend in one hand to hire labour located nearby production locations, and in the other, to position their plants in the neighbourhood of large labour markets. This in turn reduces the impact of workers' accessibility on firm's productivity.

With respect to control variables, they are all statistically significant and show the expected signs. Foreign trade activities positively affect firm productivity, the effect being higher if firms engage jointly in both exports and imports. Having affiliates either in Spain or abroad is also associated to better firm performance, and estimated effects are as expected larger than those observed for foreign capital participation. Experienced firms and those hiring higher proportions of qualified labour perform better than the firms exiting the market during the study year.

Obtained results highlight the important role played by infrastructures on firms' productivity. No wonder firms prefer their locations across best endowed territories in terms of road transport infrastructures. Furthermore, accessibility to commodities reveals, at least in the specific case of Spanish, more important to enhance firms' productivity improvements than the accessibility to workers[31].

6. Conclusions

This paper measures the impact on firms' productivity of accessibility goodness to labour markets and commodities. In order to attain it, we estimate a productivity function which includes accessibility indicators as well as those

[31] For robustness check of obtained results, firm size (in four different size classes) was included in regressions. Given that this particular variable is highly correlated with the rest of regressors, results, which did not show significant differences, have not been included in the paper.

control variables determining differences in the level of productivity across firms. We consider two accessibility measures, one to workers and other to commodities.

One of the contributions of this paper is the way in which accessibility is measured. First in terms of the impedance functions, approximated through the estimation of probability functions using microdata, to properly identify the individual features of both, workers and firms. Furthermore, the measurement is at firm level, providing the indicators for more than 60,000 firms and evaluating the distances (or journeys' times) between firms and workers or firms and territories across the full urban and intercity road network. The estimation of the TFP functions uses most updated methodology at firm level and is carried out for almost a hundred different manufacturing activities.

Obtained results confirm that the impact of accessibility on firms' productivity is positive, elasticities ranging from .097 to .192 in the case of commodities, and from .016 to .024 in terms of labour markets. An accessibility improvement to commodities equivalent to a shift from percentile 10 to 90 increases productivity in more than 23%, and 10.5% if the accessibility correction is from percentile 25 to 75. The impact on productivity in terms of workers' accessibility is significantly lower, an approximate 20% reduction is observed with respect to commodities. This is possibly due to the fact that in one hand, workers run with commuting costs instead of hiring firms, and in the other, the relatively less important role played by proper matching between labour demand and supply in Spanish labour markets, as a consequence of the specialisation in manufacturing of medium-low technological content goods.

Obtained results should not be mistaken for policy recommendation purposes. Although the positive role of road infrastructure in firms' productivity is confirmed, this does not necessarily mean that any type of transport infrastructure investment is going to generate indicated effects on productive efficiency. For this to occur, new infrastructures should increase connection between firms, firms and final consumers, and to a lesser extent, between firms and workers. Productivity improvements are expected to be larger, the most oriented they are to the productive sector, the higher is the number of firms affected by them, and rather than concentrating in particular territories, they should transform the complete infrastructure network by means of increasing connectivity. Precisely, given provided results, infrastructure policy in Spain should concentrate further on the improvement of commodity transport infrastructures, which will definitely deliver efficiency gains to Spanish productive system.

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Annex

In order to obtain the level of qualification of the labour demanded by firms (i.e. the one deduced from the type of activities carried out by employees), we carry out a rather complex measurement procedure as the information is not directly available in *SABI* database for considered time horizon. Several data statistical sources and time periods are considered depending on the availability of information. For each firm included in *SABI* we calculate the average wage for years 2001 and 2009 (w_i^{2001} and w_i^{2009}), as the ratio between labour expenditures and the number of employees. We then obtain a weighted average for the wage (considering firms' size defined in employment) by province (w_p^{2001} and w_p^{2009}) and by activity and province for both years (w_{sp}^{2001} and w_{sp}^{2009}). Additionally, from the microdata 5% sample of the *INE* 2001 Population Census, we calculate by province (h_{jp}^{2001}) and by province and sector (h_{jsp}^{2001}) the number of workers in each of the three available educational levels, primary (*j* = 1), secondary (*j* = 2), and tertiary (*j* = 3). Next we compute the average number of workers' years of schooling in each province (H_p^{2001}) and each activity and province (H_{sp}^{2001}) according to expression (A.1).

$$H_{\cdot}^{2001} = 6 \times h_{1\cdot}^{2001} + 12 \times h_{2\cdot}^{2001} + 17 \times h_{3\cdot}^{2001} \qquad \text{(A.1)}$$

Assuming that the differences in relative wages observed across activities within each province with respect to the provincial average are due to qualification differences, expression (A.2) can be estimated.

$$\frac{w_{sp}^{2001}}{w_p^{2001}} = \alpha + \beta \frac{H_{sp}^{2001}}{H_p^{2001}} + \varepsilon \qquad \text{(A.2)}$$

Rearranging expression (A.2) and assuming that the relationship holds in time, we obtain by expression (A.3) the average level of education (average number of schooling years) for workers in a given activity and province in year 2009[32].

$$\widehat{H_{sp}^{2009}} = \left(\frac{w_{sp}^{2009}}{w_{p}^{2009}} - \hat{\alpha}\right)\frac{H_{p}^{2009}}{\hat{\beta}} \qquad (A.3)$$

Similarly, wage disparities amongst firms engaged in a given activity and located in a particular province must be originated from differences in the level of employees' qualifications. Expression (A.2) can be rewritten to obtain expression (A.4) for year 2009.

$$\frac{w_{spi}^{2009}}{w_{sp}^{2009}} = \hat{\alpha} + \hat{\beta}\frac{H_{spi}^{2009}}{\widehat{H_{sp}^{2009}}} \qquad (A.4)$$

Where w_{spi}^{2009} and H_{spi}^{2009} are respectively the wage and the average number of schooling years for firm's *i* employees working in province *p* and activity *s*. Rearranging expression (A.4), the level of qualification of firm's *i* employees can be estimated by expression (A.5) [33]

$$\widehat{H_{spi}^{2009}} = \left(\frac{w_{spi}^{2009}}{w_{sp}^{2009}} - \hat{\alpha}\right)\frac{\widehat{H_{sp}^{2009}}}{\hat{\beta}} \qquad (5)$$

[32] Note that w_{sp}^{2009} and w_{p}^{2009} are known in expression (A.2) from *SABI*. H_{p}^{2009} is obtained from human capital database of IVIE.

[33] w_{spi}^{2009} and w_{sp}^{2009} are obtained from *SABI* database, whilst $\widehat{H_{sp}^{2009}}$ is estimated from expression (A.3).

TABLES

TABLE 1. ACCESSIBILITY EFFECTS ON THE PRODUCTIVITY OF SPANISH MANUFACTURING FIRMS.

Dependent variable	TFP 2009					
Accessibility to workers	0.024*** (0.003)					0.016*** (0.003)
Accessibility to commodities					0.192*** (0.008)	0.187*** (0.008)
Accessibility to intermediate consumption		0.122*** (0.007)				
Accessibility to firms' intermediate uses			0.097*** (0.005)			
Accessibility to final markets				0.191*** (0.007)		
Only exports	0.342*** (0.010)	0.340*** (0.010)	0.339*** (0.010)	0.338*** (0.010)	0.340*** (0.010)	0.340*** (0.010)
Only imports	0.308*** (0.011)	0.310*** (0.012)	0.309*** (0.012)	0.307*** (0.011)	0.309*** (0.011)	0.309*** (0.011)
Exports and imports	0.434*** (0.008)	0.436*** (0.008)	0.433*** (0.008)	0.430*** (0.008)	0.433*** (0.008)	0.433*** (0.008)
Has Spanish affiliates	0.338*** (0.009)	0.339*** (0.009)	0.339*** (0.009)	0.337*** (0.009)	0.338*** (0.009)	0.337*** (0.009)
Has foreign affiliates	0.348*** (0.017)	0.345*** (0.017)	0.347*** (0.017)	0.344*** (0.017)	0.343*** (0.017)	0.341*** (0.017)
Foreign social capital	0.324*** (0.019)	0.300*** (0.020)	0.308*** (0.019)	0.303*** (0.019)	0.298*** (0.019)	0.296*** (0.019)
Firm exits	-0.165*** (0.016)	-0.165*** (0.016)	-0.171*** (0.016)	-0.172*** (0.016)	-0.170*** (0.016)	-0.172*** (0.016)
Firm age	0.084*** (0.003)	0.081*** (0.003)	0.080*** (0.003)	0.078*** (0.003)	0.079*** (0.003)	0.078*** (0.003)
Employees qualification level	0.652*** (0.006)	0.668*** (0.006)	0.659*** (0.006)	0.665*** (0.006)	0.669*** (0.006)	0.666*** (0.006)
N	63236	60707	60707	60707	60707	60704
R2	0.332	0.339	0.341	0.343	0.342	0.343

All estimations are carried out by OLS. Age and human capital are evaluated in logarithms. Remaining ones are qualitative variables. All estimations include a sector of activity indicator, 2 digits NACE-93.

TABLE 2. PERCENTAGE CHANGES IN PRODUCTIVITY DUE TO ACCESSIBILITY IMPROVEMENTS EXPRESSED IN PERCENTILES

Accessibility to commodities

	Percentile 25	Percentile 50	Percentile 75	Percentile 90
Percentile 10	9.29	15.92	20.06	23.64
Percentile 25		6.63	10.77	14.35
Percentile 50			4.14	7.72
Percentile 75				3.59

Accessibility to workers

	Percentile 25	Percentile 50	Percentile 75	Percentile 90
Percentile 10	2.03	3.50	4.47	5.12
Percentile 25		1.48	2.45	3.09
Percentile 50			0.97	1.62
Percentile 75				0.65