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# Does productivity change in the territory? A methodological proposal for the estimation of the GDP of Spanish cities

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**Abstract:** The Gross Domestic Product (GDP) is a key indicator in urban economics, as it is included in the methodological manuals on urban statistics both at the international (UN-Habitat) and European (Eurostat) levels. However, most Spanish cities do not have an estimate of GDP. In addition, some of the cities that do have a GDP estimate are poorly updated since they do not have an annual series and, if they are located in different regions (Autonomous Communities CCAA), the comparability of the results among them cannot be guaranteed.

The aim of this work is to contribute to fill this information gap by presenting a methodology for GDP estimation at the city level based on the estimation of differential productivities by sector of the city with respect to its region. To this end, we use the information on differential salaries by sector between the cities and their regions, which for the period 2010-2016 can be estimated from the Continuous Sample of Labour Lives (in Spanish, Muestra Contínua de Vidas Laborales-MCVL). The GDP results thus estimated show values that seem to indicate that relevant aspects of the economy of the cities are being collected, such as, among others, potential economies of agglomeration.

The application of the proposed methodology would mean moving from the situation described above to one in which, for more than a hundred of the most populated Spanish cities, a fully comparable GDP series from 2010 to 2016 could be available, with an annual update, and with a methodology that takes into account one of the most relevant features of an urban economy, such as the agglomeration effect.

**Keywords**: City GDP, Productivity, Agglomeration, Wages
**JEL**: R11

## 1. INTRODUCTION

GDP is a key indicator in urban economy, as it is included in the methodological manuals on urban statistics at both the international (UN-Habitat) and European (Eurostat) levels. For example, within the framework of the United Nations Program for Cities (UN-Habitat), a method for calculating municipal GDP has been proposed based on employment and productivity data (UN-Habitat 2009). However, most Spanish cities do not have a GDP estimate[1]. In addition, some of the cities that do have a GDP estimate present a poor update since they do not have an annual series and, if they are located in different regions (Autonomous Communities CCAA), the comparability of the results among them cannot be guaranteed.

The aim of this work is to contribute to fill this information gap by presenting a methodology for GDP estimation at the city level based on the estimation of differential productivities by sector of the city with respect to its region.

In 2015, the Barcelona City Council started a project to estimate the GDP of Barcelona. Although estimations of municipal GDP can be found in the official statistics, it was considered necessary to carry out a new approximation in order to obtain more timely information, with greater breakdown by sector and with GDP growth results in real terms (and not only of nominal growth). Moreover, a relevant aspect that needed to be considered was to include the agglomeration effect of urban economies into the estimation. This effect is an important element of the economy in large cities, as it is shown in urban economic theory. For this reason it was necessary to include it in the GDP estimates for Barcelona.

At the beginning of 2016, the first GDP report on Barcelona for the years 2010-2014 was published. Shortly after, the GDP estimation for the Metropolitan Area of Barcelona (AMB)[2] was also addressed. The results for the AMB were analysed by the Institut d'Estudis Regionals i Metropolitans de Barcelona (IERMB). At present, the latest available data corresponds to 2017.

[1] In this document, the terms GDP and GVA are used interchangeably despite being different concepts. This is so because, following the Eurostat criterion, from the point of view of territorial estimation, the GDP and the GVA of a territory (cities in our case) have the same weight with respect to the national economy and, therefore, once estimated GVA, the calculation of GDP is immediate.

[2] Although the AMB corresponds to the acronym of the public administration of the Metropolitan Area of Barcelona, in this paper we use it to refer to the corresponding territory, made of Barcelona and other 35 surrounding municipalities. The constitution of the AMB as a public administration was passed by the Parliament of Catalonia on July 21st 2011 in accordance with Law 31/2010.

The strategy for the estimation of the GDP was the usual that is used in economics accounting. In the first place, the GDP for the base-year 2011 (corresponding to the Input-Output Tables in Catalonia) was estimated. The average productivities by sector of Catalonia were corrected for Barcelona using the unilocalized companies' productivity in Barcelona and Catalonia. Then the annual series were projected, but assuming equal variations by sector in productivity in Catalonia and Barcelona[3].

This last assumption, which implies supposing a fixed agglomeration effect over time, was improved with the study "*GDP estimation for Barcelona and the Barcelona Metropolitan Area. Methodological improvement in the estimation of productivity dynamics with wage information*" (2017)[4]. This study was the starting point of the present work since it applied wage differentials by sector between Barcelona and Catalonia to estimate a productivity differential between the city and the region. In the present work, we apply the same methodological strategy to other Spanish cities. The wage differences by sector of each city with respect to its region are estimated with the Continuous Sample of Labour Lives (MCVL).

This document presents, first, the theoretical foundation that relates wages and productivity. Then, with data from the Regional Accounting of Spain (CRE) published by the Spanish National Statistical Institute (INE), we estimate the coefficient that relates wages with productivity. In the following section, we obtain the GDP estimates from this approach, including a discussion on the most appropriate source of data for employment at city level, comparing two options: the affiliation with the Social Security and the estimates of jobs (localized employment) from the Urban Audit. Having decided which employment data is to be considered the most reliable in each case, we present the GDP estimates for ten Spanish cities. Finally, we compare these GDP estimates for a subset of five cities in which their corresponding Regional Statistical Institute publish a GDP figure. From this comparison, we deduce the possibility that the proposed methodology is able to capture the agglomeration effect to a greater extent than the implemented procedures by the aforementioned Statistical Institutes do.

[3] Gabinet Tècnic de Programació. Ajuntament de Barcelona (2015): *El PIB de Barcelona 2010-2014*.

[4] There are Spanish and Catalan versions (Raymond et al. 2018).

## 2. THEORETICAL FOUNDATION

In general, it can be assumed that the generation of Gross Value Added (GVA) by companies can be approximated by a production function of the type:

$$GVA = f(N, K, Z)$$

where N is the occupation, K is the capital and Z the rest of productive inputs. If companies maximize benefits, the equality between salary and marginal productivity of labour will be verified. That is to say:

$$\frac{\partial GVA}{\partial N} = \frac{\partial f(N, K, Z)}{\partial N} = W$$

where W is the salary. The established approximation supposes that this marginal productivity of labour will correspond to the apparent labour productivity (ALP).

In the case of a Cobb-Douglas production function, it is verified:

$$GVA = AN^{\beta_1} K^{\beta_2} Z^{\beta_3}$$

Taking logarithms:

$$lnGVA = lnA + \beta_1 lnN + \beta_2 lnK + \beta_3 lnZ$$

Therefore:

$$\frac{\partial GVA}{\partial N} = \beta_1 \frac{GVA}{N} = W$$

It should be noted that the ratio between Value Added and employment is the apparent labour productivity (ALP) and, therefore:

$$ALP = \frac{1}{\beta_1} W$$

Finally, taking logarithms the following can be obtained:

$$lnALP = -ln\beta_1 + lnW = \alpha + lnW$$

That is to say, assuming a Cobb-Douglas production function and that a correspondence between wages and productivity exists, is equivalent to

assuming a unitary elasticity in the double logarithmic relation between ALP and wages.

However, a more general alternative is to not impose the restriction of unitary elasticity a priori and to estimate a model of the type:

$$lnALP = \alpha + \beta lnW$$

## 3. MODELLING THE RELATIONSHIP BETWEEN WAGES AND PRODUCTIVITY: THE VALUE OF β

As indicated above, the aim of this study is to obtain an estimate of the GVA of the city based on the β relationship established between average wages and the observed apparent labour productivity. Logically it would be optimal that these estimates of β could be derived from a panel data of GDP and wages at the city level, but the availability of this data is very limited.

For this reason, the use of the official data at the regional level provided by INE's *Regional Accounting of Spain* (CRE) has been chosen. The data available contain observations for each of the 17 regions for each sector for the period 2000-2016. The combined set of regions has been used to estimate a fixed-effects model by region in which the dependent variable is the logarithm of the apparent labour productivity and the explanatory one, the logarithm of wages. The breakdown by sector used is shown in Table 1.

The apparent labour productivity is calculated as the ratio between GVA and total employment, and wages are calculated as the ratio between remuneration and salaried workers. Both magnitudes are in logarithms.

Under the standard assumptions of the fixed-effects model, the OLS estimator is unbiased. However, in this estimation the different regions receive the same weight, therefore, if due to the small number of observations for a given region there is an atypical observation, an undue weighting would be given to this atypical observation. For this reason, three alternative estimators have been considered in addition to the OLS estimator[5].

1. **OLS estimator:** All observations are given the same weight.

[5] For a detailed description of the alternative estimators used, see Raymond et al (2018). Although the possibility of estimating a dynamic β was considered, this option was finally discarded in the simulation phase of the municipal and metropolitan GVA since it did not provide significant improvements with respect to the other estimators of β.

2. **Weighted estimator, by population:** The selected weighting criterion is the value of the employed population in each sector in the respective region.
3. **Weighted estimator, corrected for heteroscedasticity:** The selected weighting criterion is the value of the standard deviation of the random disturbance in the region in the simple OLS model: $w_i = \frac{1}{\sigma_i}$.
4. **Double weighted estimator, by population and corrected for heteroscedasticity:** The selected weighting criterion is a composed weight obtained by means of the product of the preceding two: $cw_i = N_{it}/\sigma_i$

*Table 1. Aggregation of economic sectors according to the CRE*

| NACE rev.2 | | |
|---|---|---|
| 01-03 | A | Agriculture, livestock, forestry and fishing |
| 05-39 | B-E | Extractive industries; Manufacturing industry; Supply of electric power, gas, steam and air conditioning; Water supply, sanitation activities, waste management and decontamination |
| 41-43 | F | Construction |
| 45-56 | G-I | Wholesale and Retail; Repair of motor vehicles and motorcycles; Transport and storage, hospitality |
| 58-63 | J | Information and communication |
| 64-66 | K | Financial and insurance activities |
| 68 | L | Real estate activities |
| 69-82 | M-N | Professional, scientific and technical activities; Administrative activities and auxiliary services |
| 84-88 | O-Q | Public administration and defence; compulsory social security; Education; Health activities and social services |
| 90-98 | R-U | Artistic, recreational and entertainment activities; Repair of household items and other services |

Source: Own elaboration from CRE, INE.

Starting from $\ln ALP = \alpha + \beta \ln W$, the interpretation of the possible values of β is derived. If β=1, changes in wages are proportionally transferred to the variations in productivity. If β>1, the changes in wages translate into a variation in productivity proportionally greater than the variation in wages. On the other hand, if β<1 the changes in wages translate into a productivity variation proportionally lower than that of wages.

Next, Table 2 summarizes the results of the four estimates of β for all sectors[6]. The goodness of fit ($R^2$) of the four models are considerably high. The values of the β coefficients are statistically significant in practically all the sectors and the average value for all the sectors approaches the unit, that is, on average the wage differentials are translated proportionally to the variations in productivity.

As can be seen, the estimator that uses a double weighting (weighting by the adjustment capacity - σ - and by the size of the sector - N -) is the one that shows greater stability in all the sectors and, therefore, it has been the chosen estimator to simulate the GVA of the selected Spanish cities, together with the more simplified option that assumes β=1.

*Table 2. Estimation results of the β coefficients by sector*

| | Sectors | OLS | Weighted LS by σ | Weighted LS by N | Double weighted LS (σ, N) | Maximum | Minimum |
|---|---|---|---|---|---|---|---|
| A | Agriculture, livestock, forestry and fishing | 0.50 | 0.66 | 0.50 | 0.62 | 0.66 | 0.50 |
| B-E | Extractive and manufacturing industry; supply of energy, gas, steam and air; supply of water, sanitation, waste management and decontamination | 1.36 | 1.30 | 1.36 | 1.30 | 1.36 | 1.30 |
| F | Construction | 1.07 | 1.04 | 1.06 | 1.05 | 1.07 | 1.04 |
| G-I | Wholesale and Retail; vehicle repair; transport and storage, hospitality | 0.82 | 0.81 | 0.87 | 0.84 | 0.87 | 0.81 |
| J | Information and communications | 0.09 | 0.40 | 0.23 | 0.55 | 0.55 | 0.09 |
| K | Financial and insurance activities | 0.94 | 1.00 | 0.94 | 1.01 | 1.01 | 0.94 |
| L | Real estate activities | 2.11 | 1.58 | 2.14 | 1.60 | 2.14 | 1.58 |
| M-N | Professional, scientific and technical activities; administrative activities and auxiliary services | 0.05 | 0.49 | 0.21 | 0.58 | 0.58 | 0.05 |
| O-Q | Public administration and defence; compulsory education; health and social services activities | 1.08 | 1.07 | 1.06 | 1.06 | 1.08 | 1.06 |
| R-U | Artistic, recreational and entertainment activities; repair of household items and other services | 0.72 | 0.77 | 0.73 | 0.77 | 0.77 | 0.72 |
| | Total | 1.11 | 1.10 | 1.11 | 1.10 | 1.11 | 1.10 |

Source: Own elaboration from CRE (INE).

[6] The results shown correspond to the estimates made with the most recent data corresponding to the period 2000-2016. In contrast, the results published in Raymond et al (2018) correspond to the estimates made with data for the period 2000-2015.

## 4. ESTIMATION OF THE GVA OF THE CITIES

From the estimations of β carried out and once the chosen elasticities have been decided, that is, β=1 and the β estimator with double weighting, the next step is to apply these values to obtain the apparent labour productivity (ALP) at the city level, from which it is possible to obtain an estimation of the corresponding GVA.

We assume that at regional level is verified that:

$$lnALP_{it} = \alpha_i + \beta lnW_{it} + v_{it}$$

At the city scale, it is also verified that:

$$lnALP^*_{it} = \alpha_i + \beta lnW^*_{it} + v^*_{it}$$

where "lnALP" corresponds to the logarithm of the apparent labour productivity in the region, "lnW" is the logarithm of wages in the same area. "$v_{it}$" is the corresponding residual that includes the rest of the effects that have not been taken into account. The sub-index "i" refers to the economic sector, the sub-index "t" corresponds to the year and the symbol * refers to the city scale.

The values of ALP*, therefore, can be obtained simply by the difference (lnALP - lnALP*), so that:

$$lnALP^*_{it} = \ln ALP_{it} + \beta(lnW^*_{it} - lnW_{it}) + (v^*_{it} - v_{it})$$

If we apply the conditional expectation to the previous population expression, the following can be obtained:

$$E[lnALP^*_{it} | lnALP^*_{it}, lnW^*_{it}, lnW_{it}] = \ln ALP_{it} + \beta(lnW^*_{it} - lnW_{it}) + E[v^*_{it} - v_{it}]$$

Under the hypothesis that $E[v^*_{it} - v_{it}] = 0$, therefore:

$$lnALP^*_{it} = \ln ALP_{it} + \hat{\beta}(lnW^*_{it} - lnW_{it})$$

is the expression that allows us to obtain the values of the ALP*. Note that this expression implies that the fixed effect of the city is equal to that of the region.

The selected cities are those that in 2011 have more than 150,000 jobs (see Table 3). Additionally, the cities of Santiago de Compostela and Oviedo have

also been included, although their employment in 2011 is lower, since they are cities whose Regional Statistics Institutes publish the GDP of the city, which will make it possible to compare with our results.

*Table 3. Selected Spanish cities and corresponding region (Autonomous Community)*

| City | Region |
|---|---|
| Barcelona | Catalonia |
| Bilbao | Basque Country |
| Madrid | Madrid |
| Malaga | Andalusia |
| Oviedo | Asturias |
| Palma de Mallorca | Balearic Islands |
| Santiago de Compostela | Galicia |
| Seville | Andalusia |
| Valencia | Valencia |
| Zaragoza | Aragon |

Source: Own elaboration.

To perform these simulations, three data sets are needed (see Table 4). It should be noted that in all cases an equivalent breakdown by sector is available. The primary sector is excluded from this treatment because of its low weight in the selected cities (it is not possible to use the MCVL to capture salary differences in this sector). Therefore, in this sector we apply the regional average productivity. This is not a problem considering that the contribution of this sector to urban GDP is residual.

*Table 4. Data sets used in the city GVA simulations*

| Data set | Source | Period of time | Units | Territorial disaggregation |
|---|---|---|---|---|
| GVA | CRE | 2000 – 2016 | Thousands of euros | Autonomous Communities |
| Employment | CRE | 2000 – 2016 | Thousands of people | Autonomous Communities |
| | Social Security | 1999 – 2017 | Individuals | Municipalities |
| | Urban Audit | 2010 – 2016 | Individuals | Selection of municipalities with >50,000 inhabitants |
| Daily wages | MCVL | 2010 – 2016 | Euros | Municipalities with >40,000 inhabitants |

Source: Own elaboration.

The estimation of the GDP of the city implies choosing between several options regarding the calculation of productivity, jobs and the value of β.

The regional productivity could be calculated using the CRE employment, but it seems more convenient to use the Social Security data since this source is the only one available for cities and it improves the comparability between cities and regions.

More complex is the choice of the source of jobs data in the cities. There are two sources of information available: the localized employment of Urban Audit (Eurostat)[7] and workers affiliated with the Social Security (in all regimes)[8]. In addition to these two sources that can be used directly, we identify a third option: a projection of the Urban Audit data (Eurostat) for the base year 2011, based on the time trend observed in the Social Security data.

To decide the most appropriate option, we made an analysis of the graphic information of the different options presented in Figure 1. The conclusions are the following:

1. Eurostat's Urban Audit series show significant volatility in many cities (practically half of them). In addition, at sector level, two years of the considered period are missing, aggravating the problem of volatility. Therefore, its direct use is discarded.

2. The Social Security series overestimates the employment by the well-known "headquarters effect". For this reason, its direct use is also discarded.

3. The option labelled "Projection" seems to be the best solution for most cities (eight out of ten cities). This series uses the Urban Audit level of employment for the base year (fixed in 2011) and projects the rest of the years with the evolution shown by the Social Security series.

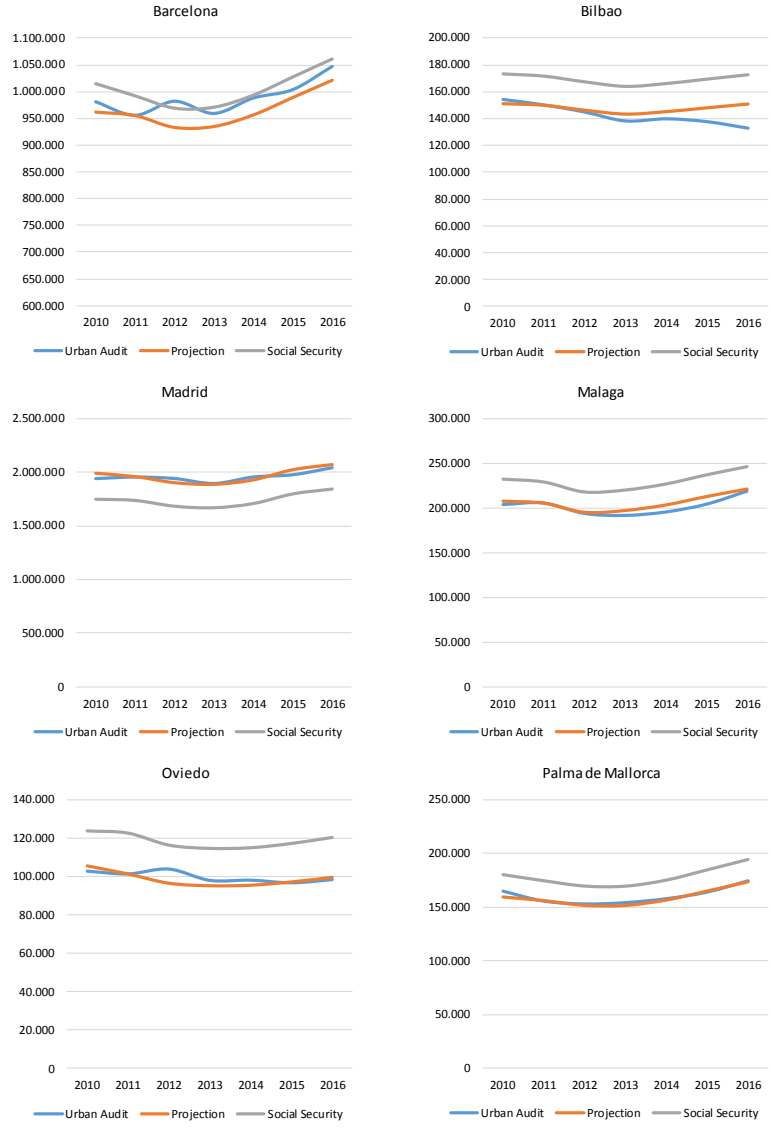
4. Two anomalous cases are detected: Madrid and Seville. In these two cases, the Urban Audit series show employment levels even

[7] The Urban Audit project was launched in the late 1990s in order to collect statistical information comparing the quality of life of major European cities. Since then it has been developing in different phases or cycles of data collection, approximately three years each. The project is sponsored by the European Commission Directorate-General Regional and Urban Policy (DG Regio) in collaboration with Eurostat and is currently in its sixth collection round. The data for Spanish cities is published by INE.

[8] The Spanish Social Security System is a set of schemes through which the state guarantees the people included in their scope of application, in this case due to carrying out a professional activity, suitable protection for the contingencies and situations defined by the law. Affiliation is mandatory for all workers.

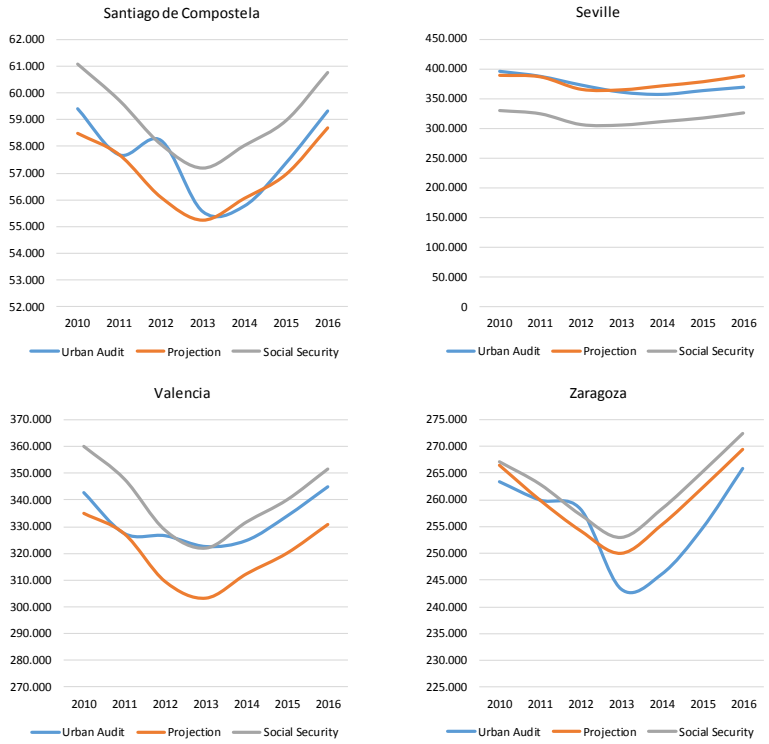
higher than Social Security, so the "headquarter effect" is not only not corrected, but increased. For this reason, in these two cities we have opted to use the Social Security series directly.

*Figure 1. Jobs in the cities according to Urban Audit (Eurostat), projection from 2011 Urban Audit (Eurostat) with Social Security trend, and Social Security (continues)*




Source: Own elaboration.

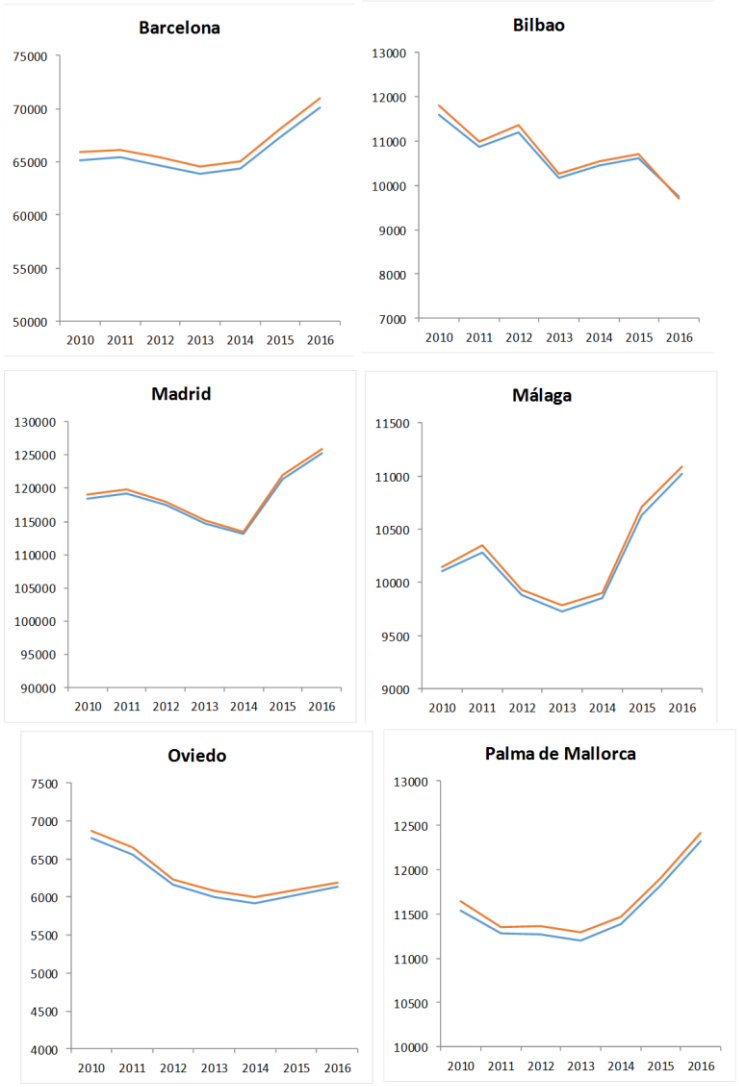
*Figure 1. Jobs in the cities according to Urban Audit (Eurostat), projection from 2011 Urban Audit (Eurostat) with Social Security trend, and Social Security (continuation)*




Source: Own elaboration.

Below are the results of the GVA simulations obtained for the ten selected Spanish cities (see Figure 2). The results for the two options for the value of β (unit value or econometric estimation with double weighting) are included.

*Figure 2. GVA of the cities obtained according to the value of β (in millions of euros) (continues)*




β = 1
estimated β
Source: Own elaboration.

*Figure 2. GVA of the cities obtained according to the value of β (in millions of euros) (continuation)*


β = 1
estimated β
Source: Own elaboration

The results shown are in levels for the period 2010 to 2016. We found that neither in growth taxes nor in levels there were significant differences between applying β=1 or an estimated β. In fact, as shown in Raymond et al (2018), the results in terms of GVA are practically equivalent[9].

[9] Raymond et al. (2018) perform a contrast of hypotheses on the four β coefficients (section 3) twice, one for estimates in levels and one in first differences of logarithms, in which it is concluded that, of eight contrasts made, the null hypothesis that the simplified predictor (β=1) constitutes an unbiased predictor of the more elaborated predictor (β estimated), is not rejected, which justifies the use of the simplified approximation.

Therefore, for simplicity reasons, city GVA estimates will be made based on a value of β=1. Raymond et al 2018, tests the relationship between apparent labour productivity and wages using microdata from the Survey on Business Strategies (SEPI Foundation). The results show that the elasticity between apparent labour productivity and wages is approximately equal to the unit. So, we conclude there is a good basis to apply this value, both from a theoretical point of view and from the estimates that relate productivity and wages, using microdata as well as with territorially aggregated data.

## 5. COMPARISONS WITH THE GVA OF THE CITIES FROM OFFICIAL SOURCES

In order to assess the results obtained from the estimations of the GVA of the cities we have compared them to those published by the corresponding Regional Statistical Institutes. Only five of the ten cities selected for this study have an estimate of the GVA published by these Institutes: Barcelona (Statistical Institute of Catalonia - Idescat), Madrid (Institute of Statistics of the Community of Madrid), Bilbao (Basque Statistical Office - Eustat), Oviedo (Asturian Society of Economic and Industrial Studies - SADEI) and Santiago de Compostela (Statistical Institute of Galicia - IGE).

The data published by these Institutes are not homogeneous, since in some cases they publish information of GDP and in other cases of GVA. In addition, unfortunately, in most cases a time series is not available. Therefore, in order to compare these values with the values obtained here of the GVA of the city, we have proceeded firstly to a homogenization of the results by means of their transformation to GVA in those cases where only the GDP value is available. Following the Eurostat criterion, taxes are assumed to be proportional to the regional GVA share in the country's total. Therefore, the value of taxes thus calculated has been subtracted from the GDP values to obtain the GVA of the city.

As can be seen in Table 5, the estimate of the GVA of the cities that we obtain is systematically higher than the GVA published for the five cities studied, specifically between 8% and 18% higher. This result could indicate, in our opinion, that the GVA estimated here, that are based on the methodology developed in Raymond et al. (2018), would be better capturing the agglomeration effect associated with cities.

*Table 5. Comparison between GDP and GVA of the city published by different Regional Statistical Institutes and the GVA estimated for the city (millions of euros).*

| City | Year | Published GDP | Published GVA | Homogeneous GVA (1) | Estimated GVA (2) | Difference (1) - (2) (in %) |
|---|---|---|---|---|---|---|
| Barcelona | 2014 | 65,410 | 59,528 | 59,528 | 64,375 | -7.5 |
| Barcelona | 2015 | 66,609 | 60,155 | 60,155 | 67,294 | -10.6 |
| Bilbao | 2012 | 10,828 | na | 9,908 | 11,182 | -11.4 |
| Madrid | 2015 | 122,609 | na | 112,187 | 121,399 | -7.6 |
| Oviedo | 2014 | na | 4,831 | 4,831 | 5,918 | -18.4 |
| Santiago | 2014 | 3,127 | na | 2,861 | 3,235 | -11.6 |

(1) When there is no published GVA, the GVA is calculated from the published GDP and homogenized according to the Eurostat criterion.
(2) Corresponds to the estimation made in this study, using employment data from a projection of Urban Audit values using the time trend from Social Security data (except for Madrid, where the data source is Social Security) and β=1.
Source: Own elaboration from Idescat, Eustat, Instituto de Estadística de la Comunidad de Madrid, SADEI and IGE.

To quantify in a simplified way this possible agglomeration effect, we have calculated the quotient between the average city salary and the average regional salary (see Table 6).

*Table 6. Agglomeration effect (approximation)*

| City | Year | Regional daily wage (eur) (1) | City daily wage (eur) (2) | Difference (1) – (2) (in %) |
|---|---|---|---|---|
| Barcelona | 2014 | 81.49 | 90.19 | -9.6 |
| Barcelona | 2015 | 83.31 | 92.69 | -10.1 |
| Bilbao | 2012 | 95.36 | 110.04 | -13.3 |
| Madrid | 2015 | 91.44 | 95.60 | -4.4 |
| Oviedo | 2014 | 75.66 | 85.78 | -11.8 |
| Santiago | 2014 | 67.89 | 73.05 | -7.1 |

Source: Own elaboration from MCVL.

A correlation between, on one side, the difference between our estimations and those from the Regional Statistical Institutes (Table 5, last column), and on the other side, the estimation of the agglomeration effect (Table 6, last column) can be remarked. That is, if we suppose that this effect does not exist, then the estimated values of GDP would be more similar to those of the published GDP.

So far, we have referred exclusively to the information published by the Regional Statistical Institutes. In the case of Madrid and Barcelona a further comparison can be made between the estimates made here and those offered

by their City Councils. In the case of Barcelona, as mentioned at the beginning of this document, the wage differential method has been adopted, but only to estimate the annual growth in productivity from the base year. The GVA level is estimated using data of unilocalized companies. On the other hand, Madrid has a very elaborate accounting system, with its own directory and business surveys. Table 7 shows the comparison between the estimates published by each City Council (column 1) and those estimated here using our methodology (column 2). These figures show a better adjustment than those from the previous comparison (Table 5), so that we can conclude that both the Madrid City Council and the Barcelona City Council reflect the productivity differentials and, in particular, the agglomeration effect, to a greater extent than their respective Regional Statistical Institutes.

*Table 7. Comparison between city the GVA of the city published by the City Councils and the estimated GVA of the city (millions of euros).*

| City | Year | Published GVA (1) | Estimated GVA (2) | Difference (1) - (2) (in %) |
|---|---|---|---|---|
| Barcelona | 2014 | 66,081 | 64,375 | 2.7 |
| Barcelona | 2015 | 68,061 | 67,294 | 1.1 |
| Madrid | 2014 | 112,161 | 113,163 | -0.9 |
| Madrid | 2015 | 116,868 | 121,399 | -3.7 |

Source: Own elaboration from Madrid City Council and Barcelona City Council.

## 6. CONCLUSIONS

The main conclusions of this study can be summarized in the following points:

1. There is a significant lack of knowledge of the macroeconomics of our cities, especially due to the lack of estimations of annual GDP and the structure by economic sector of the GVA.
2. The United Nations Programme for cities (UN-Habitat) has proposed a methodology for calculating the GDP of cities based on employment and productivity information. This method has been used by Spanish Regional Statistical Institutes. The procedure involves having reliable data on jobs by sector and a reliable approximation of productivity also by sector for the urban economy.
3. In relation to the employment by sector located in cities, besides the decennial information of the censuses (which provide information on labour mobility), two other sources are systematically available annually: Social Security affiliation and Urban Audit. It is known that the first has biases affecting the total amount (stemming from the "headquarters effect") and the second has problems of temporary volatility. Therefore, a reasonable option is to assume a base year of Urban Audit data (we opted

for the year 2011) and project annually the employment following the Social Security data trend. This procedure seems to be the best option for the cities considered with the exception of two cases, Madrid and Seville, whose Urban Audit data on employment levels are higher than those of Social Security, which could worsen the problem of "headquarters effect".

4. Regarding productivity by sector, we show a clear relationship between it and wages by sector. This relationship is plausible from both a theoretical and econometric point of view. On this basis, the availability of salaries by sector at the city level offered by the Continuous Sample of Labour Lives (MCVL) is an opportunity to reliably estimate productivity by sector for the economies of larger Spanish cities.
5. In the calculation of productivity, the response of wage differences on productivity can be approximated by a coefficient of $\beta=1$ or alternatively with an estimation of the parameter $\beta$. Since the results are similar in both cases, for simplicity we adopt $\beta=1$, that is to say, variations in wages translate into proportional variations in productivity.
6. Finally, when comparing the estimated GDP of the cities obtained from the proposed procedure with the results published by the Regional Statistical Institutes, we observe that the results of these institutes are systematically below those calculated here. This difference is related to the local productivity differential, so we can consider the possibility that, in their approaches, an effect stemming from agglomeration or other sources, that imply greater productivity by sector in larger Spanish cities, may not be fully captured.

In short, we can conclude that the application of the proposed methodology could improve the present availability of information regarding GDP of Spanish cities. It would involve moving from a situation in which only some Spanish cities have an estimation of their GDP (and in many cases, only for one year) to a situation in which more than a hundred of the most populated Spanish cities could have one, for the years from 2010 to 2016 and updated yearly, fully comparable and including one of the most relevant features of an urban economy, such as the agglomeration effect, which affects the productivity of the activities that take place in the city.

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