Testing Baumol's diseases in the German economy

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Abstract. In his paper "Baumol's diseases: a macroeconomic perspective", Nordhaus (2008) applies a new testing framework in order to estimate the six hypotheses that lie at the core of Baumol's (1967) model, following an industry perspective that neglects the input-output structure of the economy. In this work, we extend Nordhaus' testing framework to estimate Baumol's diseases in the German economy over the period 2001-2014 according to a subsystem perspective, which allows us to incorporate input-output linkages in the Baumolian framework. While our results support the cost and price disease hypothesis and the hypothesis of uniform wage growth, we do not find robust evidence in favour of the hypotheses of persistent demand and declining nominal value added and employment shares in the progressive sector. As a result, Baumol's growth disease does not substantially lower aggregate labour productivity growth over the period.

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1. Introduction.

Even over fifty years after its publication, Baumol's (1967) paper "Macroeconomics of Unbalanced Growth" is still regarded as one of the main contributions in the literature on structural change to the understanding of the drivers of the service sector expansion (tertiarisation) and its impact on economic growth.

Baumol builds a highly stylised model, based on unbalanced productivity growth between the two sectors in which he divides the economy: the progressive sector (manufacturing), which exhibits above-average productivity growth, and the stagnant sector (services), with below-average productivity growth. Regardless of this productivity growth differential between sectors, wages rise at a similar pace in both sectors. This leads to above-average increases in unit costs and prices in the service sector in a phenomenon known as Baumol's cost and price disease. However, despite their "exploding costs", services have "persistent demand" (ten Raa and Schettkat, 2001), which means that real output grows at about the same pace in both sectors. As a result, this sector takes ever-increasing shares in employment and nominal output.

Nevertheless, Baumol's model is not limited to acknowledge the factors that drive the expansion of the service sector, as it also points out the negative impact that this process brings to economic growth. Since aggregate productivity growth is just a weighted average of the sectoral productivity growth rates (where the weights are the nominal value added shares), the gradual reallocation of nominal value added towards the service sector that comes with tertiarisation increasingly undermines aggregate productivity growth. This negative impact is known in the literature as "Baumol's growth disease" (BGD) (Nordhaus, 2008).

In an attempt to test the model empirically, Nordhaus (2008) proposes the application of a panel data analysis to the hypotheses that lie at the core of Baumol's model. According to Nordhaus (see also Hartwig, 2011), it is possible to distinguish the following six hypotheses, which he also labels as syndromes or variants of Baumol's diseases:

1) The cost and price disease hypothesis. Costs and prices in stagnant industries rise relative to the average.

2) The persistent demand hypothesis. Real output grows at about the same rate in both sectors.

3) The hypothesis of declining employment shares in the progressive sector. If there is unbalanced productivity growth and persistent demand across sectors, then labour reallocates towards the stagnant sector.

4) The hypothesis of declining nominal value added shares in the progressive sector. If real output grows at about the same rate in both sectors and the relative productivity gains of the progressive sector dissipate into the consumers' rent "[by means of declining relative prices] instead of raising the nominal value added earned by the [sector]" (Peneder and Streicher, 2018), then the stagnant sector gains weight in terms of nominal value added.

5) The hypothesis of uniform wage growth. Wages grow at about the same pace in both sectors.

6) The growth disease hypothesis. If hypothesis (4) is fulfilled, then the reallocation of nominal value added towards the stagnant sector will undermine aggregate productivity growth.

Despite the valuable contribution made by Baumol and Nordhaus to the literature on structural change, their work is undermined by the fact that they take industries as independent units of production, thereby assuming that the service sector and manufacturing are not inter-linked between each other through the provision of intermediate inputs. As such, they neglect the changing input-output structure as a possible driver of the expansion of the service sector.

However, this assumption has been contested in the literature. In light of the strong expansion of intermediate services, the increasing reliance of the manufacturing sector on these services has been pointed out as an important driver of the tertiarisation process (Lind, 2014). Furthermore, some authors have claimed that tertiarisation partly arises due to the outsourcing of services that were previously performed in-house in manufacturing firms to specialised suppliers (Berlingieri, 2014; Ciriaci and Palma, 2016; Greenhalgh and Gregory, 2001; Montresor and Vittucci Marzetti, 2011; Russo and Schettkat, 2001; Petit, 1986).

Besides qualifying the Baumolian explanation of the tertiarisation process, the increasing integration between intermediate services and manufacturing might also jeopardise BGD. As noted by Oulton (2001), BGD only holds when services are not inter-linked with the manufacturing sector. If these service industries supply intermediate inputs to the manufacturing sector and present below-average but positive productivity growth, manufacturing benefits from these productivity gains and tertiarisation boosts aggregate productivity growth[1].

This paper assesses whether this integration between intermediate services and manufacturing has affected Baumol's diseases in the German economy over the period 2001-2014. To achieve this goal, we extend Nordhaus' testing framework and compare the results that stem from the application of two different approaches. Firstly, the subsystem approach, which allows us to introduce input-output linkages in the Baumolian framework. And, secondly, the traditional industry approach, which neglects the input-output structure of the economy and takes industries as autonomous units of production. By focusing on Germany, this study provides the first comprehensive analysis of Baumol's diseases in this economy. This country is a particularly relevant case among advanced economies, since wage moderation policies along with the structural weakness of domestic demand have been crucial for its exporting performance and might have acted as barriers to the expansion of some personal (stagnant) services, thus containing Baumol's diseases

Differently from the industry perspective, the subsystem approach disaggregates the economy into an ideal classification of autonomous units of production (subsystems, also known as vertically integrated sectors or value chains), each of which incorporates all the domestic activities that are directly or indirectly needed to satisfy its final demand (Antonioli *et al.*, 2020; Di Berardino and Onesti, 2020a, 2020b; Ciriaci and Palma, 2016; Montresor and Vittucci Marzetti, 2011; Sarra *et al.*, 2019). Consequently, this classification is made on the basis of final output, so that it identifies how each industry contributes to the production of each subsystem's final commodity through the provision of intermediate inputs. As such, this approach allows us to take into account, on the one

[1] In the same vein, there has been a growing number of empirical studies that stress the role of knowledge intensive business services to generate positive spillovers, even for the manufacturing sector (Ciarli *et al.*, 2012; Ciriaci *et al*., 2015; Guerrieri and Meliciani, 2005; Kox and Rubalcaba, 2007).

hand, the increasing reliance of manufacturing subsystems on intermediate services, and, on the other hand, how the productivity gains originated in these services are not limited to these industries, but rather induce further productivity gains in the rest of the subsystem (De Juan and Febrero, 2000).

The remainder of this paper is organised as follows. Section 2 addresses the methodological considerations regarding the procedure to classify the production process according to subsystems and Nordhaus' testing strategy used to test Baumol's diseases. Section 3 discusses the results regarding each of the six hypotheses. Given that testing hypothesis (6) requires a different method, this section first discusses results on hypotheses (1) to (5) and subsequently deals with BGD. Lastly, section 4 summarises the main conclusions drawn from this study.

2. Method.

2.1. Remaping data from industries to subsystems.

Given that national statistics services do not directly report data on subsystems, we need to apply the following lineal operator O to remap data from industries to subsystems by making use of the national input-output tables:

$$O = (\hat{x})^{-1}(I - B)^{-1}\hat{e} \quad (1)$$

Where $\hat{x}$ is the diagonalised vector of industry gross output, I refers to the identity matrix, B denotes the industry-by-industry domestic direct requirements matrix and $\hat{e}$ is the diagonalised vector of industry final demand.

After calculating O, this operator is used to derive matrix N:

$$N = \hat{v}O \quad (2)$$

Where $\hat{v}$ is the diagonalised vector of the variable that needs to be remapped from industries to subsystems.

On the one hand, each column j in matrix N shows the amount of the variable v referred to each industry i that is directly or indirectly used by subsystem j in order to produce its final output. Consequently, the sum across all the elements of column j yields the value of the variable for subsystem j. On the other hand, each row i shows the amount of the variable v referred to industry i that is directly or indirectly used by each subsystem j. As a result, the sum across all the elements of row i yields the value of the variable for industry i.

This operation is repeated for each year over the period 2000-2014. This paper uses data from the German National Input-Output Tables (NIOT), obtained from the World Input-Output Database (release 2016) (Timmer et al., 2015), which offers data for 56 economic activities, classified according to the ISIC revision 4.

Adopting the subsystem approach allows us to confirm the important role played by intermediate services in driving the tertiarisation process. Figure 1 decomposes the service sector size (industry approach) by type of service, distinguishing between final services and three kinds of intermediate services (within service subsystems, within manufacturing subsystems and within other subsystems). As this figure shows, intermediate services, taken together, play a larger role than final services in driving the expansion of the service sector both in terms of employment and nominal value added.

When distinguishing between the three types of intermediate services, it can be noted that intermediate services in service subsystems are the main contributors to the tertiarisation process. However, the reliance of manufacturing subsystems on intermediate services also arises as an important factor in explaining the rise of the service sector when measured in terms of employment.

Therefore, employment tertiarisation in the German economy over the period 2000-2014 is not only linked to the expansion of services in service subsystems, but also to the rise of intermediate services in manufacturing subsystems. This explains why the expansion of service industries (and the concomitant decline of manufacturing industries) is larger than the one exhibited by service subsystems (and manufacturing subsystems). As Table 1 shows, service (manufacturing) industries have gained (lost) more weight in total employment than service (manufacturing) subsystems between 2000 and 2014.

Consequently, the rise of intermediate services in manufacturing subsystems gives rise to the fact that the extent of the tertiarisation process diverges between the subsystem approach and the subsystem one. In the next section, we outline the testing strategy used to check whether this integration of intermediate services in manufacturing subsystems is able to substantially qualify results on Baumol's diseases in the German economy.

[Insert Figure 1 here]

[Insert Table 1 here]

2.2. Testing strategy for Baumol's diseases.

Assuming a Cobb-Douglas economy and an almost ideal demand system, Nordhaus shows that hypotheses (1) to (5) can be econometrically tested as reduced-form equations with the following specification:

$$x_{it} = \beta_{0i} + \beta_1 q_{it} + z_t + \varepsilon_{it} \quad (3)$$

Where q is labour productivity growth, x is the growth of the variable that defines the hypothesis that is being tested, z denotes time dummies, ε is the error term, subscript i refers to industry or subsystem i and subscript t denotes the time period.

Since hypotheses (1) to (5) established a predicted correlation between productivity growth and the growth of another variable, the coefficient of interest to test each of the six hypotheses is β_1. Accordingly, these are the coefficients that must be found in order to get evidence in favour of each hypothesis:

1) The cost and price disease hypothesis: β_1 must be significantly lower than zero. This implies that there is a negative correlation between productivity growth and price growth (p) across industries or subsystems.
2) The persistent demand hypothesis: β_1 cannot be significantly different from zero. This means that productivity growth is not correlated with real output growth (rva) across industries subsystems.
3) The hypothesis of declining employment shares in the progressive sector: β_1 must be significantly lower than zero, which implies that there is a negative correlation between productivity growth and employment growth (l) across industries or subsystems.

4) The hypothesis of declining nominal value added shares in the progressive sector: β_1 must be significantly lower than zero, so that there is a negative correlation between productivity growth and nominal value added growth (nva) across industries or subsystems.
5) The hypothesis of uniform wage growth: β_1 cannot be significantly different from zero. This implies that productivity growth is not correlated with wage growth (w) across industries or subsystems.

Equation (3) is estimated controlling both fixed and time effects for the period 2001-2014. Following Nordhaus and Hartwig (2011), in order to check for the robustness of the results, we estimate this equation using 7-year moving averages and cross-sectionally for the period average 2001-2014.

Nordhaus tests these five hypotheses for the US economy using industry data from the BEA and finds supporting evidence for all of them except for the persistent demand hypothesis. More recently, Hartwig has applied Nordhaus' testing framework to other economies such as Switzerland (Hartwig, 2010), the EU economies (Hartwig, 2011) and Japan (Hartwig, 2019). While he finds that the EU economies and the US are similarly affected by Baumol's diseases, Japan and Switzerland exhibit a weaker price disease. As a result, evidence in favour of declining nominal value added shares in the progressive sector seems to be stronger for the US and the UE economies than for Japan and Switzerland. Still, in all these economies real output seems to grow faster in progressive industries than in stagnant ones, providing robust evidence against hypothesis (2).

Regarding hypothesis (6), Nordhaus proposes a different methodology to test BGD. As he shows, aggregate labour productivity growth can be approximated as a weighted average of the industry or subsystem productivity growth rates, where the weights are the nominal value added shares[2]:

$$q_t = \sum w_{it-1} q_{it} \quad (4)$$

Where w denotes nominal value added share.

According to equation (4), if progressive industries or subsystems gradually lose weight in terms of nominal value added, as Baumol's model predicts, aggregate productivity growth will follow a declining trend. In order to capture this, we need to keep the weights in equation (4) fixed with respect to the base period:

$$q_t = \sum w_{it-1} q_{it} = \sum w_{i0} q_{it} + \sum (w_{it-1} - w_{i0}) q_{it} \quad (5)$$

As a result, aggregate labour productivity growth is broken down into two terms or effects. The first term on the right-hand side captures the so-called within effect and measures how much productivity would grow if there was not any structural change in terms of nominal value added. The second term estimates the impact that the cumulative reallocation of nominal value added (that has taken place since the base period) exerts on aggregate productivity growth when there is unbalanced productivity growth across industries or subsystems. Consequently, this second term corresponds to BGD.

[2] Nordhaus abstracts from the contribution to aggregate labour productivity growth stemming from the reallocation of labour across subsystems with heterogeneous nominal productivity levels. In a previous paper (Nordhaus, 2001), he argues that a welfare measure of aggregate productivity growth should not consider this effect.

However, Nordhaus proposes an additional refinement on the estimation of BGD. Given that BGD in equation (5) is affected by the instability of the cross-industries or subsystem differences in productivity growth, he recommends to use the average productivity growth rates for each industry or subsystem during the period under study and update their respective nominal value added shares:

$$\sum c_{it}^{BGD} = \sum(w_{it-1} - w_{i0})\overline{q_{\iota t}} \quad (6)$$

Where $\sum c_{it}^{BGD}$ corresponds to the aggregate BGD effect and the symbol $^{-}$ stands for the average value of the variable over the whole period. If, consistently with Baumol's prediction nominal value added gradually reallocates towards stagnant industries or subsystems, then we will expect to see how this effect exhibits a negative magnitude and follows a declining trend.

When applying this formula to the US economy, Nordhaus finds that BGD lowered aggregate productivity growth by about 0.5 percentages points over the second half of the twentieth century. Besides Nordhaus, equation (6) has also been applied by other authors to test for BGD in different economies. Hartwig (2011) finds that annual aggregate productivity growth slowed down in 0.5 percentages points in the UE economies due to BGD over the period 1970-2005. Contrary to the previous studies, Hartwig (2010), Nishi (2019) and Oh and Kim (2015) do not find evidence in favour of BGD in Switzerland, Japan and Korea, respectively. Lastly, similarly to Nordhaus, Duernecker *et al*. (2017) finds that BGD lowered aggregate productivity growth by 0.6 percentage points in the US economy over the period 1948-2010.

As equation (6) shows, the aggregate BGD effect can be broken down into industry or subsystem contributions. This will allow us to assess which industries or subsystems behave consistently with Baumol's prediction by exerting a negative and declining contribution. However, given that equation (6) does not normalise industry or subsystem productivity growth with respect to aggregate productivity growth ($\overline{q_t}$), industry or subsystem contributions to BGD do not yield plausible economic results. In order to correct this flaw, deviations from means are taken:

$$\sum c_{it}^{BGD} = \sum(w_{it-1} - w_{i0})(\overline{q_{\iota t}} - \overline{q_t}) \quad (7)$$

According to equation (7), industries or subsystems with above-average productivity growth will only exert a negative contribution to BGD if they lose (gain) weight in terms of nominal value added.

In order to analyse these industry or subsystem contributions, industries or subsystems are classified in different groups according to the nature of their product and their progressive/stagnant status[3]. Accordingly, we distinguish the following industries or subsystem groups: manufacturing, progressive manufacturing, stagnant manufacturing, services, progressive services, stagnant services and other industries or subsystems. By disaggregating both services and manufacturing, we take into account that the dichotomy between services and manufacturing on which both Baumol's model is based has been questioned in the empirical literature. After Baumol *et al*. (1985) corrected his previous position to admit the existence of progressive services, several authors have emphasized the need to distinguish between different types of services in the analysis (Duarte and Restuccia, 2017; Duernecker *et al*., 2017; Fernandez and Palazuelos, 2011; IMF, 2018; Inklaar and Timmer, 2014; Jorgenson and Timmer, 2011; Maroto-Sánchez

[3] An industry or subsystem is classified as progressive (stagnant) if it exhibits a productivity growth rate higher (lower) than that of the economy on average over the period.

and Cuadrado-Roura, 2009; Maroto and Rubalcaba, 2008). Although the literature on BGD do not stress the existent heterogeneity within manufacturing, arguably due to the small and declining share of the manufacturing sector in employment and nominal value added, this internal diversity is not neglected *a priori* in this study. In light of this heterogeneity within both sectors, whether BGD evolves consistently with Baumol's prediction depends on which industries or subsystems are the ones that gain weight in terms of nominal value added.

3. Results.

3.1. Testing hypotheses (1) to (5).

Table 2 shows the results on the estimation of hypotheses (1) to (5). For each disease and framework (either an industry one or a subsystem one), three coefficients are reported according to the type of data (panel, cross section or 7-year non-overlapping moving averages) that is used. Following Nordhaus (2008) and Hartwig (2011), we also report the weighted (where the weights are provided by the number of observations) and unweighted coefficients across all the specifications for each framework. The last rows of Table 2 show Nordhaus and Hartwig's coefficients, so that our results can be easily compared to theirs. While Nordhaus estimates Baumol's diseases in the US economy over the period 1948-2001 using BEA data (1987 SIC), Hartwig analyses the diseases in the EU economies over the period 1970-2005 using EU KLEMS data.

Regarding the cost and price disease hypothesis, we find robust evidence that both stagnant subsystems and stagnant industries exhibit above-average price increases. Our weighted and unweighted coefficients are similar to Hartwig's, but significantly lower than those found in Nordhaus[4]. While Nordhaus finds that consumers mostly capture all productivity gains due to a coefficient that is about -1, our results show that both progressive subsystems and progressive industries use to some extent their relative productivity gains to increase their nominal value added.

Consistently with the previous literature (Hartwig, 2010, 2011, 2019; Nordhaus, 2008; Oh and Kim, 2015), our results on the persistent demand hypothesis provide robust evidence against it. All the coefficients are positive and significant at the 1% level. Consequently, the faster real output growth in both progressive subsystems and progressive industries works as a palliative against Baumol's diseases, restraining the reallocation of employment and nominal value added towards stagnant subsystems or stagnant industries. Compared to our estimates, Nordhaus and Hartwig find substantially lower coefficients.

Regarding hypothesis (3), we do not find robust evidence in favour of a reallocation of employment towards stagnant subsystems or stagnant industries. Even though we find a significantly negative coefficient in some specifications, this result is not robust across all estimations. While in Germany the stagnant sector does not gain weight in terms of employment, Nordhaus and Hartwig find a significant reallocation of employment towards the stagnant sector in the US and the EU economies, respectively. Given the evidence provided in hypothesis (2), it seems that unbalanced real output growth is more

[4] Even though Hartwig's results contrasts with Nordhaus', he downplays this difference by attributing it to the different dataset used in both studies (the BEA in Nordhaus and EU KLEMS in Hartwig). He argues that when this disease is estimated for the US economy using EU KLEMS data the coefficients are similar to the ones found here and in Hartwig.

pronounced in Germany, thereby restraining more effectively the expansion of the stagnant sector in total employment.

With respect to hypothesis (4), we do not obtain robust evidence in favour of a reallocation of nominal value added towards stagnant subsystems or stagnant industries. While some of the coefficients even point to a significant reallocation of nominal value added towards the progressive sector, this result is not robust across all the specifications. In order to understand this lack of evidence in favour of this hypothesis, it is important to note that the coefficient on hypothesis (4) theoretically equals the sum of the coefficient on hypothesis (1) and the coefficient on hypothesis (2). In other words, the coefficient on hypothesis (4) depends on both the extent to which the relative productivity gains of progressive subsystems (industries) are passed on to consumers (coefficient on hypothesis (1)) and the extent to which real production growth in progressive subsystems (industries) exceeds real production growth in stagnant subsystems (industries) (coefficient on hypothesis (2))[5]. Since the relative productive gains of the progressive subsystems (industries) are not completely passed on to consumers and real output grows at a slower rate in stagnant subsystems (industries), nominal output does not significantly reallocate towards stagnant subsystems (industries). Compared to our results, Nordhaus and Hartwig do not obtain robust evidence in favour of this hypothesis either, but they downplay this finding by claiming that their test of BGD provides indirect evidence in favour of a reallocation of nominal value added towards stagnant industries.

The estimation of hypothesis (5) seems to confirm that higher productivity growth does not lead to higher wages. Even though we find a significantly positive (but small) coefficient for subsystems at the 1% level when panel data is used, this result is not robust across all estimations. In conjunction with evidence on hypothesis (1), it seems that relative productivity gains dissipate into the consumer’s rent rather than raising wages in progressive subsystems (industries). These results are consistent with Nordhaus and Hartwig findings, who also acknowledge that productivity growth does not seem to lead to higher wage growth in progressive industries.

All in all, the evidence reported on hypotheses (1) to (5) stresses that results do not differ much between a subsystem perspective and an industry one. For both subsystems and industries, our findings reject the persistent demand hypothesis and the hypotheses of declining employment and nominal value added shares in the progressive sector, while they confirm the cost and price disease hypothesis and the hypothesis of uniform wage growth.

[Insert Table 2 here]

3.2. Testing BGD.

Figure 2 shows the results on the actual subsystem contributions to BGD. We find that the aggregate contribution to BGD across subsystems does not follow a significant declining trend. This result on the irrelevance of the BGD effect is consistent with the

[5] Alternatively, the coefficient on hypothesis (4) also equals the coefficient on hypothesis (3) plus the sum of one and the coefficient on hypothesis (1).

lack of robust evidence in favour of a significant reallocation of nominal value added towards stagnant subsystems reported in Table 2.

Looking at the contributions of the different subsystem groups in Figure 2, it also becomes clear that no subsystem group behaves consistently with Baumol's model, exerting a substantial and declining contribution. This result must be mostly explained by the fact that progressive (stagnant) subsystem groups do not gradually and considerably lose (gain) weight in terms of nominal value added. In line with the econometric results reported in Table 2, this fact must be linked to the evidence found on hypothesis (1) and (2), which ultimately explains why hypothesis (4) was rejected and why BGD does not substantially lower aggregate productivity growth over the period.

Two simple counterfactual exercises allows us to assess what is the link between each subsystem group and the results found for hypothesis (1) and (2), that is, the factors that explain why nominal value added does not reallocate towards stagnant subsystems and why aggregate labour productivity growth is not increasingly undermined by BGD. The results on these two counterfactual exercises are depicted in Figure 3 and Figure 4.

Figure 3 shows the counterfactual subsystem contributions to BGD if relative productivity gains were fully passed on to consumers. To calculate these counterfactual contributions, instead of using the actual nominal value added shares in equation (7), we use the actual employment shares as counterfactual nominal value added shares. Therefore, we assume in this scenario that the counterfactual cumulative reallocation of nominal value added mirrors the actual cumulative reallocation of employment, which would only happen if relative productivity gains were fully passed on to consumers. By comparing the results shown in Figure 3 with the ones depicted in Figure 2, it is possible to obtain indirect evidence about the subsystem groups that mostly explain the fact that the relative productivity gains did not fully dissipate into the consumer's rent and the impact that his has on BGD.

According to the evidence reported in Figure 3, if relative productivity gains were fully passed on to consumers, BGD would follow a significant declining trend and would lower aggregate labour productivity growth in 0.08 points over the period, that is, 0.06 additional points compared to the actual BGD. Looking at the subsystem contributions, stagnant services seem to explain the more negative impact of BGD on this counterfactual scenario, contributing in -0.04 percentage points with respect to the actual BGD. This suggests that stagnant services restrain the growth of their relative prices and, as a result, there is an incomplete pass of the relative productivity gains of progressive subsystems on to these services. However, given the small magnitude of this additional negative impact, the incomplete pass of the relative productivity gains does not seem to explain why BGD has not substantially undermined aggregate labour productivity growth over 2001-2014.

Figure 4 shows the counterfactual subsystem contributions to BGD if hypothesis (2) was fulfilled, that is, if real output grew at about the same pace in progressive subsystems and stagnant subsystems. To estimate these counterfactual contributions, instead of using the actual nominal value added shares in equation (7), we use counterfactual nominal value added shares that are calculated from the assumption that real output grows at the same rate in every subsystem. By subtracting for each subsystem its real output growth differential (that is, with respect to the economy's average) from its actual nominal value added growth, we calculate counterfactual nominal growth rates for every subsystem. These counterfactual rates allows us to estimate counterfactual nominal value added shares that fulfill hypothesis (2). By comparing the results shown in Figure

4 with the ones depicted in Figure 2, it is possible to obtain indirect evidence about the subsystem groups that mostly explain the rejection of hypothesis (2) and its impact on BGD.

According to Figure 4, if real output grew at the same rate in every subsystem, BGD would follow a declining trend and would lower aggregate labour productivity growth in 0.19 percentage points over the period, that is, 0.17 additional points compared to the actual BGD. Consequently, contrary to the incomplete pass on to consumers of the relative productivity gains, unbalanced real output growth seems to substantially restrain the actual BGD. Looking at the subsystem contributions, the negative impact of BGD on this counterfactual scenario is linked to stagnant services, progressive manufacturing and progressive services. Each of these groups contribute in -0.05 percentage points with respect to the actual BGD. Therefore, this evidence suggests that demand is shifting away from stagnant services to progressive manufacturing and progressive services, providing an effective palliative against BGD.

[Insert Figure 2 here]

[Insert Figure 3 here]

[Insert Figure 4 here]

After having estimated BGD across subsystems, in Figure 5 to 7 we repeat this analysis following an industry perspective.

As Figure 5 shows, we do not find evidence of a substantial negative impact of BGD across industries and, contrary to when analysed at a subsystem perspective, BGD even follows a significant increasing trend. Again, there is no industry group that behaves consistently with Baumol's prediction.

Figure 6 sheds light on the role of the incomplete pass on to consumers of the relative productivity gains in explaining BGD's impact across industries. According to our results, if relative productivity gains fully dissipated into the consumer's rent, then BGD would lower aggregate labour productivity growth in 0.15 percentage points over the period, that is, 0.22 additional points with respect to the actual BGD. As a result, this mechanisms seems more relevant to restrain BGD for industries than for subsystems. Looking at the industry contributions, stagnant services mostly explain the more negative impact of BGD on this counterfactual scenario, contributing in -0.13 points with respect to the actual BGD. As for subsystems, there seems to be an incomplete pass of the relative productivity gains of progressive industries on to stagnant services, although this happens to a larger extent than for subsystems.

Figure 7 depicts the results on the counterfactual industry contributions to BGD if hypothesis (2) was fulfilled. On this counterfactual scenario, the cumulative reallocation of nominal value added would lower aggregate labour productivity growth in 0.44 percentage points over the period, that is, 0.52 additional points with respect to the actual BGD. As for subsystems, unbalanced real output growth seems more relevant to restrain BGD than the incomplete pass on to consumers of the relative productivity gains. This evidence is consistent with the results reported in Table 2 on hypothesis (2). Looking at the industry contributions, stagnant services, progressive services and progressive manufacturing mostly explain the more negative impact of BGD on this counterfactual scenario, contributing in -0.22, -0.14 and -0.11 percentage points with respect to the actual BGD, respectively.

All in all, our results on hypothesis (6) stress that BGD does not substantially lower aggregate labour productivity growth mainly because unbalanced real output growth provides a strong palliative for this disease across both subsystems or industries[6]. To a large extent, this is explained by the fact that demand shifts away from stagnant services to progressive manufacturing and progressive services, which restrains the reallocation of nominal value added towards stagnant subsystems or industries.

[Insert Figure 5 here]

[Insert Figure 6 here]

[Insert Figure 7 here]

4. Concluding remarks.

This paper has examined whether the increasing integration between intermediate services and manufacturing has affected Baumol's diseases in the German economy over the period 2001-2014. To achieve this goal, we have extended Nordhaus' testing framework and compared the results that stem from the application of two different approaches. Firstly, the subsystem approach, which allows to introduce input-output linkages in the Baumolian framework. And, secondly, the traditional industry approach, which neglects the input-output structure of the economy and takes industries as autonomous units of production.

The empirical evidence found in this paper shows that Baumol's diseases do not differ much between a subsystem perspective and an industry one. Regarding hypothesis (1) to (5), for both subsystems and industries, our findings reject the persistent demand hypothesis and the hypotheses of declining employment and nominal value added shares in the progressive sector, while they confirm the cost and price disease hypothesis and the hypothesis of uniform wage growth.

With respect to BGD, our results stress that BGD does not substantially lower aggregate labour productivity growth across both subsystems and industries. All in all, the small magnitude of BGD is linked to the rejection of the persistent demand hypothesis. This rejection seems to be explained by the fact that demand shifts away from stagnant services to progressive manufacturing and progressive services, restraining the reallocation of both nominal value added and employment towards the stagnant sector and thereby providing a strong palliative against BGD.

These results on Baumol's diseases contrast with Nordhaus (2008) and Hartwig (2011)'s estimations for the US and the EU economies. Even though they also provide evidence against the persistent demand hypothesis, unbalanced real output growth is weaker than in Germany. As a result, in the US and the EU economies, real output growth in the progressive sector is not able to stop the reallocation of employment and nominal value added towards the stagnant sector, which leads to the emergence of BGD.

Despite these differences with Nordhaus and Hartwig's findings, our results are comparable to the ones reported in Hartwig (2019) and Nishi (2019) for Japan, so that

[6] Unlike Nordhaus (2008) and Hartwig (2011) (who find a substantial negative impact stemming from BGD, but do not find robust evidence in favour of hypothesis (4)), our results are consistent with the evidence reported on hypothesis (4).

this economy and Germany seem to be “similarly affected by Baumol’s diseases” (Hartwig, 2011).

To conclude, this study has found that evidence in favour of Baumol’s diseases is only partial and that these results are robust to the introduction of input-output linkages in the Baumolian framework. Thus, Baumol and Nordhaus’ abstraction of the input-output structure does not seem unwarranted according to the empirical evidence found in this paper. However, given that our results are limited to the German economy, in a future investigation it would be interesting to check whether this “irrelevance” of input-output linkages holds when extending this analysis to a wide sample of developed economies.

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Tables and figures.

Figure 1. Decomposition of the service sector size (industry approach) by different types of services.

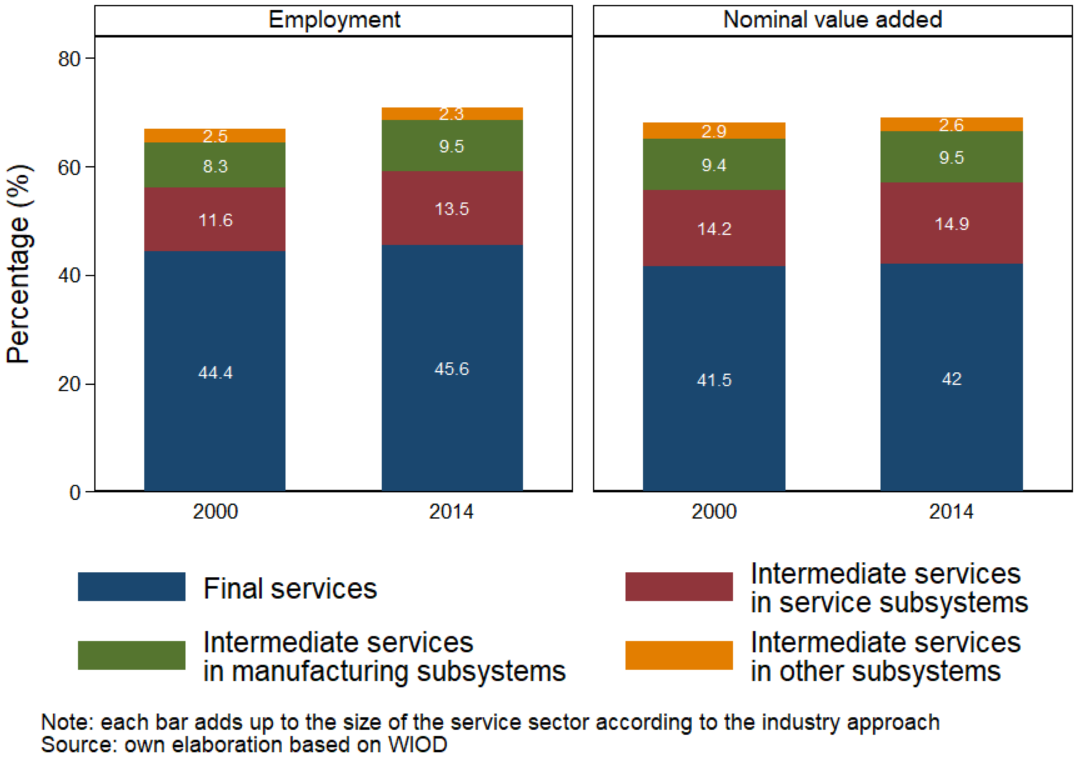


Table 1. Size of the manufacturing and the service sectors according to the subsystem and the industry approaches (average share and change, 2000-2014).

	Employment		Nominal value added	
	Subsystem approach	Industry approach	Subsystem approach	Industry approach
Services (%)	61.1	69.8	59.3	69.2
Change (pp)	2.7	4.1	1.2	1.0
Manufacturing (%)	29.5	21.3	31.6	22.5
Change (pp)	0.2	-1.8	0.7	-0.4

Source: own elaboration based on WIOD.

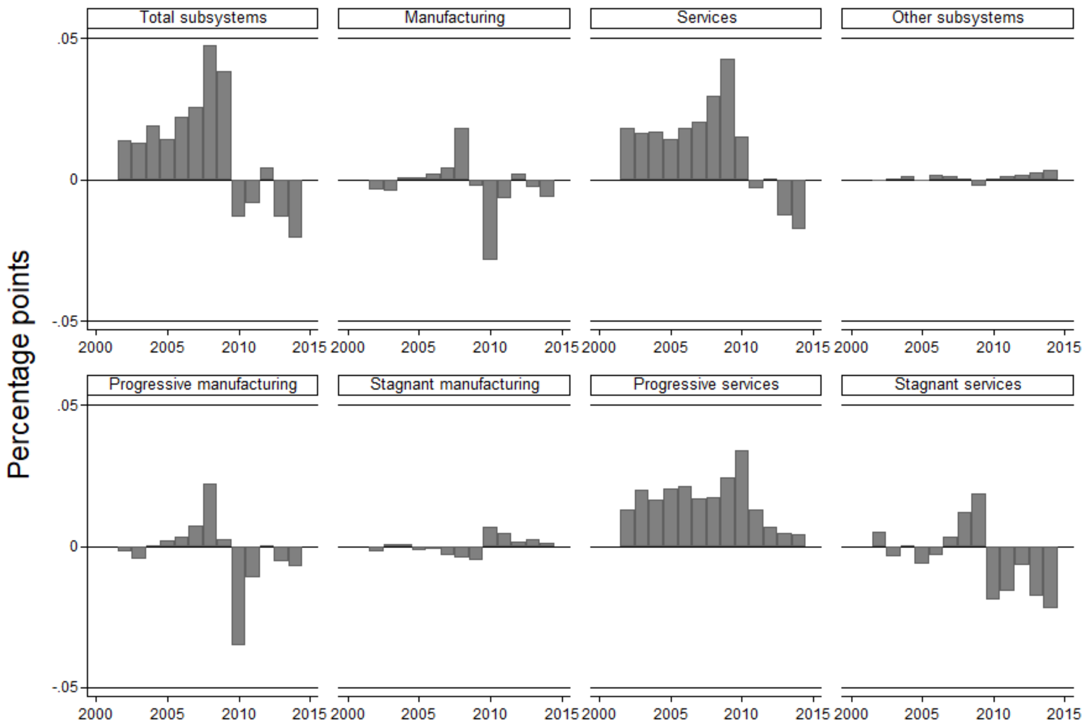
Table 2. Estimation of hypotheses (1) to (5).

	(1) p		(2) rva		(3) l		(4) nva		(5) w	
	Coefficient	No. of obs.	Coefficient	No. of obs.	Coefficient	No. of obs.	Coefficient	No. of obs.	Coefficient	No. of obs.
Subsystems										
Panel	-0.481***	770	0.931***	770	-0.0695	770	0.449***	770	0.0399***	770
	(0.0238)		(0.0559)		(0.0559)		(0.0599)		(0.0148)	
7-year MA	-0.475***	110	0.954***	110	-0.0456	110	0.479**	110	-0.0290	110
	(0.0816)		(0.180)		(0.180)		(0.197)		(0.0477)	
Cross section	-0.668*** (0.0694)	55	0.523*** (0.178)	55	-0.477*** (0.178)	55	-0.145 (0.165)	55	0.0610* (0.0339)	55
Summary statistics (subsystems)										
Weighted	-0.491		0.910		-0.091		0.418		0.033	
Unweighted	-0.541		0.803		-0.197		0.261		0.024	
Industries										
Panel	-0.556***	770	0.991***	770	-0.00926	770	0.435***	770	-0.0127	770
	(0.0228)		(0.0101)		(0.0101)		(0.0241)		(0.0139)	

7-year MA	-0.680***	110	0.869***	110	-0.131**	110	0.188**	110	0.0299	110
	(0.0833)		(0.0504)		(0.0504)		(0.0849)		(0.0424)	
Cross section	-0.693***	55	0.799***	55	-0.201**	55	0.106	55	0.0699**	55
	(0.0671)		(0.0820)		(0.0820)		(0.0770)		(0.0292)	
Summary statistics (industries)										
Weighted	-0.579		0.965		-0.035		0.387		-0.003	
Unweighted	-0.643		0.886		-0.114		0.243		0.029	
Nordhaus (2008)										
Weighted	-0.96		0.67		-0.28		-0.28		-0.001	
Unweighted	-0.94		0.67		-0.26		-0.28		0.017	
Hartwig (2011)										
Weighted	-0.47		0.57		-0.38		0.12		0.197	
Unweighted	-0.59		0.49		-0.48		-0.11		0.122	

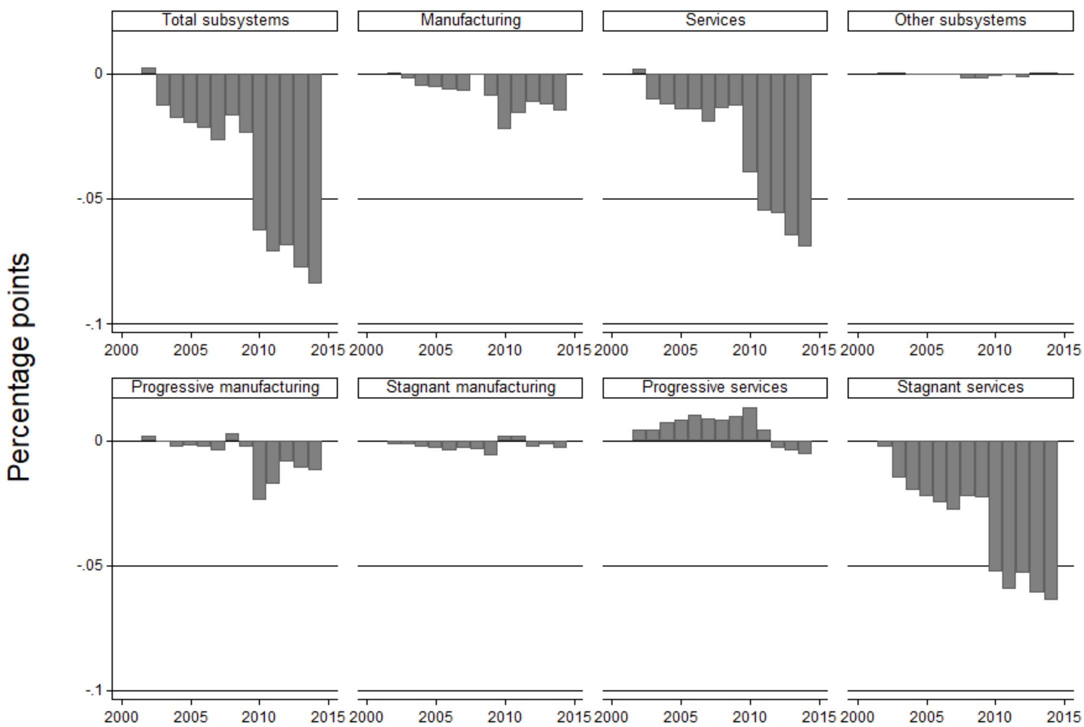
Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Fixed and time effects are used in all panel estimations
Source: own elaboration based on WIOD

Figure 2. Subsystem contributions to BGD.



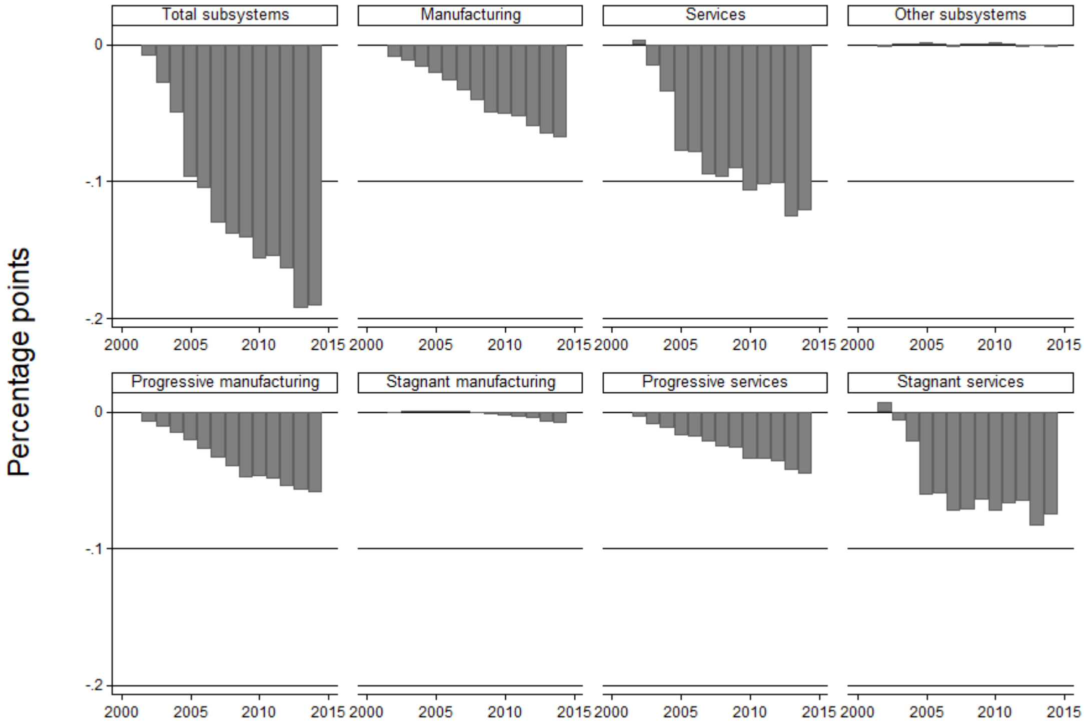
Source: own elaboration based on WIOD

Figure 3. Counterfactual subsystem contributions to BGD if relative productivity gains were fully passed on to consumers.



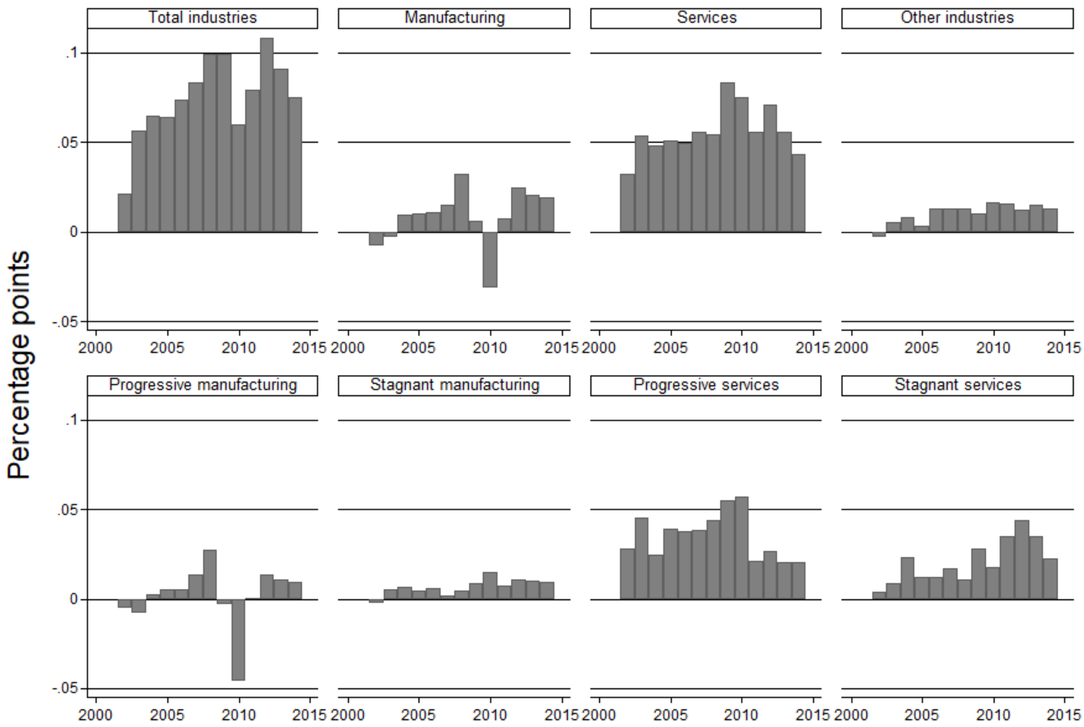
Source: own elaboration based on WIOD

Figure 4. Counterfactual subsystem contributions to BGD if hypothesis (2) was fulfilled.



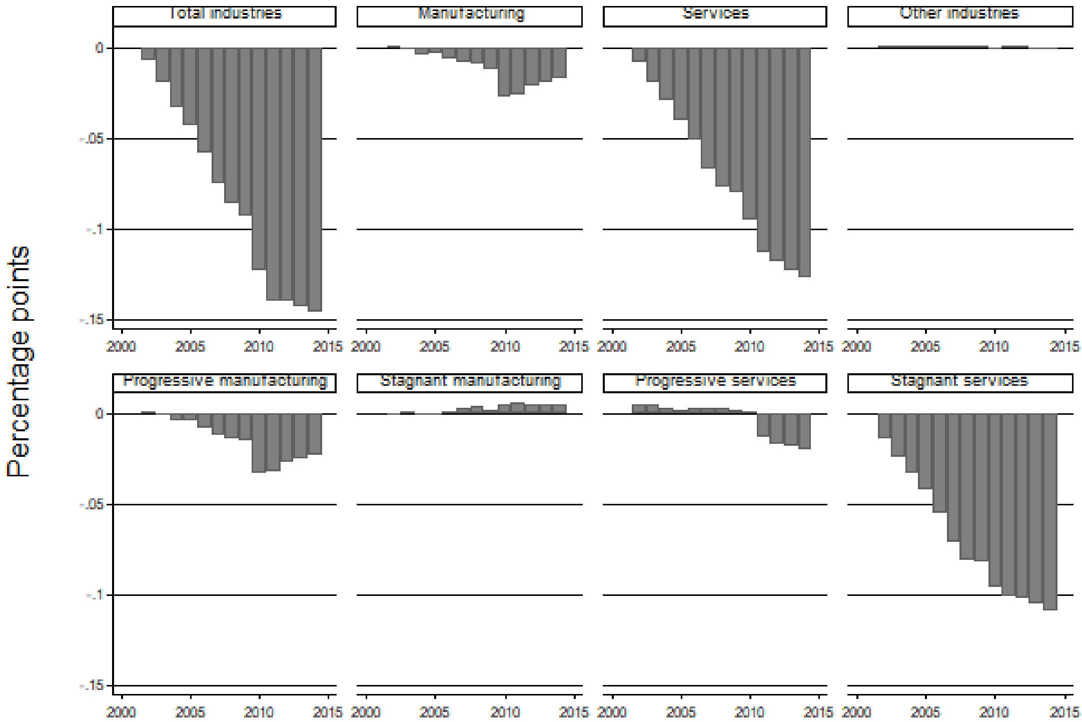
Source: own elaboration based on WIOD

Figure 5. Industry contributions to BGD.



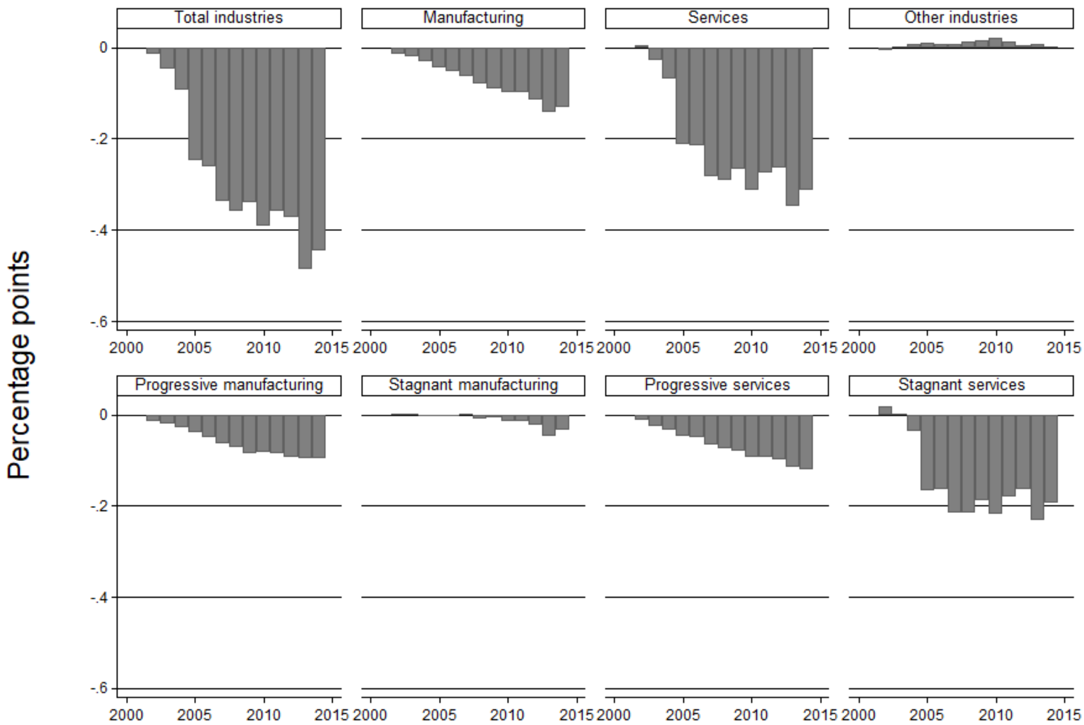
Source: own elaboration based on WIOD

Figure 6. Counterfactual industry contributions to BGD if relative productivity gains were fully passed on to consumers.



Source: own elaboration based on WIOD

Figure 7. Counterfactual industry contributions to BGD if hypothesis (2) was fulfilled.



Source: own elaboration based on WIOD