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Sources and Consequences of Productivity Growth Dynamics: Is Japan Suffering from Baumol's Diseases?

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Abstract

This study examines the sources and consequences of labour productivity growth dynamics in Japan (1970–2011) to investigate the extent to which Japanese economic performance has been affected by Baumol's growth and cost diseases. We find that although it is not as apparent in actual aggregate labour productivity dynamics, Baumol's growth disease lies behind the Japanese economy. In regard to Baumol's cost disease, the Japanese economy has undergone a change from productivity growth rate differential inflation to productivity growth rate differential deflation since the end of the 1990s. In other words, Baumol's cost disease appears atypically as deflation in the recent performance of the Japanese economy.

Keywords: Baumol diseases, Productivity growth rate differential, Japanese economy

JEL Classification: L11, L16, O41, O47

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1 Introduction

This study empirically investigates the sources and consequences of productivity growth dynamics in Japan by using the Baumol (1967) model. While this classical model provides insights to analyse macroeconomic performance from a multi-sectoral perspective, its empirical aspects have not thus far been sufficiently evaluated, especially for Japan.

With regard to the sources, we explore sectoral labour productivity growth and contribution to the aggregate labour productivity growth rate, while also considering industrial structural change. By doing so, we investigate whether the Japanese economy is suffering from Baumol's growth disease. With regard to the consequences, we explore the relationship between sectoral labour productivity growth and the evolution of costs and prices. On this basis, we also reveal whether the Japanese economy is suffering from Baumol's cost disease.

Baumol (1967) divides the whole economy into progressive sectors, which have a high productivity growth rate, and non-progressive sectors, which have a low productivity growth rate. He explains theoretically that aggregate productivity growth declines monotonically as the nominal value added (or employment) share of the latter expands (Baumol's growth disease). In addition, the productivity growth rate differential (PGRD) also leads to Baumol's cost disease. That is, a constant PGRD induces an increase in the relative price of the non-progressive sector's products and hence the nominal expenditure share for this sector's products.

Studies after Baumol attempted to assess if expansion in a non-progressive sector has a negative impact on macroeconomic performance. These studies consider the expansion of the tertiary sector, also classified as a non-progressive low-productivity sector in most cases, to represent structural change. Although many studies have examined Baumol's growth disease and Baumol's cost disease, there is no consensus that these diseases are universal. With regard to the former, some research supports Baumol's prediction (Fase and Winder (1999); Baumol et al. (1985); Peneder (2003); Tang and Wang (2004); Nordhaus (2008); Hartwig (2008, 2011b, 2012)), while other studies present contrary results (Triplett and Bosworth (2003); Maroto-Sánchez and Cuadrado-Roura (2009); Dietrich (2012)) or concur with his findings partially (Oh and Kim (2015)). With regard to the latter, Nordhaus (2008), Hartwig (2011b) Schettkat (2007), and Oh and Kim (2015) present empirical evidence for this disease, whereas Inklaar and Timmer (2014) find that the market services sector does not necessarily show a rise in relative prices. Studies of Baumol's cost disease further explore this phenomenon in specific sectors that have labour-intensive and stagnating characteristics. For example, Hartwig (2011a) confirms that the relative price of medical care is significantly explained by Baumol's theory, as is the rapidly increasing cost in education according to Baumol (2012). By contrast, by emphasising the role of innovation, Cowen (1996) insists that the performing arts are not stagnant.

Thus, whether Baumol's disease is a universal phenomenon is inconclusive from the exiting literature. Indeed, the results of Baumol's diseases may differ empirically by country, period, and sector, even if the original theory is true. This fact means that productivity growth dynamics are specific to each country, period, and sector and, accordingly, the implications of the sources and consequences may well differ. Hence, what implications does this model suggest for the Japanese economy?

In this context, the current study focuses on the Japanese economy, considering the sources and consequences of labour productivity dynamics to reveal in detail whether the Japanese economy suffers from Baumol's disease.[1]

[1]It is also useful to examine theoretical development based on Baumol (1967)'s model. This model is simple in that the sectoral productivity growth rates are exogenous and all products are employed entirely for final consumption. Recent studies have attempted to modify these terms. For example, Pugno (2006) introduces consumption services such as healthcare and education services that lead to human capital accumulation and De Vincenti (2007) examines the extent to which the positive externality of the services sector affects manufacturing productivity and the learning-by-doing process in both sectors. These works have contributed to endogenise the productivity growth rate and showed that aggregate productivity growth does not necessarily decline over time. On the contrary, some works consider the inter-sectoral transaction of a sector's products as an input. Oulton (2001) sets up a model in which services are employed entirely as intermediate inputs into industry. He then concludes that as the employment share of services increases, the rate of economic growth also rises. Sasaki (2007) builds a model in which services are used for both intermediate inputs into manufacturing and final consumption. He reaches a conclusion similar to Baumol (1967) of a monotonically declining economic growth rate with a tendency toward services. These two extensions are integrated into Sasaki (2015) in which services are used for both final consumption and intermediate inputs in manufacturing production and the productivity of the manufacturing and services sectors endogenously evolves. The dynamics of the economic growth rate thus depend on the human capital accumulation function in this model. If this function exhibits constant returns to scale with respect to the per capita consumption of services, the relationship between the employment share of services and economic growth rate is U-shaped. To summarise, while Baumol (1967)'s model presents the result of a constantly decreasing growth rate, these extensions show that the growth rate is not necessarily monotonically decreasing. Such a theoretical result corresponds to the result in the current paper, confirming the theoretical contribution of these studies, especially that the growth rate is not necessarily monotonically declining. However, as a first step to empirically examine Baumol's disease, we investigate the sources and consequences of productivity growth dynamics in a simple Baumol framework.

Such an attempt makes at least three contributions to the existing literature. First, this study investigates both the sources and the consequences of labour productivity growth dynamics. Although the existing literature assesses these topics in advanced countries, their focus is biased either to growth disease or to cost disease. For instance, the decomposition analysis by Peneder (2003) and Tang and Wang (2004) reveals the sources of productivity growth dynamics, but does not focus on the consequences. On the contrary, Hartwig (2011a) and Baumol (2012) discuss the consequences of productivity growth dynamics, but they do not explore the sources. Consequently, the sources and consequences of productivity growth dynamics are unclear. Further, Nordhaus (2008) and Hartwig (2011b) for the US economy and Oh and Kim (2015) for the Korean economy examine whether these economies suffer from Baumol's growth and cost diseases based on the classical sectoral classification of the agriculture, industry, and services sectors. We follow their method in some parts, but also extend their framework to explore sectoral performance more in detail. For example, we show a change in the sources and consequences of productivity growth dynamics not only among the agriculture, industry, and services sectors but also within these sectors. Since these sources and consequences differ widely by sector, we must explore sectoral performance to precisely assess whether Japan is suffering from Baumol's diseases.

Second, we introduce a multi-sectoral perspective into the empirical analysis of the Japanese economy. The Japanese economy has experienced growth and stagnation over time, particularly long-run stagnation with serious deflation since the 1990s. With regard to growth, stagnation, and deflation, the existing literature has focused on aggregate demand (e.g. Yoshikawa (2007)) and supply (e.g. Hayashi and Prescott (2002)) as well as the institutional determinants (e.g. Boyer et al. (2011)). While these determinants are important, the diverse performance levels among industries play a decisive role in shaping macroeconomic performance. Indeed, motivated by the rising availability of comprehensive industry-level data in Japan, recent studies have emphasised the increasing heterogeneity of industries and firms (Fukao and Miyagawa (2008); Ito and Lechevalier (2009); Fukao and Kwon (2006); Fukao (2012); Jorgenson and Timmer (2011); Morikawa (2014)).[2] Following the findings of these works, this study develops a multi-sectoral

[2] They especially focus on the supply side, with the investigation of total factor productivity (TFP) growth the most popular. Fukao and Miyagawa (2008) indicates that the TFP growth rate differs at the industry and firm levels. Fukao and Kwon (2006) finds that the slow reallocation of resources from less efficient to more efficient firms in the manufacturing sector slows TFP growth, while Fukao (2012) emphasises that Japan lags in ICT investment.

analysis to investigate the sources and consequences of labour productivity growth dynamics in Japan.

Third, this is the first attempt to deal with the Japanese economy in terms of Baumol's disease. In fact, to our best knowledge, no study has yet investigated whether the Japanese economy suffers from Baumol's disease. Even though Japan has been analysed in previous studies, it has only been one part of the whole sample of cross-country data. Hence, the Japanese economy has not been subject to close scrutiny in this regard. We shed light on this issue by using the JIP database created by RIETI, which enables us to examine macroeconomic performance in terms of industrial foundation.

The main results regarding Baumol diseases are as follows. With regard to Baumol's growth disease, although it is not as apparent in aggregate labour productivity dynamics, Baumol's growth disease is silently latent in the Japanese economy. With regard to Baumol's cost disease, the Japanese economy has undergone atypical growth since the end of the 1990s by way of PGRD deflation.

The remainder of this paper is organised as follows. Section 2 explains the database used in this study and defines the sectoral classification. Section 3 explores the sources of productivity growth dynamics from several angles. Specifically, this section concerns whether the Japanese economy is undermined by Baumol's growth disease. Section 4 focuses on the consequences of productivity growth dynamics. This section investigates issues related to Baumol's cost disease in the Japanese economy. Section 5 confirms these arguments by using an econometric analysis. The conclusion is presented in Section 6.

2 JIP database 2014 and sectoral classification

We use the JIP database 2014 compiled by RIETI throughout our empirical analysis. The JIP database 2014 consists of various types of annual data for 1970–2011 required to estimate the economic activities of 108 industries in the Japanese economy. The JIP database also

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Morikawa (2014) finds that firm productivity in the services sector is not necessarily low. Ito and Lechevalier (2009) focus on the dispersion of productivity growth across heterogeneous firms, finding evidence that internationalisation has a significant and positive impact on productivity dispersion. Jorgenson and Timmer (2011) insist that the classical trichotomy of agriculture, manufacturing, and services has lost most of its relevance and emphasise the heterogeneity of different subsectors, especially in services.

presents a foundation for EU KLEMS Growth and Productivity Accounts. Because investigating the sources and consequences of labour productivity growth dynamics requires considering the changes affecting disaggregated units, we need statistical data that can capture multi-sectoral performance. The JIP database of RIETI is one of the most appropriate databases for this purpose.

This study uses 106 sectors at the lowest classification level in the JIP database. The housing sector (JIP classification no. 72) and activities not classified elsewhere (JIP classification no. 108) are excluded, because some important data such as the number of workers and man-hours are unavailable. To analyse the sources and consequences, we aggregate these 106 low-level classifications into eight main sectors. Table 1 summarises the correspondence among these classifications.

Table 1: Large, intermediate and small classification based on JIP database

Code in Large classification		Code in intermediate classification		Original no. in JIP (Small classification)
L1	Agriculture	M1	Agriculture	1-6
L2	Industry	M2	Export core manufacturing	42-57
		M3	Other manufacturing	8-41, 58-59, 92
		M4	Other industries	7, 60-66
L3	Service	M5	Financial services	69-70
		M6	Business-related services	67, 73-88, 91, 93, 99, 106
		M7	Consumer services	68, 71, 89-90, 94-97
		M8	Public services	80, 82-84, 98, 100-105, 107

Note: By author on the basis of JIP 2014, Franke and Kalmbach (2005), and Uemura and Tahara (2015).

The highest-level classification is based on the standard classification of the agriculture, industry, and services sectors. The agriculture sector (L1) directly corresponds to the agriculture sector M1; the industry sector (L2) corresponds to M2, M3, and M4; and the services sector (L3) includes M5, M6, M7, and M8.

We employ this industrial classification on the basis of Franke and Kalmbach (2005) and Uemura and Tahara (2015). Uemura and Tahara (2015) classify industries on the basis of Franke and Kalmbach (2005), confirming that the Japanese industrial structure is similar to that in Germany and that there is a strong industrial linkage between the export core manufacturing and business-related services sectors in both countries. In particular, the export core manufacturing sector plays an important role in leading productivity growth dynamics in both the current study and their studies. This sector is defined as the sectors whose export-output ratios are constantly over 20% from 1980 and 2000.

Instead of the TFP growth rate, we use the labour productivity growth rate in this study. First, labour productivity growth is the fundamental determinant of the differences in living standards in the long run. In this sense, it is important to examine labour productivity growth dynamics. Second, labour is only a factor of production in the Baumol model, and productivity growth can be interpreted as both labour productivity and TFP growth. However, the cost and price determination in this model is concerned with the labour cost. Therefore, it is more appropriate to use labour productivity to discuss the cost disease. Finally, the JIP database 2014 has limited information on sectoral TFP growth rates. Although it includes sectoral TFP growth rates in the growth accounting table, because it lacks data on sectoral TFP levels, the data do not fit with some of the analysis in this study such as the decomposition technique and the construction of variables at the intermediate sectoral classification.

By using Table 1, we investigate the sources and consequences of labour productivity growth dynamics in Japan. According to the highest-level classification, we pay attention to the economic performance of these three classically defined sectors. In addition, by using the intermediate classification, we explore heterogeneous performance within the same sector.

3 Sources of productivity growth dynamics

3.1 Decomposition analysis and source of labour productivity dynamics

Many studies examine the sources of labour productivity growth.[3] Among these, we use the decomposition technique presented by Tang and Wang (2004) and Dumagan (2013), for which the calculation is exact for any long period, base-year invariant, and valid for all types of price indexes. The Appendix explains the detailed derivation of aggregate labour productivity growth using this technique. Aggregate labour productivity growth $\hat{q}_t$ in one period from $t-1$ to t can

[3] Baily et al. (1992), Bartlesman and Doms (2000), and Foster et al. (2001) are useful surveys in regard to the decomposition technique. The existing literature employs different productivity variables such as TFP and labour productivity. It also develops different techniques to decompose the aggregate productivity growth rate into within effects, static and dynamic reallocation effects, and entry and exit effects. For example, the decomposition technique proposed by Tang and Wang (2004) and Dumagan (2013) can capture within effects as well as static and dynamic reallocation effects. Incidentally, because the JIP database 2014 does not contain the number of firms within an industry, entry and exit effects cannot be captured by using this database.

be written as

$$\hat{q}_t = \underbrace{\sum_i y_{i,t-1}\hat{q}_{i,t}}_{\text{PPGE}} + \underbrace{\sum_i \bar{q}_{i,t-1}\Delta s_{i,t}}_{\text{DE}} + \underbrace{\sum_i \bar{q}_{i,t-1}\hat{q}_{i,t}\Delta s_{i,t}}_{\text{BE}}. \tag{1}$$

Equation (1) shows that the aggregate labour productivity growth rate $\hat{q}_t$ can be decomposed into the pure productivity growth effect (PPGE), Denison effect (DE), and Baumol effect (BE).

The PPGE is the sum of the weighted sectoral labour productivity growth rates $\hat{q}_{i,t}$; the weight is the sectoral nominal output share at the beginning of period $y_{i,t-1}$. This captures the sectoral contribution purely due to sectoral labour productivity improvements. Therefore, it is alternatively called the within effects. The DE is the sum of the weighted changes in relative size $\Delta s_{i,t}$; the weight is the sectoral relative labour productivity level at the beginning of period $\bar{q}_{i,t-1}$. A change in relative size can be further traced to a change in employment shares or in real output prices. Although the sectoral labour productivity rate is the same among sectors, the movement of labour employment from a relatively low to a relatively high sector can raise the aggregate productivity growth rate. Hence, this effect is also called the static reallocation effect. The BE is the sum of the weighted dynamic sectoral interaction between labour productivity growth rates $\hat{q}_{i,t}$ and the change in relative size $\Delta s_{i,t}$. The weight is the sectoral relative labour productivity level at the beginning of period $\bar{q}_{i,t-1}$. Baumol (1967) and Baumol et al. (1985) find that sectors with low productivity growth could show an increase in relative size. This effect is negative when non-progressive sectors are absorbing relative size over time. This effect is also called the dynamic reallocation effect.

By extending the decomposition technique in Equation (1) for annual average growth for five years, we investigate the sources of labour productivity growth dynamics. Table 2 shows the decomposition of the aggregate labour productivity growth rate in terms of the three effects' contribution and sectoral contribution. Among these three effects, the PPGE positively contributed to aggregate labour productivity growth in most periods. The contribution of the DE was especially large in 2005–2010, but rather small before 2000. The BE negatively contributed to the aggregate growth rate. In terms of the three sectors, Table 2 shows that the services sector positively contributed to the aggregate labour productivity growth rate. The industry sector also contributed to the aggregate labour productivity growth rate, but to a lower extent than services. Agriculture had no substantial influence on the aggregate labour productivity growth rate.

The aggregate labour productivity growth rate is determined by the sum of the contribution of

Table 2: Aggregate labour productivity growth rate and sectoral contributions

(A) Decomposition into three effects

		1970–75	1975–80	1980–85	1985–90	1990–95	1995–2000	2000–05	2005–10
PPGE	Agriculture	0.47%	-0.01%	0.30%	0.15%	-0.04%	0.19%	0.03%	0.02%
	Industry	2.70%	3.26%	2.32%	2.53%	0.62%	1.01%	2.43%	1.46%
	Service	2.20%	1.95%	1.27%	2.23%	1.51%	1.14%	1.87%	0.07%
	Total	5.36%	5.20%	3.89%	4.92%	2.09%	2.34%	4.33%	1.55%
DE	Agriculture	-0.21%	-0.27%	-0.24%	-0.15%	-0.03%	-0.11%	-0.01%	0.04%
	Industry	-1.31%	-0.16%	-0.43%	-0.51%	-0.61%	-0.46%	-0.23%	0.99%
	Service	1.53%	0.07%	0.62%	0.45%	0.50%	0.62%	1.37%	3.57%
	Total	0.02%	-0.36%	-0.05%	-0.22%	-0.14%	0.06%	1.13%	4.60%
BE	Agriculture	-0.14%	-0.01%	-0.10%	-0.05%	-0.01%	-0.07%	-0.01%	-0.01%
	Industry	-1.29%	-2.25%	-0.75%	-0.57%	-0.47%	-0.30%	-1.36%	-1.38%
	Service	-0.55%	-0.30%	-0.23%	-0.63%	-0.26%	-0.07%	-0.37%	-0.09%
	Total	-1.98%	-2.56%	-1.08%	-1.25%	-0.75%	-0.43%	-1.74%	-1.48%

(B) Decomposition into sectoral contribution

	1970–75	1975–80	1980–85	1985–90	1990–95	1995–2000	2000–05	2005–10
Agriculture	0.11%	-0.29%	-0.04%	-0.05%	-0.09%	0.01%	0.01%	0.06%
Industry	0.11%	0.85%	1.14%	1.44%	-0.45%	0.26%	0.84%	1.06%
Service	3.17%	1.72%	1.65%	2.06%	1.74%	1.69%	2.87%	3.56%
ALP growth rate	3.39%	2.28%	2.76%	3.45%	1.20%	1.96%	3.72%	4.68%

Note: Each sectoral contribution shown in (B) is the sum of contribution by three effects in each sector shown in (A). Aggregate labour productivity (ALP) growth rate is the sum of sectoral contribution or alternatively it is also the sum of contribution from three effects.

the three effects or the contribution of the three sectors, which is shown at the bottom of Table 2. On average, Japanese aggregate labour productivity growth grew by more than 2% from 1970 to 1990, but this rate decreased to less than 2% during the lost decade. In the first half of the 2000s, aggregate labour productivity growth recovered rapidly, which was pushed mainly by the PPGE. The acceleration of growth in the second half of the 2000s was sustained by the DE as well.

Table 2 also shows that the aggregate labour productivity growth rate was not monotonically decreasing in Japan as Baumol (1967) predicts. Rather, it was cyclical. In most periods except after 2000, the cyclical dynamics of labour productivity were determined mainly by the positive role of the PPGE, which was partially offset by the negative BE. The DE was small until 2000, but contributed positively thereafter.

Table 2 further provides detailed information on which sector mainly contributed to each effect. With regard to the sectoral decomposition of the PPGE, the agriculture sector did not make a substantial contribution, only a 0.47% contribution at most during 1970–1975. Instead, both the industry and the services sectors determined the dynamics of the PPGE. Of these two sectors, the industrial sector had a higher contribution except for the lost decade. In this period, the industrial sector was especially depressed, whereas the services sector's contribution increased.

With regard to the DE, the agriculture sector did not make a substantial contribution. The degree of contribution by the industry and services sectors to this effect was contrasting. While the services sector contributed positively, the industry sector's contribution was negative. As a result, the aggregate DE had the least magnitude of the three effects in absolute terms until 2000. Thereafter, however, the positive contribution accelerated largely, especially led by services, and the aggregate DE rose substantially. The DE was caused by a change in relative size between sectors with a relatively low productivity level and sectors with a relatively high productivity level, which is independent of the productivity growth rates in these sectors.

According to the sectoral decomposition of the BE, all three sectors made a negative contribution. The BE was negative because sectors with a negative productivity growth rate gained larger relative size and sectors with a positive productivity growth rate lost relative size. The industry sector recorded the largest negative contribution to the BE. In particular, industry sectors with high productivity growth rates lost relative size over time.

In summary, the main source of aggregate labour productivity gains was productivity improvements within sectors. That is, technological progress at the sector level is an important source of productivity gains. In terms of sectoral performance, the main source of aggregate labour productivity growth was the contribution by services, especially compared with that by the industry sector. By taking these observations into consideration, we can also observe the sectoral diversity in the driving forces behind labour productivity dynamics. The agriculture sector contributed non-substantially to the overall productivity growth rate, because the three effects were very weak and the PPGE was offset by a negative DE and BE in most cases. Although the industry sector recorded the highest PPGE, both the DE and the BE were negative in most cases. As a result, the contribution by the industry sector lagged that by the services sector. Indeed, the services sector showed a positive DE, which contributed substantially to the overall productivity growth rate together with the PPGE. The BE was also negative, but its magnitude was sufficiently small not to limit the overall productivity growth rate. The next section explores the sources of these labour productivity growth dynamics in more detail.

3.2 A further investigation into Baumol's growth disease

This section complements the results presented in the previous section. First, we observe selected variables that determine the three effects examined here. Second, by calculating the transitional probability matrix to reveal how sectors change their degrees of contribution, we examine the transformation between progressive and non-progressive sectors in both the short run and the long run. Lastly, by using Nordhaus (2008)'s fixed-shares growth rate (FSGR) analysis, we investigate the dynamic relationship between economic growth and industrial structural change. On this basis, we assess whether the Japanese economy suffers from Baumol's disease.

Table 3 presents the factors determining the contribution of each effect in Equation (1). Panel (A) shows the sectoral productivity growth rates in each period. Focusing on the industry and services sectors, it is difficult to determine which productivity growth was the higher until the end of the 1990s; after 2000, the industry sector played the role of the progressive sector, as Baumol (1967) indicates. Panel (B) shows that the agriculture and industry sectors gradually lost relative size, while the services sector expanded relative size, which accelerated after 2000. Panel (C) shows sectoral-weighted labour productivity growth. The agriculture sector recorded the lowest growth because of its very low relative productivity level (see Panel (E)). Weighted productivity growth in the industry and services sectors traced similar dynamics as the sectoral productivity growth rate shown in Panel (A). Panel (D) shows that agriculture and industry also gradually lost

Table 3: Selected variables determining sectoral contribution

(A) Sectoral productivity growth rate $\hat{q}_i$

	1970–75	1975–80	1980–85	1985–90	1990–95	1995–2000	2000–05	2005–10
Agriculture	6.70%	0.14%	7.13%	3.93%	-2.62%	8.12%	0.84%	1.82%
Industry	2.87%	0.97%	2.39%	3.56%	0.33%	2.07%	5.83%	10.78%
Services	2.32%	2.45%	1.94%	2.59%	1.75%	1.38%	2.32%	0.30%

(B) Change in relative size Δs_i

	1970–75	1975–80	1980–85	1985–90	1990–95	1995–2000	2000–05	2005–10
Agriculture	-5.25%	-5.27%	-4.73%	-2.35%	-0.44%	-2.16%	-0.09%	0.44%
Industry	-4.93%	1.68%	0.34%	-0.60%	-2.57%	-2.27%	-5.02%	-8.21%
Services	8.55%	1.65%	2.40%	2.40%	3.40%	3.83%	6.01%	17.59%

(C) Sectoral weighted labour productivity growth $\bar{q}_i\hat{q}_i$

	1970–75	1975–80	1980–85	1985–90	1990–95	1995–2000	2000–05	2005–10
Agriculture	1.84%	0.04%	2.11%	1.35%	-0.82%	2.60%	0.31%	0.61%
Industry	3.73%	1.20%	2.85%	4.30%	0.38%	2.37%	7.24%	16.55%
Services	2.65%	2.69%	2.14%	2.79%	1.80%	1.44%	2.42%	0.29%

(D) Sectoral nominal value added share y_i

	1970	1975	1980	1985	1990	1995	2000	2005
Agriculture	6.02%	5.63%	3.74%	3.13%	2.46%	1.91%	1.78%	1.54%
Industry	49.35%	42.64%	42.10%	42.01%	41.98%	37.46%	35.29%	33.29%
Services	44.63%	51.73%	54.17%	54.87%	55.56%	60.63%	62.93%	65.17%

(E) Sectoral relative labour productivity level $\bar{q}_i$

	1970	1975	1980	1985	1990	1995	2000	2005
Agriculture	0.240	0.284	0.257	0.318	0.329	0.272	0.366	0.322
Industry	1.226	1.207	1.138	1.125	1.143	1.096	1.106	1.238
Services	1.089	1.044	1.058	1.024	0.992	1.021	0.995	0.941

nominal value added share, which shifted to the services sector. Panel (E) represents the relative labour productivity level of each sector. In terms of level, the industry sector realised higher labour productivity than aggregate labour productivity, while the services sector's level was close to or less than the aggregate level. The relative productivity level of agriculture was much smaller than the aggregate level.

As Equation (1) shows, the contribution from the PPGE is calculated by the sum-product of the sectoral labour productivity growth rate and its nominal value added share. The variables concerning this effect are shown in Panels (A) and (D) in Table 3. In light of this calculation, although the labour productivity growth rate of industry was generally high, because its nominal value added share reduced, the industry sector's contribution to aggregate labour productivity growth was limited. Agriculture followed a similar trend with an extremely small nominal value added share. On the contrary, the services sector recorded constant productivity growth rate, while expanding its nominal value added share. Consequently, the services sector's contribution to aggregate labour productivity growth was sustained.

The DE is the sum-product of the relative productivity level and change in relative size. The negative DE in industry results from, according to Panels (B) and (E) in Table 3, both decreasing relative size and a gradual decline in its productivity level. On the contrary, the services sector realised a positive DE by expanding relative size, although its relative productivity level was close to the aggregate level. With regard to agriculture, the relative productivity level was small, and this sector decreased its relative size. As a result, the DE in agriculture was negative and very small.

Equation (1) allows us to focus on the causes of the BE in detail. The BE is the sum-product of the weighted productivity growth rate and change in relative size. According to Panels (B) and (C) in Table 3, even when the industry sector realised high weighted productivity growth rates, it also decreased in relative size. In particular, industry sectors with high productivity growth rates lost relative size over time, which caused the negative BE in this sector. The services sector also showed a negative BE, although the weighted productivity growth rates in this sector were positive and its relative size expanded.

To check the magnitude of the correlation between the change in relative size and labour productivity growth rate, we calculated the correlation coefficients in each sector for 1970–2010. These variables determine the BE as the dynamic interaction terms. The correlation coefficient is -0.194 for all sectors, -0.354 for agriculture, -0.291 for industry, and -0.084 for services. In addition, the coefficient is significant at the 1% level for all sectors and industry and at the 5% level for agriculture. Thus, the negative coefficients are especially large and significant, except for the services sector, suggesting that if there was any movement in relative size, the resources would be moving from sectors with high productivity growth to sectors with low productivity growth in industry and agriculture. Although aggregate productivity growth is not monotonically declining as Table 2 shows, we can find a silent symptom of Baumol's growth disease in these statistics. Indeed, there is evidence that the BE is negative and substantial except for services.

Table 4: Transitional probability matrix

		t+j (short-run)				**t+k** (long-run)			
		1–10	11–53	54–96	97–106	1–10	11–53	54–96	97–106
t	1–10	53.8%	25.4%	7.7%	13.1%	40.0%	32.7%	6.0%	21.3%
	11–53	7.7%	50.1%	31.8%	10.4%	11.6%	47.4%	32.9%	8.1%
	54–96	1.4%	33.5%	60.3%	4.8%	2.2%	34.4%	57.8%	5.6%
	97–106	6.9%	45.4%	26.2%	21.5%	0.7%	45.3%	34.0%	20.0%

Note: t symbolizes the base period that starts with 1970–1975. Left side of the table shows the short-run transitional probability matrix, where $j = 5$ and 10. Number of sample for comparison is 13. Right side of the table shows the long-run transitional probability matrix, where $k = 15, 20, 25, 30$ and 35. Number of sample for comparison is 15. t is taken by every 5 years since 1970–1975 until 2005–2010.

By calculating the transitional probability matrix for the PPGE, we can also investigate how sectors change their degrees of contribution over time. A canonical Baumol model predicts that progressive sectors whose productivity and nominal value added share are initially high gradually lose their degrees of contribution. On the contrary, it predicts that non-progressive sectors whose productivity and nominal value added share are initially small gradually gain their degrees of contribution. As a result of structural change, the aggregate growth rate is gradually determined by the productivity growth in non-progressive sectors. If this prediction is true, the transitional probability matrix would show that progressive sectors at an initial point fall into lower contribution sectors by losing their degrees of contribution, whereas non-progressive sectors at an initial point creep into higher contribution sectors by gaining their degrees of contribution over time. By classifying progressive (non-progressive) sectors as sectors within the top 10 (bottom 10) contribution, we examine whether the structural change in the Japanese economy follows Baumol's prediction. The short run covers the period between five and 10 years later, while the long run covers the period more than 15 years later.

Table 4 shows the results for 1970–2010. In general, the sectors starting around the middle position (11–96) tend to remain in the same initial position. For example, in the short run, the sectors in 11–53 remain in the same position at 50.1% and those in 54–96 remain in the same position at 60.3%. Similarly, in the long run, the sectors in 11–53 remain in the same position at 47.4%, while those in 54–96 remain in the same position at 57.8%.

Based on the dynamics of the progressive and non-progressive sectors, the structural change in the Japanese economy has the following properties. First, in the short run, initially progressive sectors remain in the same position with a probability of 53.8%. This probability is higher than the probability that initially non-progressive sectors remain in the same position (21.5%). Second, the probability that initially progressive sectors descend to non-progressive sectors is 13.1%, whereas the probability that initially non-progressive sectors creep up to progressive sectors is 6.9%. The former is higher than the latter, meaning that the industrial structure has changed: while it is easier to descend from top to bottom, it is more difficult to grow from bottom to top. Third, in the long run, the probability that initially progressive sectors remain in the same position is still relatively high at 40.0%. This probability is higher than the probability that initially non-progressive sectors remain in the same position (20.0%). Specifically, the probability of remaining in the top position is lower in the long run than in the short run, meaning that it is more difficult to keep a progressive position over time. Fourth, compared with short-run industrial dynamics, the probability that initially progressive sectors descend to non-progressive sectors is 21.3%, which is much larger than the probability that initially non-progressive sectors creep up to progressive sectors (0.7%). That is, the long-run industrial structure has changed: although it is much easier to descend from top to bottom, it is much more difficult to grow from bottom to top. This is the same as the short-run case, but the magnitude is larger in the long-run case.

In summary, the probability that initially progressive sectors descend to non-progressive sectors rises from the short run to the long run (13.1% to 21.3%), whereas the probability that initially non-progressive sectors creep up to progressive sectors falls from the short run to the long run (6.9% to 0.7%). Therefore, progressive sectors are more likely to lose their contribution than non-progressive sectors are to gain. Such long-run dynamics show that industrial structural change has occurred in a manner that limits aggregate economic growth in Japan.

To confirm that the Japanese economy has gradually been suffering from Baumol's growth disease, we finally examine aggregate labour productivity on the basis of Nordhaus (2008) analytics. Nordhaus (2008)'s method to examine Baumol's growth disease is based on the diagnosis that if non-progressive sectors have rising nominal output shares over time, then the aggregate growth rate will reduce as the share of output moves toward the non-progressive sectors. The FSGR is

$$\mathrm{FSGR}_T = \sum_{i=1}^{n} y_{i,T}\hat{q}_{i,t} \tag{2}$$

meaning that it is derived from the sum of pure productivity growth weighted by nominal value added. By comparing the FSGR for different base years (T), we can determine the impact of structural change on labour productivity growth. If the FSGR is lower for later T, then the Baumol growth effect is negative, indicating that shares are moving toward non-progressive sectors. By contrast, if the FSGR is higher for later T, then the Baumol growth effect is positive, indicating that shares are moving toward progressive sectors. We detect which sector is suffering from Baumol's growth disease by dividing the whole industry into eight main sectors.[4]

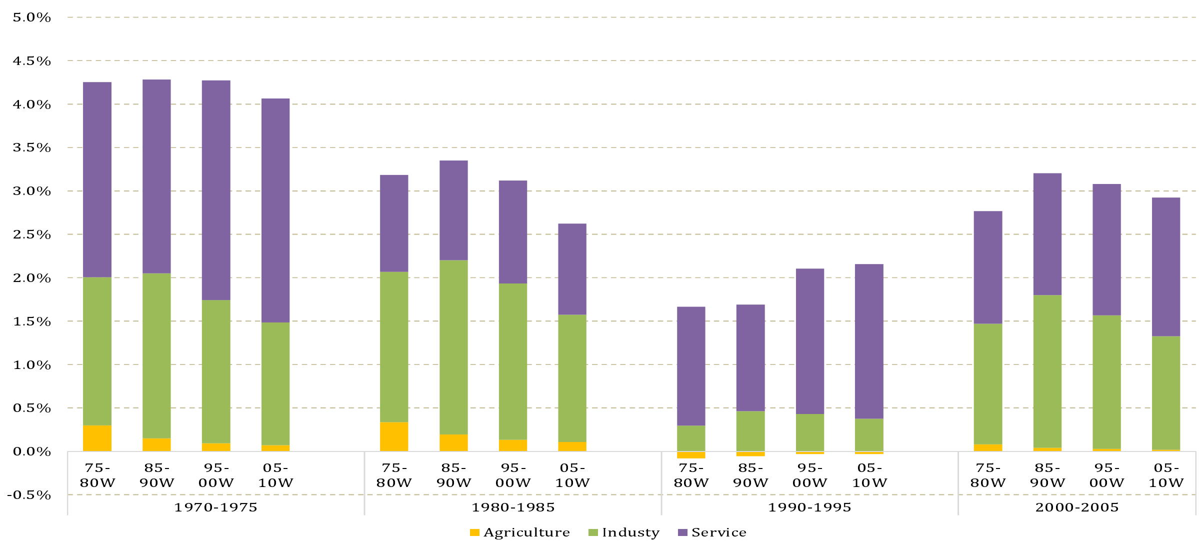

Figure 1: FSGR of labour productivity for different base years and periods (all sectors)

Figure 1 shows the FSGR for aggregate labour productivity growth, by dividing the contribution of agriculture, industry, and services. The weights are the five-year average nominal value

[4]The BE in the decomposition technique captures the actual growth contribution in terms of relative size, while the FSGR calculation is a type of counterfactual analysis using different periods' nominal value added shares to capture the growth bonus or burden of structural change.

added share and the FSGR is calculated every 10 years from 1975. First, at the aggregate level, the Baumol growth effect seems to reduce the aggregate labour productivity growth rate except for during the lost decade. To be more precise, the nominal value added weights in 1985–1990 shift to reduce aggregate growth. The atypical evolution of the FSGR for 1990–1995 may be caused by the bursting of the bubble, which was not a structural trend but rather a temporary shock. Second, the Baumol growth effect works negatively and monotonically for the agriculture sector in all periods. This effect for the industry sector is also depressing on the basis of the 1985–1990, 1995–2000, and 2005–2010 weights. That is, the higher productivity growth sectors in the industry sector have been losing their nominal value added share over time and the industry sector has been suffering from negative Baumol's growth disease. Third, the services sector is not affected by the negative BE. The FSGR for services is not monotonically decreasing for all weights. Hence, the structural change in terms of the nominal value added share favours growth through the services sector's contribution, while it restrains growth through the industry sector's contribution. Such a result is consistent with the result using the correlation coefficient shown above.

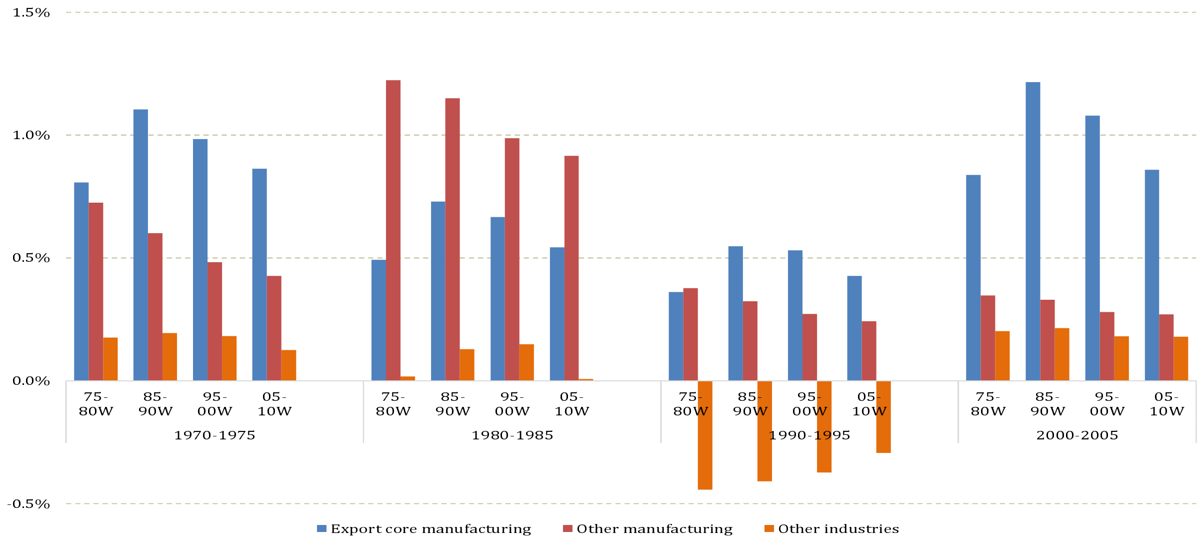

Figure 2: FSGR of labour productivity for different base years and periods (industry sectors)

To investigate the sectoral sources of the negative and positive BE in more detail, Figures 2 and 3 show the evolution of the FSGR for industry and services at the intermediate classification, respectively. Sectors within industry and services show diverse configurations. According to Figure 2, the contribution of the export core manufacturing sector is the highest of the three sectors in industry except for 1980–1985, which is followed by other manufacturing and other industry. Figure 2 shows that all three sectors lose their contribution when using weights after 1985–1990. That is, Baumol's growth disease is negative in most sectors in industry, which explains why the overall contribution from industry has been decreasing. This result is consistent with the decomposition analysis result that the BE is negative for industry.

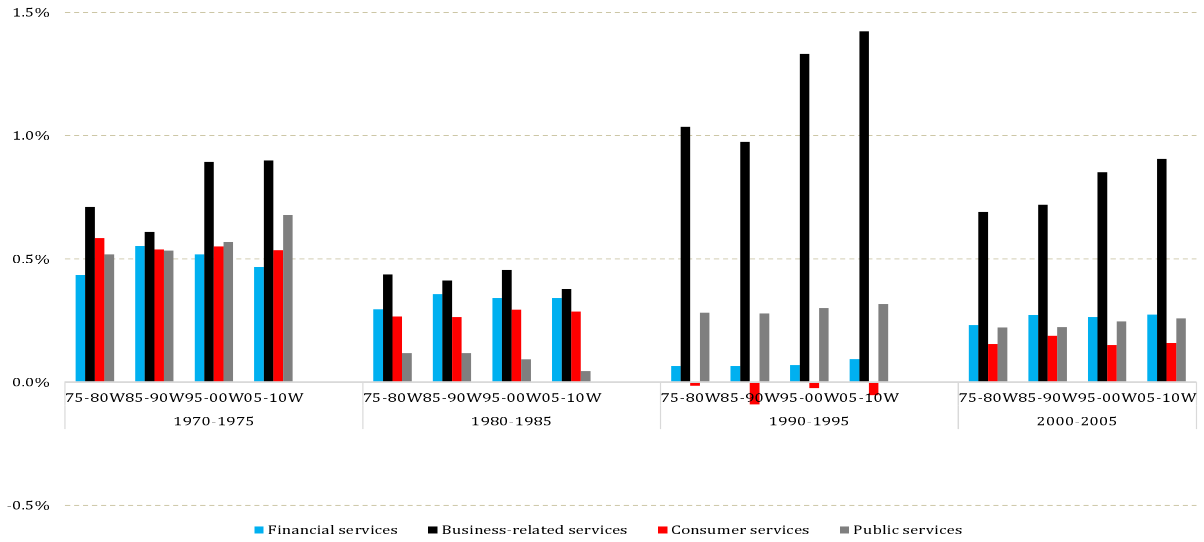

Figure 3: FSGR of labour productivity for different base years and periods (services sectors)

Figure 3 shows the evolution of the FSGR for services at the intermediate classification. The business-related services sector has the most important contribution in all periods. Except for 1980–1985, this sector's contribution is increasing with later T, meaning that the Baumol growth effect is positive and that higher productivity growth sectors within this sector attract the nominal value added share over time. The public services' contribution is slightly increasing over time except for 1980–1985. With regard to consumer services and financial services, the contributions move cyclically and seem to be almost constant. In the services sector, the positive Baumol growth effect is working in certain sectors such as business-related services and public services, whereas the other two sectors' contributions are almost constant, which mainly determines the overall contribution of the services sector. Thus, the Baumol growth effect is not uniquely working in the services sector.

This section examined the sources of productivity growth dynamics and considered whether the Japanese economy is affected by Baumol's growth diseases. The main findings are as follows. First, although labour productivity growth is not declining monotonically as in Baumol's model, it is silently affected by Baumol's growth disease. Second, progressive sectors are more likely to lose their contribution than non-progressive sectors are to gain their contribution over time, implying that industrial structural change has been restraining aggregate economic growth in Japan. Third, Baumol's growth disease is not necessarily apparent in the services sector. However, it is uniquely negative in most industry sectors, which causes the overall decrease in the contribution by industry. Baumol's growth disease lies behind the Japanese economy. It is silent but it undermines labour productivity dynamics.

4 Consequences of productivity growth dynamics

Baumol (1967) explains that when a PGRD exists, the cost per unit of output in non-progressive sectors will rise without limit relative to that in progressive sectors, which is known as the cost disease. This section explores the consequence of the PGRD, namely its impact on cost and price dynamics at the sector level in the Japanese economy. We also discuss the within and between sectoral configurations of these variables and reveal how the Japanese economy has been affected by the consequences of PGRD dynamics.

4.1 Empirical dynamics of Baumol's model parts

Baumol's model mainly consists of both real sides such as output, employment, and labour productivity and nominal sides such as wage rates, unit labour costs, and prices. Figure 4 shows the evolution of real output, employment, labour productivity, wage rates, unit labour costs, and prices in the agriculture, industry, and services sectors (in index numbers with 1973=100). Table 5 shows the annual average growth of these variables for 1974–2011, 1974–1997, and 1997–2011. For the later discussion, this table also presents the PGRD of each variable compared with the industry sector in parentheses.

Figure 4 shows that output in the agriculture, industry, and services sectors diverged after 1973. Services grew the most rapidly until the mid-2000s, followed by growth in industry. Output in industry expanded more strongly after 2000, only catching up with services at the index level after 2010. Output in the agriculture sector stagnated after 1973. Baumol (1967) assumes that despite the increasing relative costs and prices of non-progressive sectors, the relative outputs of these sectors may be maintained because of government aid or demand for goods.[5] This

[5]This is called the paradox of the services, namely that demand for services persists even when their costs are exploding. The studies in ten Raa and Schettkat (2001) investigate this issue from different points of view.

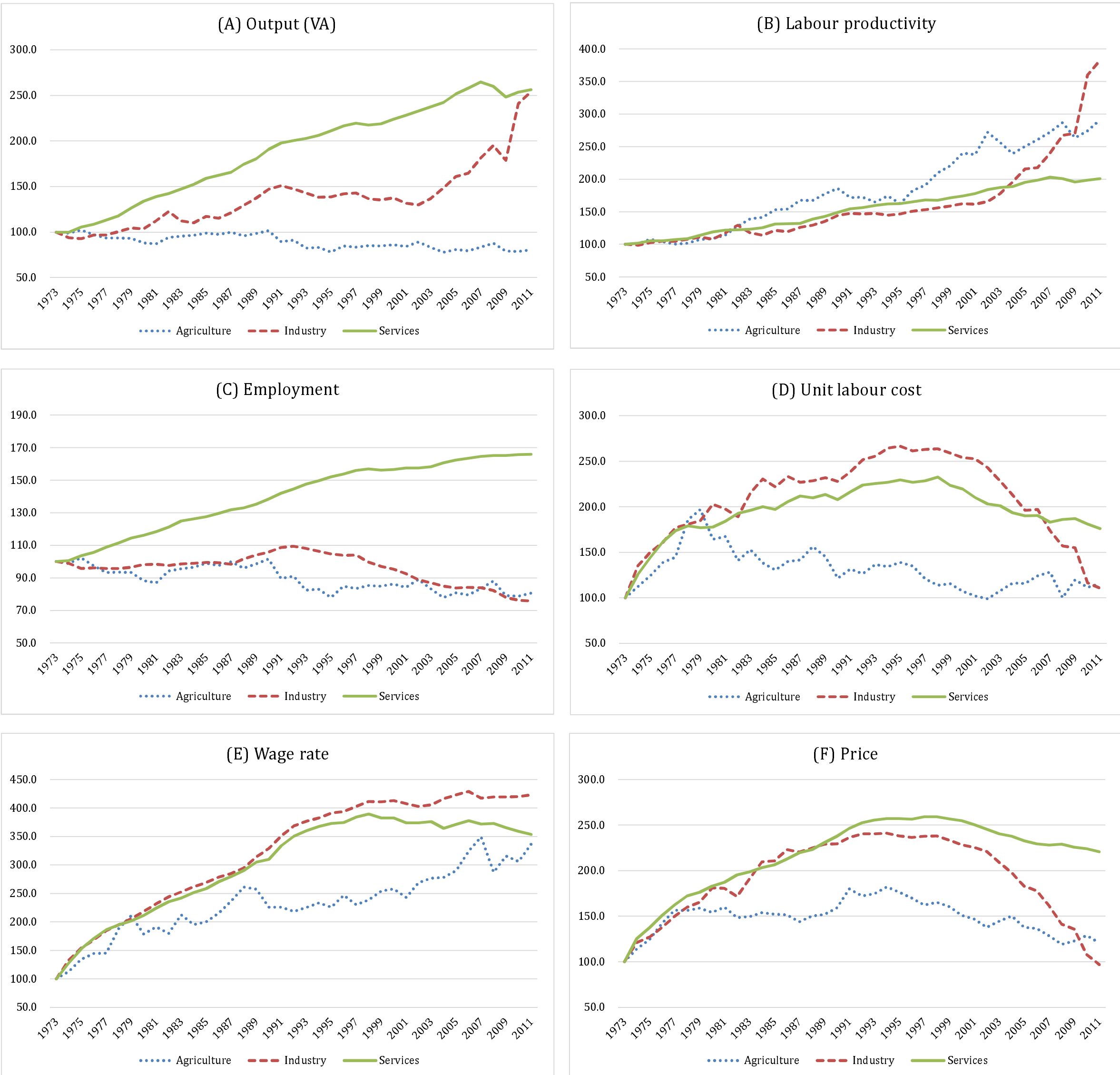

Figure 4: Developments of the key variables in the agriculture, industry, and services sectors

assumption is not observed empirically as far as Figure 4 shows, because output growth at the sector level does not change at the same rate over time.

There was increasing employment in the services sector and decreasing employment in the industry sector. These dynamics are the complex effects of output and labour productivity growth dynamics. Agriculture showed a comparatively constant increase in labour productivity, whereas output dynamics stagnated at a low level, which resulted in a decreasing employment trend in this sector after 1973.

Employment in the services sector increased before the PGRD for the industry sector became obvious. Employment in the services sector grew constantly after 1973; not until 2000 did the labour productivity growth rate in industry accelerate above that in services. Employment in services increased constantly because of the constant increase in output growth. Although the productivity growth gap was not obvious between these two sectors, when output grew constantly in the services sector, employment in this sector also rose.[6] Figure 4 shows that labour productivity growth in the industry as a whole slightly lagged that of the services sector, while output grew at a higher rate in the services sector than in the industry sector until the end of the 1990s. As a result, there was a steady increase in employment in the services sector during this period. After 2000, however, labour productivity in the industry sector accelerated much more than ever, reaching more than triple the level of 1973. We discuss that this acceleration contributed to de-industrialisation in employment terms in the next section.

According to the dynamics of the real sides of the economy, it is difficult until the end of the 1990s to uniquely define the industry sector as a progressive sector and the services sector as a non-progressive sector as in the Baumol (1967) model. This is because both sectors continued to contribute to the overall productivity growth rate both negatively and positively and each sector's

[6]This is confirmed in an extended Baumol's model. Suppose a progressive sector 1 and non-progressive sector 2. The labour productivity growth rate in each sector is given by $\hat{q}_1 = \hat{X}_1 - \hat{L}_1$ and $\hat{q}_2 = \hat{X}_2 - \hat{L}_2$. Subtracting and arranging both sides leads to

$$\hat{L}_2 - \hat{L}_1 = (\hat{q}_1 - \hat{q}_2) + (\hat{X}_2 - \hat{X}_1)$$

Baumol (1967)'s assumption is that relative output at the sector level is constant, meaning that the growth rates of these sectors are the same $\hat{X}_2 = \hat{X}_1$. Led by the PGRD ($\hat{q}_1 > \hat{q}_2$), the progressive sector pushed out employment to the non-progressive sector. However, although the PGRD was very small (i.e. $\hat{q}_1 \doteq \hat{q}_2$), employment in the services sector still increased as long as output grew sufficiently and more rapidly compared with the industry sector ($\hat{X}_2 > \hat{X}_1$).

Table 5: Average growth rates and sectoral growth rate differential of selected variables

	(A) 1974–2011				(B) 1974–1997				(C) 1997–2011			
	All	L1	L2	L3	All	L1	L2	L3	All	L1	L2	L3
LP	2.75%	2.91%	3.74%	1.86%	2.36%	2.81%	1.94%	2.21%	3.40%	3.07%	6.76%	1.28%
		(-0.83)	(0.00)	(-1.88)		(0.87)	(0.00)	(0.27)		(-3.69)	(0.00)	(-5.47)
Wage	3.12%	3.00%	3.18%	2.79%	5.18%	3.15%	4.94%	4.91%	-0.18%	2.75%	0.36%	-0.60%
		(-0.19)	(0.00)	(-0.39)		(-1.79)	(0.00)	(-0.03)		(2.39)	(0.00)	(-0.95)
Price	0.65%	0.15%	-0.60%	1.54%	3.01%	1.55%	2.98%	3.20%	-3.12%	-2.10%	-6.21%	-1.14%
		(0.75)	(0.00)	(2.14)		(-1.43)	(0.00)	(0.22)		(4.11)	(0.00)	(5.07)

Note: Realized average growth rates are shown upper side. Values lower side in parenthese are the growth rate differential on each variable, compared with the industry sector (L2).

productivity growth rate was similar. On the contrary, after the end of the 1990s, the industry sector began to play the role of the progressive sector and the services sector became a non-progressive sector. The labour productivity growth and employment dynamics during this period were similar to those under the Baumol (1967) model. Labour productivity in the industry sector grew more rapidly than that in the services sector; further, employment was constantly absorbed by the services sector, while the industry sector pushed out employment.

Focusing on the dynamics of the nominal sides of the economy, wage rates in the industry and services sectors also increased similarly until the end of the 1980s. Then, the rates began to diverge gradually, noticeably so after the end of the 1990s. While the evolution of wage rates in the industry sector grew only slowly, that of wage rates in the services sector decreased slightly. The wage rate in agriculture grew cyclically.

According to Figure 4, the unit labour costs in the industry and services sectors changed similarly until 1980. The unit labour cost index was higher in industry than in services between 1980 and the mid-2000s. After the end of the 1990s, the unit labour cost in industry began to fall rapidly, with the index of the unit labour cost in the industry sector dropping below that in the services sector in 2011. The unit labour cost in industry began to fall rapidly in the period that labour productivity in this sector began to accelerate. Hence, the relative decline in the unit labour cost in the industry sector reflected the relative increase in labour productivity in this sector.

Another consequence of the PGRD is reflected in the relative price differential between the products of these sectors. Figure 4 and Table 5 show that with the somewhat higher growth rate in services, prices in both the industry and the services sectors changed similarly until the end of the 1990s, during which sectoral wage rates also grew similarly. The Japanese economy showed overall inflation of 3% between 1974 and 1997. On the contrary, there was a gradual price growth differential between the two sectors after the end of the 1990s, when labour productivity accelerated much more in the industry sector. During this period, the Japanese economy showed overall deflation of -3%.

The Japanese economy has been undermined by atypical Baumol's cost disease since the end of the 1990s, as the recent consequence of the PGRD is not the same as that under Baumol's original model. While the Baumol (1967) model predicts relative and overall inflation, the recent Japanese economy shows relative and overall deflation. The original Baumol (1967) model assumes that wages grow in accordance with labour productivity in progressive sectors. Then, the unit labour cost and price in progressive sectors remain constant, while those in non-progressive sectors rise constantly, which causes overall inflation. The PGRD thus leads to so-called PGRD inflation.[7]

By contrast, after the end of the 1990s, when the industry sector began to play the role of the progressive sector and the services sector became a non-progressive sector, the unit labour cost and price of the services sector slightly decreased, while those of the industry sector declined largely. As a result, overall prices in the economy fell gradually. Table 5 shows that the PGRD between the industry and services sectors was -5.47% for 1997–2011, with a rate of change in relative prices of 5.07%. The rate of change in relative prices almost followed the PGRD. In contrast to Baumol's case, the absolute prices in the progressive sector decreased largely, whereas those in the non-progressive sector underwent small deflation. Thus, while the PGRD led to PGRD deflation, the Japanese economy suffered from overall deflation.[8]

[7]We explain why the Japanese economy underwent PGRD inflation at the sector level during 1974–1997 in the next section. However, it is difficult to assert that this phenomenon is also true when we compare the industry and services sectors at the highest classification level. This is because the PGRD is small and does not necessarily correspond to the price growth differential in this period. Given their similar wage growth rates, the labour productivity growth rate is slightly higher in the services sector than in the industry sector, while the inflation rate is also slightly higher in the former than in the latter. The econometric test results shown in Table 9 also imply that the sectorally different impacts of productivity growth are not significant during this period.

[8]By using a simple model, PGRD inflation and deflation can be explained as follows. Suppose there are two sectors: progressive (sector 1) and non-progressive (sector 2). The price in each sector is given by $p_1 = w/q_1$ and $p_2 = w/q_2$, where w is a uniform wage rate. In a dynamic extension, they are $\hat{p}_1 = \hat{w} - \hat{q}_1$ and $\hat{p}_2 = \hat{w} - \hat{q}_2$, where $\hat{q}_1 > \hat{q}_2$. The Baumol (1967) case corresponds to the case in which the wage growth rate follows the productivity

4.2 A further investigation into Baumol's cost disease

The previous section focused on the highest-level classification. However, whether the dynamics of the industry and services sectors show similar or different configurations is an outcome of within sectoral dynamics. In this context, we investigate in more detail the configuration of Baumol's cost disease in each sector. Based on the intermediate classification, we consider the consequences of labour productivity dynamics in the industry and services sectors.

Figure 5 shows the evolution of real output, employment, labour productivity, wage rates, unit labour costs, and prices in the industry sector (represented by index numbers with 1973=100). Table 6 shows the annual average growth of these variables for 1974–2011, 1974–1997, and 1997–2011. For the later discussion, this table also presents the growth rate difference of each variable compared with export core manufacturing in parentheses.

Output in industry showed heterogeneous performance. The export core manufacturing sector presented the most rapid growth, especially after 2000. Output in other manufacturing and other industry expanded with cyclicity until the beginning of the 1990s, but constantly decreased thereafter. The ratio was almost constant between other manufacturing and other industry as under Baumol (1967)'s assumption, but the export core manufacturing sector presented exceptional output growth.

Employment in export core manufacturing and other industry tended to grow until the beginning of the 1990s, although it also involved some downward phases. The other manufacturing

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growth rate of the progressive sector. Since it is $\hat{w} = \hat{q}_1$ in this case, then the price dynamics in both sectors are

$$\hat{p}_1 = \hat{q}_1 - \hat{q}_1 = 0$$
$$\hat{p}_2 = \hat{q}_1 - \hat{q}_2 > 0$$

That is, the unit labour cost and price of the non-progressive sector rise constantly, while those of the progressive sector are constant. As a result, overall prices in the economy rise gradually. This is PGRD inflation. By contrast, in the recent Japanese economy, the wage growth rate is rather stagnating and relatively close to the productivity growth rate of the non-progressive sector. For simplicity, we assume $\hat{w} = \hat{q}_2$, meaning that the price dynamics in both sectors are

$$\hat{p}_1 = \hat{q}_2 - \hat{q}_1 < 0$$
$$\hat{p}_2 = \hat{q}_2 - \hat{q}_2 = 0$$

That is, the unit labour cost and price of the non-progressive sector remain constant, while those of the progressive sector decrease constantly. This is PGRD deflation.

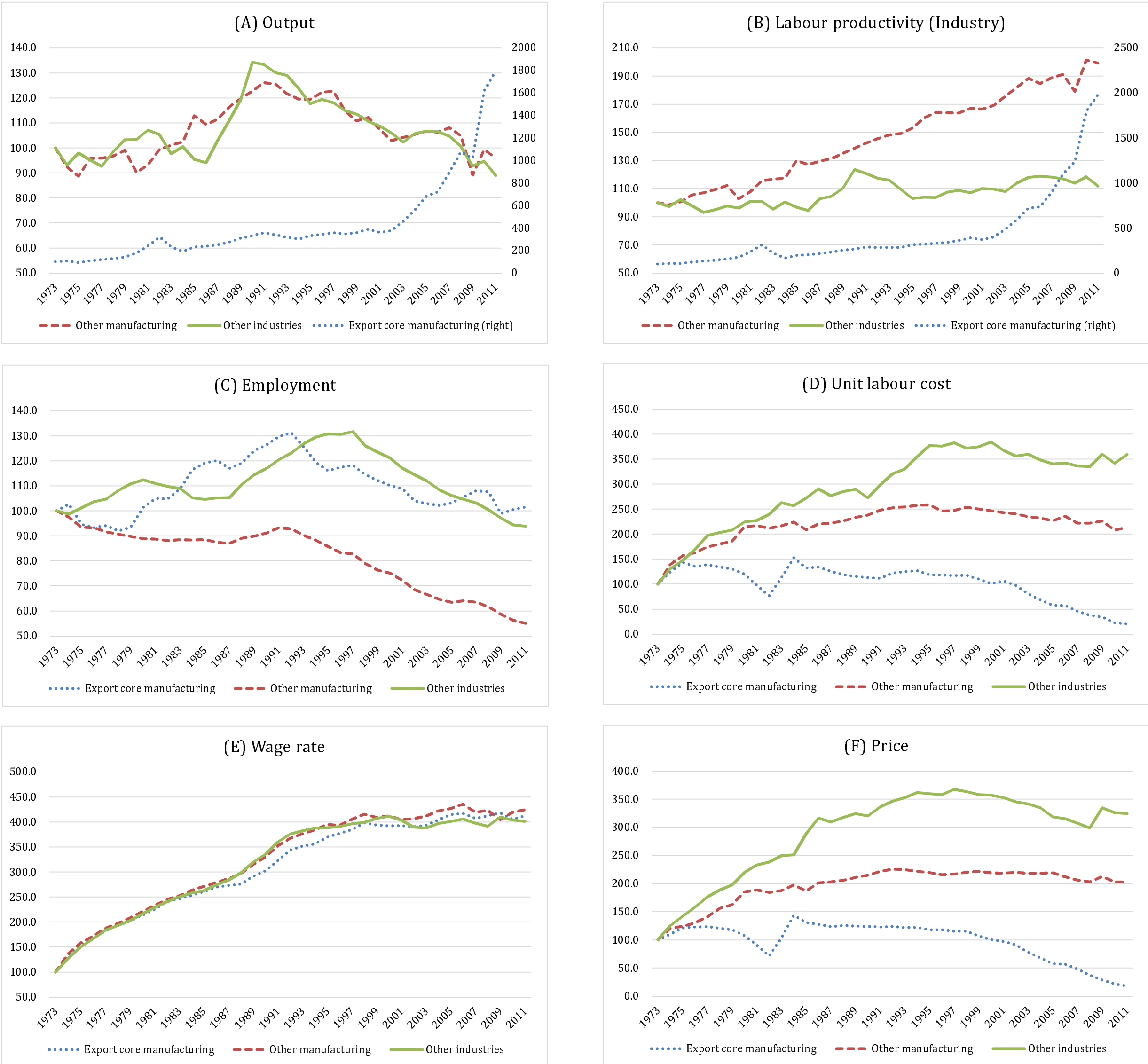

Figure 5: Developments of the key variables in the industry sector

sector decreased employment constantly, which was the main source of de-industrialisation in employment terms. After the mid-1990s, employment in the export core manufacturing and other industry sectors also began to decrease, which accelerated the overall decrease in employment in industry, as shown in Figure 4.

The labour productivity and output dynamics together determine the evolution of employment. Labour productivity in other manufacturing was constantly growing, and its output began to decrease after the mid-1990s. As a result, employment in this sector decreased. Although labour productivity in other industry was rather stagnant, output in this sector also began to decrease after the mid-1990s. Consequently, employment in this sector gradually decreased. Labour productivity in export core manufacturing was accelerating at an exceptional level, especially after 2000: the level was 20 times higher in 2011 than in 1973. Both output and labour productivity in export core manufacturing was rapidly growing, but the latter was higher than the former, suggesting that employment in this sector was decreasing.

It is surprising that wage rates in the industry sector increased similarly over time. Although the wage rate in the export core manufacturing sector temporally lagged those in the other two sectors at the end of the 1980s, no divergence in wage rates was apparent. The sectoral wage growth rate in the industry sector almost follows Baumol (1967)'s supposition.

The unit labour cost in industry showed a contrasting trajectory between the three sectors. The unit labour cost index began to diverge after the mid-1970s and the other industry recorded the highest growth in the unit labour cost, followed by other manufacturing. The unit labour cost in export core manufacturing began to clearly decrease after the end of the 1990s, when labour productivity growth in this sector began to accelerate.

Figure 5 shows that the trajectory of the price index in each sector traced a similar trajectory to that of the unit labour cost. During 1974–1997, Baumol's cost disease was rather clear in the industry sector. As Table 6 shows, the export core manufacturing sector was a progressive sector that recorded the highest productivity growth; the other two sectors were non-progressive. In addition, the wage growth rates of the three sectors closely followed the productivity growth of the progressive sector (4.99%), similar to Baumol (1967)'s model. As a result, the rate of change in prices in the progressive sector was rather constant (0.22%), while that in the non-progressive sectors rose. Moreover, the PGRD was much larger than the wage growth rate differential, leading to an inflation differential. Thus, during this period, there was PGRD inflation in the industry

Table 6: Average growth rates and sectoral growth rate differential of selected variables

(A) 1974–2011

	M1	**M2**	M3	M4	**M5**	M6	M7	M8
LP	2.91%	8.20%	1.92%	0.38%	3.15%	2.23%	1.61%	0.98%
		(0.00)	(-6.27)	(-7.82)	(0.00)	(-0.91)	(-1.54)	(-2.16)
Wage	3.00%	3.11%	3.11%	3.17%	3.33%	2.58%	2.54%	2.77%
		(0.00)	(0.00)	(0.05)	(0.00)	(-0.75)	(-0.80)	(-0.56)
Price	0.15%	-4.78%	1.42%	2.61%	-0.29%	1.09%	1.84%	2.46%
		(0.00)	(6.20)	(7.39)	(0.00)	(1.38)	(2.13)	(2.75)

(B) 1974–1997

	M1	**M2**	M3	M4	**M5**	M6	M7	M8
LP	2.81%	4.99%	2.25%	0.28%	5.38%	2.55%	1.73%	1.21%
		(0.00)	(-2.74)	(-4.71)	(0.00)	(-2.82)	(-3.65)	(-4.17)
Wage	3.15%	4.74%	4.84%	5.09%	5.49%	4.76%	4.47%	5.18%
		(0.00)	(0.10)	(0.34)	(0.00)	(-0.73)	(-1.01)	(-0.30)
Price	1.55%	0.22%	2.59%	4.80%	-0.08%	3.00%	3.30%	4.35%
		(0.00)	(2.37)	(4.58)	(0.00)	(3.07)	(3.38)	(4.43)

(C) 1997–2011

	M1	**M2**	M3	M4	M5	**M6**	M7	M8
LP	3.07%	13.68%	1.39%	0.53%	-0.42%	1.71%	1.40%	0.62%
		(0.00)	(-12.29)	(-13.14)	(-2.13)	(0.00)	(-0.31)	(-1.09)
Wage	2.75%	0.48%	0.33%	0.08%	-0.11%	-0.89%	-0.56%	-1.08%
		(0.00)	(-0.16)	(-0.40)	(0.79)	(0.00)	(0.33)	(-0.18)
Price	-2.10%	-12.46%	-0.47%	-0.88%	-0.64%	-1.97%	-0.52%	-0.58%
		(0.00)	(11.99)	(11.58)	(1.33)	(0.00)	(1.46)	(1.39)

Note: Realized average growth rates are shown upper side. Values lower side in parenthese are the growth rate differential on each variable, compared with the highest productivity growth sector within same category. Emphasis by bold represents progressive sector.

sector, leading to overall inflation (2.98%).

On the contrary, the recent unit labour cost and price dynamics in industry follow PGRD deflation. Figure 5 and Table 6 show much larger PGRD among the three sectors since 1997. They also show that the wage rates of these three sectors were rather close to the productivity growth rate of the non-progressive sector (e.g. 0.53% of other industries). Thus, the PGRD directly led to PGRD deflation. The unit labour cost and price of the non-progressive sector remained constant or fell slightly, since the productivity growth rate can offset the wage growth rate only marginally. By contrast, those of the progressive sector decreased largely over time, because productivity growth sufficiently offsets the wage growth rate. Figure 5 shows that after the end of the 1990s, the price index of the other industry and other manufacturing sectors (non-progressive) showed a slow and decreasing trend, whereas that of export core manufacturing (progressive) decreased rapidly, leading to overall deflation in industry (-6.21%). Thus, PGRD deflation has also appeared not only between different sectors but also within sectors in the recent Japanese economy.

Figure 6 shows the evolution of real output, employment, labour productivity, wage rates, unit labour costs, and prices in the services sector (represented by index numbers with 1973=100). Table 6 shows the annual average growth of these variables for 1974–2011, 1974-1997, and 1997–2011. For the later discussion, this table also presents the growth rate difference of each variable compared with financial services (M5) for 1974–2011 and 1974–1997 and business-related services (M6) for 1997–2011 in parentheses.

The evolution of output in services is not uniform. Baumol (1967)'s assumption of a constant output ratio between sectors was not observed in this sector. Business-related services and public services grew constantly, but consumer services were stagnant after 1990. Output growth in the financial services sector was remarkable during the bubble period, but it decreased during the global financial crisis in 2008.

Employment in services grew under a divergent trajectory after the mid-1990s. While employment growth in public services grew constantly, that in business-related services and consumer services slowed. The financial services sector began to lose employment in the same period. The Japanese economy involved de-industrialisation, and employment in services expanded. The configuration is more divergent in the services sector, with some sectors absorbing employment and others not. For example, the public sector showed increasing employment, but

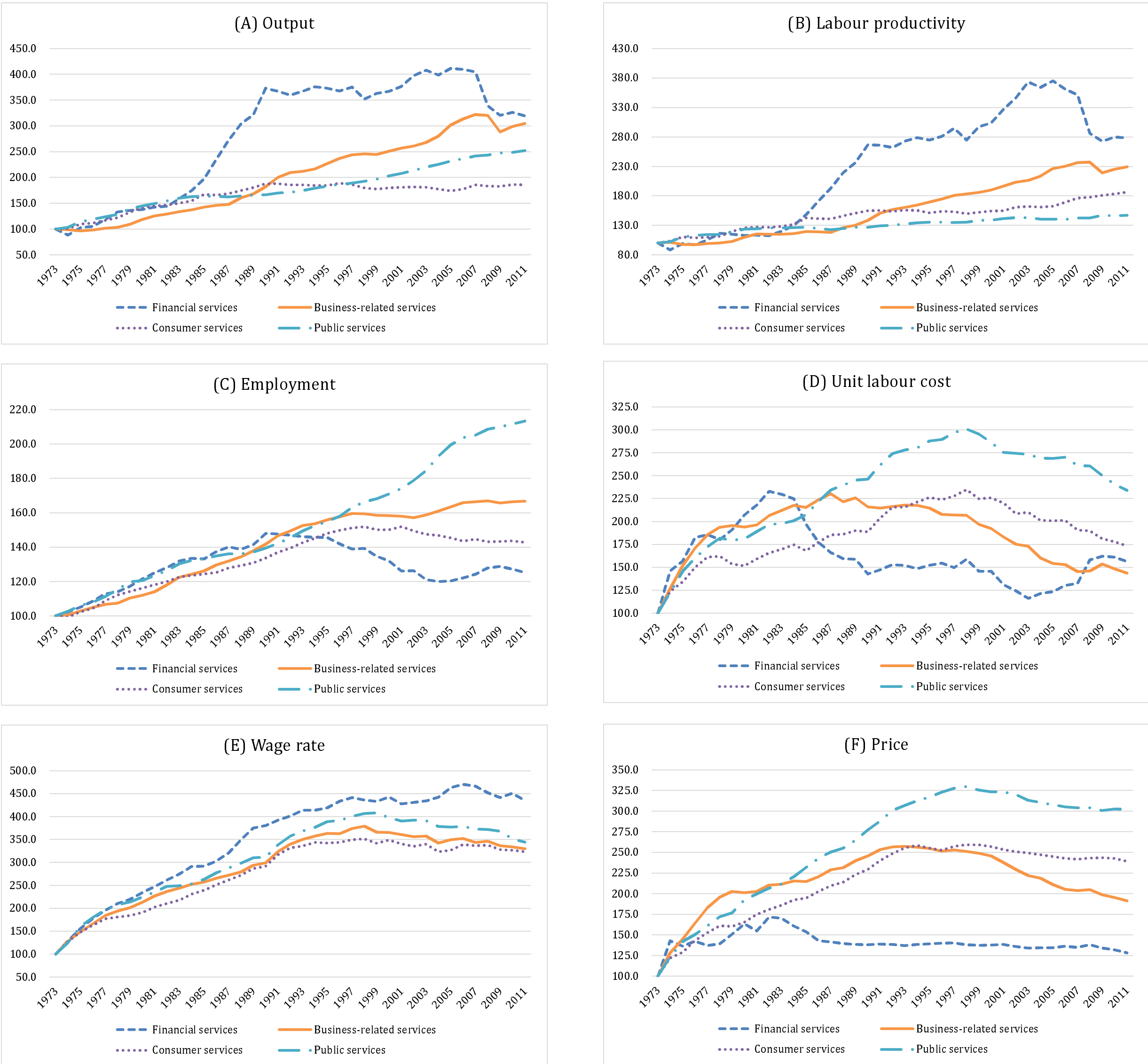

Figure 6: Developments of the key variables in the services sector

employment in financial services fell owing to the dynamics of the PGRD. Labour productivity in the financial sector expanded until the global financial crisis. Although output in the financial sector grew rapidly until the bubble burst, the index remained constant after the early 1990s. Thereafter, the financial sector pushed out employment, led by its productivity dynamics. On the contrary, labour productivity in the public sector was stagnant in the long run, whereas its output grew constantly. Thus, the public sector absorbed employment by way of an output expansion.

Figure 6 shows the trajectory of the unit labour cost and price index in each sector of the services sector. The unit labour cost and price in services showed a divergent trajectory between its four sectors after the mid-1980s. The unit labour cost index and price of the public sector showed a constant increase until the end of the 1990s, whereas the rise in the variables for consumer services and business-related services showed a rather slow rate. These variables in financial services fell rapidly before the bubble period and remained constant in the 1990s. After the end of the 1990s, the unit labour cost index and price began to fall in most services sectors at different rates, whereas financial services showed a hike in the cost during the global financial crisis.

Cost and price dynamics are related to productivity dynamics. During 1974–1997, Baumol's cost disease was clear in the services sector. As Table 6 shows, during this period, financial services was a progressive sector that recorded the highest productivity growth, while the other three sectors were non-progressive. In addition, the wage growth rates of these sectors closely followed the productivity growth of the progressive sector (5.38%). Thus, the situation was similar to that under Baumol (1967)'s model. As a result, the rate of change in prices in the progressive sector was rather constant (-0.08%), while that in the non-progressive sector increased. Moreover, the PGRD was much larger than the wage growth rate differential. Thus, during this period, PGRD inflation existed in the services sector.

On the contrary, the unit labour cost and price dynamics within services followed PGRD deflation, although their magnitude was smaller than that in the industry sector. That is, the unit labour cost and price of progressive sectors fell largely, while those of non-progressive sectors underwent small deflation. Figure 6 and Table 6 show that after 1997, financial services exited from the progressive sector, business-related services entered that sector, and there was still a low productivity differential. They also show that the wage rates of these sectors were negative and closer to the productivity growth of the non-progressive sector (e.g. -0.42% for financial services). Then, PGRD directly led to PGRD deflation. According to Figure 6 and Table 6, the price indexes of the financial, consumer, and public services sectors showed a slow and decreasing trend, whereas that of the business-related services sector (progressive) decreased rapidly. Such a configuration led to overall deflation within services (-1.14%). Thus, PGRD deflation also appeared in the services sector in the recent Japanese economy.

In summary, during 1974–1997, the typical trend for Baumol's cost disease can be observed, especially in both the industry and the services sectors, whereas an atypical Baumol's cost disease trend can be detected within and between the industry and services sectors during 1997–2011. Thus, the consequences of productivity growth dynamics occurred in a nested manner across sectors. The typical Baumol's cost disease appeared as PGRD inflation, whereas the atypical Baumol's cost disease appeared as PGRD deflation. Thus, the consequence of productivity dynamics changed after the end of the 1990s, undermining the Japanese economy by way of deflation.

5 Econometric analysis of the sources and consequences of productivity dynamics

The proceeding sections shed light on the sources and consequences of productivity dynamics in Japan on the basis of the statistical data. This section complements these issues by using an econometric analysis. First, by using the panel Granger test, we detect the causes of productivity dynamics. Second, by using the same test, we also detect the consequences of productivity dynamics. Finally, to reveal the main determinants of price dynamics that reflect Baumol's cost disease, a panel data analysis is conducted.

We focus on the demand- and supply-side factors to reveal which factor causes labour productivity dynamics in Granger's sense. By dividing the whole industry into eight sectors (see Table 1), we conduct the panel Granger test in a panel environment. In particular, we test for Granger causality by assuming that causality is sectorally homogeneous (stacked test) and causality is sectorally heterogeneous (Dumitrescu–Hurlin test).[9]

[9] In a panel environment with T periods and N individuals, for each individual $i = 1, .., N$, at time $t = 1, .., T$, $x_{i,t}$ is said to Granger cause $y_{i,t}$ if the past values of $x_{i,t}$ have a significant impact on $y_{i,t}$ in addition to the past values of $y_{i,t}$. We checked this by using Eviews 9. To check this causality in bivariate regressions, the stacked test treats the panel data as one large stacked dataset. Then, it performs the Granger causality test in the standard way, while assuming that all coefficients are the same (i.e. homogeneous) across all cross-sections. By contrast,

Table 7: Panel Grenger causality tests (1974–2011)

CAUSES			CONSEQUENCES		
	Stacked test F-Stat.	Dumitrescu Hurlin test W-Stat.		Stacked test F-Stat.	Dumitrescu Hurlin test W-Stat.
Lags	GDE to Labour productivity		Lags	Labour productivity to Price	
1	3.261	0.422	1	541.3***	21.23***
2	5.726***	3.188	2	304.6***	25.43***
3	3.546**	3.48	3	236.8***	25.8***
	Capital to Labour productivity			Labour productivity to Wage	
1	0.422	0.634	1	0.057	1.225
2	1.113	3.309	2	0.104	3.148
3	1.415	5.028	3	0.065	5.072
	Man-hour labour to Labour productivity			Labour productivity to unit labour cost	
1	0.286	0.675	1	513.5***	27.25***
2	2.365	1.957	2	293.2***	43.61***
3	1.885	3.004	3	200.1***	39.33***
	Capital-labour ratio to LP			Labour productivity to labour	
1	0.081	1.085	1	2.365	0.871
2	3.791**	3.521	2	6.293***	3.469
3	2.888**	5.246**	3	3.241**	4.387

Note: Significance is denoted by *** 1 % and ** 5 % level.

Sectoral labour productivity growth is given in the original Baumol model and hence how it is induced is unclear. In the proceeding sections, we did not explore the main causes of sectoral labour productivity growth. Here, we consider gross domestic expenditure (GDE), capital input, man-hour labour input, and the capital-labour ratio as possible determinants of labour productivity growth from a theoretical point of view. GDE is a proxy of effective demand according to Keynesian theory. Capital and man-hour labour are factors that expand output, as emphasised by standard neoclassical theory. These factors also enhance the supply side to increase output. The role of the capital-labour ratio is emphasised by Kaldorian theory. For example, Kaldor (1957) introduces the technological progress function that links the growth rates of capital per labour and output per labour.

After checking the stationarity of each variable, we conducted the panel Granger causality test to explore whether GDE, capital input, man-hour labour input, and the capital-labour ratio cause labour productivity growth in Granger's sense.[10] The left-hand side of Table 7 shows the results for the causes of labour productivity growth. Growth in aggregate demand and in the capital-labour ratio cause labour productivity growth in Granger's sense. They both have Granger causality with two and three lags. As the stacked test shows, they are significant at least at the 5% level when we assume the same coefficient across sectors. That is, the causality from growth in GDE and the capital-labour ratio to labour productivity growth is homogeneous across sectors. In the case of the capital-labour ratio, the causality with three lags is also heterogeneous as the Dumitrescu–Hurlin test shows. That is, the casualty from the capital-labour ratio to labour productivity growth occurs heterogeneously across sectors. With regard to single factor inputs such as capital and man-hour labour, none of them has Granger causality either homogenously

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the Dumitrescu–Hurlin test performs the Granger causality regressions for each cross-section individually, while assuming that all coefficients are different (heterogeneous) across cross-sections.

[10]We conducted panel unit root tests to confirm the presence of stationarity. As the panel data include cross-sectional items, we need to consider whether these items have a common unit root as well as individual unit root processes. Therefore, we conducted four types of panel unit root tests, namely the Levin, Lin, and Chu and Breitung tests, which assume common unit roots in panel data, and the Im, Pesaran, and Shin and Fisher-type augmented Dickey–Fuller tests, which assume individual unit roots in panel data. Although we do not report the detail because of space limitations, one or other (or both) of these common and individual unit root tests reject the null hypothesis of unit root processes at the 5% significance level. The lag length in these tests was selected by using the automatic lag length selection based on the Schwarz information criterion. On this basis, we employed these variables without taking differences.

and heterogeneously. Thus, in terms of the panel Granger causality test, the growth rates of effective demand and the capital-labour ratio rather than input factors cause labour productivity growth dynamics.

The right-hand side of Table 7 shows the results for the consequences of labour productivity growth. We test whether and the extent to which labour productivity dynamics cause wage, unit labour cost, price, and employment dynamics in Granger's sense. Labour productivity growth causes growth in the price and unit labour cost in Granger's sense. These causalities with one, two, and three lags are significant at the 1% level; moreover, as the stacked test and Dumitrescu–Hurlin test show, they are also homogeneous and heterogeneous across sectors. Another consequence of labour productivity dynamics concerns the change in employment, which homogenously causes a change in employment with two and three lags in Granger's sense. On the contrary, labour productivity growth does not cause the growth in wages in Granger's sense in any form. In other words, the wage rate moves independently of labour productivity dynamics. The above evidence corresponds to the implication of the Baumol model that employment, unit labour cost, and price dynamics are the consequences of labour productivity dynamics.

Finally, we examine the magnitude of the impact of labour productivity growth on the change in prices, one of the final consequences of labour productivity growth dynamics. In Baumol (1967), both the wage and the productivity growth rates are the main determinants of product prices. On this basis, we detect which of these factors influence price dynamics more. In addition, we also take into account the sectorally different impacts of the labour productivity growth rate on price dynamics by introducing the industry and services dummy in a simple model. To this end, we estimate the equations by introducing the labour productivity growth rate, wage rate, and cross terms of the sectoral dummy and labour productivity growth rate one by one as regressors.

The panel data analysis is conducted for 1974–2011, 1974–1997, and 1997–2011. Since the JIP database provides data from 1970 to 2011, the period division can be made at several points. This study takes 1997 as the period division for the following reasons. First, as shown in Tables 5 and 6, the wage rate growth between the industry and services sectors began to diverge around this year. Second, a severe financial crisis attacked the Japanese economy in this year, which resulted in a large fall in the GDP growth rate to -1.8 in 1998. Thus, from this year, structural change had an important impact on the Japanese economy.

We set up seven models to estimate price dynamics. All models include the labour productivity growth rate, to which the wage growth rate is added in models (2), (4), and (6). In addition, models (3) and (4) consider the inherent productivity growth impact by the industry sector (L2), while models (5) and (6) consider the inherent productivity growth impact by the services sector (L3). Model (7) takes account of the inherent productivity growth impact of both the industry and the services sectors.[11] Since the cross-section effect is partially controlled for by introducing the sector dummy variables into some models, we introduce the period effect only and choose the type of speciation by using the Wu–Hausman test at the 5% significance level.

Table 8: Estimations for price dynamics based on Baumol's framework (1974–2011)

Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)
period				1974–2011			
Const.	0.039***	0.037***	0.038***	0.037***	0.037***	0.036***	0.038***
	(3.685)	(3.501)	(3.537)	(3.461)	(3.503)	(3.402)	(3.483)
LP	-0.622***	-0.623***	-0.575***	-0.637***	-0.626***	-0.626***	-0.688**
	(-12.26)	(-11.79)	(-2.888)	(-3.041)	(-12.13)	(-11.64)	(-2.071)
Wage		0.063		0.065		0.060	
		(0.313)		(0.318)		(0.299)	
Industry dummy·LP			-0.050	0.014			0.063
			(-0.244)	(0.066)			(0.189)
Service dummy·LP					0.108	0.063	0.167
					(0.448)	(0.254)	(0.422)
Observations				304			
Period effect	Random	Fixed	Random	Fixed	Random	Fixed	Random
F-stat.	150.8***	6.026***	75.16***	5.853***	75.33***	5.856***	50.09***
Adjusted R-squared	0.331	0.393	0.329	0.390	0.329	0.391	0.327

Note: Dependent variable in all regressions is the growth rate of prices. Significance is denoted by *** 1 %, ** 5 % and * 10 % level. Value in parentheses represent t-value. Reference sector for models (3)–(7) is agricultural sector.

Table 8 shows the result for the long run (1974–2011). We see that labour productivity growth is significant in all models. Its coefficient for all models shows a negative sign and a rise in labour productivity growth leads to a fall in prices, which is a similar result to that of Baumol (1967). The coefficient for the wage growth rate is positive but not significant, meaning that a rise in

[11] Each of these eight sectors belongs to agriculture, industry, or services. In the estimation, we define the dummy variable for two of these three sectors, namely industry and services.

the wage rate does not have a substantial impact on price dynamics in the long run. By using the dummy variables, we also introduce the sectorally different impact of the labour productivity growth rate on price dynamics. However, in the long run, such a sectoral difference does not have a significant impact on price dynamics. Therefore, from 1974 to 2011, the labour productivity growth rate is the main determinant of price dynamics. Hence, the wage rate and sectorally different impacts of productivity growth are not the main determinants of price dynamics.

Table 9: Estimations for price dynamics based on Baumol's framework (1974–1997)

Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)
period				1974–1997			
Const.	0.065***	0.037**	0.068***	0.041**	0.068***	0.040**	0.068***
	(4.637)	(2.504)	(4.521)	(2.588)	(4.582)	(2.563)	(4.710)
LP	-0.631***	-0.639***	-0.839***	-0.849***	-0.626***	-0.633***	-0.837
	(-9.644)	(-9.946)	(-2.736)	(-2.819)	(-9.440)	(-9.724)	(-1.529)
Wage		0.487***		0.485***		0.484***	
		(2.998)		(2.959)		(2.944)	
Industry dummy·LP			0.216	0.219			0.214
			(0.695)	(0.716)			(0.389)
Service dummy·LP					-0.200	-0.222	-0.002
					(-0.564)	(-0.634)	(-0.004)
Observations				192			
Period effect	Random	Random	Random	Random	Random	Random	Random
F-stat.	93.45***	52.94***	46.86***	35.27***	46.72***	35.21***	31.04***
Adjusted R-squared	0.326	0.352	0.324	0.345	0.324	0.350	0.321

Note: Dependent variable in all regressions is the growth rate of prices. Significance is denoted by *** 1 %, ** 5 % and * 10 % level. Value in parentheses represent t-value. Reference sector for models (3)–(7) is agricultural sector.

By dividing the study period into 1974–1997 and 1997–2011, we find contrasting evidence. During 1974–1997, not only the labour productivity growth rate but also the wage growth rate has a significant impact on price dynamics. Except model (7) in Table 9, the coefficients for both variables are significant at the 1% level. In this period, the wage growth rate positively pushes the rate of change in prices, whereas the labour productivity growth rate restrains it. Although we also introduce the sectorally different impacts of the labour productivity growth rate on price dynamics by using the dummy variable, such a difference does not have a significant impact on price dynamics. To sum up the result from 1974 to 1997, both the wage and the labour productivity growth rates are the main determinants of price dynamics. The sectorally different impacts of the productivity growth rate are not the main determinants of price dynamics.

Table 10: Estimations for price dynamics based on Baumol's framework (1997–2011)

Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)
period				1997-2011			
Const.	-0.005	-0.005*	-0.007**	-0.007**	-0.006**	-0.007**	-0.007**
	(-1.647)	(-1.693)	(-2.108)	(-2.125)	(-1.987)	(-2.033)	(-1.997)
LP	-0.593***	-0.601***	-0.243***	-0.257***	-0.645***	-0.651***	-0.464***
	(-13.65)	(-13.80)	(-3.309)	(-3.470)	(-16.48)	(-16.71)	(-4.307)
Wage		0.135		0.100		0.133*	
		(1.488)		(1.300)		(1.777)	
Industry dummy·LP			-0.424***	-0.412***			-0.207*
			(-5.190)	(-5.021)			(-1.826)
Service dummy·LP					0.560***	0.556***	0.381***
					(5.652)	(5.653)	(2.736)
Observations				120			
Period effect	Fixed	Fixed	Random	Random	Random	Random	Random
F-stat.	13.87***	13.29***	0.681***	86.50***	134.8***	92.69***	93.80***
Adjusted R-squared	0.619	0.623	0.681	0.683	0.692	0.698	0.701

Note: Dependent variable in all regressions is the growth rate of prices. Significance is denoted by *** 1 %, ** 5 % and * 10 % level. Value in parentheses represent t-value. Reference sector for models (3)–(7) is agricultural sector.

On the contrary, after 1997, the sectorally different impacts of the productivity growth rate began to be apparent as the determinants of price dynamics. Table 10 shows the result for 1997–2011. As with the previous results, the labour productivity growth rate has a negative and significant coefficient at the 1% level in all models. The coefficient of the wage growth rate is positive, but it is significant for model (6) only. In addition, the magnitude of the wage impact becomes weaker in this period (0.133) than in the previous period (0.484). In these senses, the impact of wages is of less importance for price dynamics.[12] The most notable result is the sectorally different impacts of the labour productivity growth rate on price dynamics. Although the rise in

[12]We also confirmed that the wage rate is stagnating overall during this period in the Japanese economy. Although we do not explore this issue in detail, wage stagnation is concerned with institutional and structural changes. For example, Boyer et al. (2011) indicate that the demise of "shunto" (spring offensive) in the mid-1990s that assured

the productivity growth rate generally decreases prices, the decrease in prices is accelerated by productivity growth in the industry sector, whereas it is decelerated by productivity growth in the services sector. As we showed above, during this period, the industry sector plays the role of the progressive sector, whereas the services sector is the non-progressive sector. The econometric test here confirms that the PGRD leads to different consequences on price dynamics as PGRD deflation.

To summarise, important heterogeneity between the industry and services sectors appears during PGRD deflation. From 1997 to 2011, labour productivity growth is still important, but the wage rate loses importance for price dynamics compared with 1974–1997. Moreover, the sectorally different impacts of productivity growth are also the main determinants of price dynamics. The econometric tests conducted in this section also support the symptom of atypical Baumol's cost disease during 1997 and 2011. The fall in prices by labour productivity growth is larger in the industry sector than in the services sector.

6 Conclusion

This study revealed the sources and consequences of labour productivity growth dynamics in the Japanese economy. We conducted an empirical analysis based on Baumol (1967)'s implication of growth and cost diseases. By shedding light on the Japanese economy, this study thus presents new evidence that adds to the existing literature in this field. We conclude this paper by summarising the main results.

First, aggregate labour productivity growth does not monotonically decline but is rather cyclical over time. According to Baumol (1967), given the PGRD between the non-progressive (services) and progressive (industry) sectors, labour is transferred to the former and the aggregate productivity growth rate falls monotonically over time. By contrast, in the Japanese economy, both the industry and the services sectors continued to contribute to the overall growth rate both negatively and positively until the end of the 1990s. Therefore, it is difficult to define the industry sector as progressive and the services sector as non-progressive during this period. After the end of the 1990s, however, the industry sector began to play the role of the progressive sector, led especially by the export core manufacturing sector, while the services sector became the

the spillover effect of wage increases for the overall economy and increased the number of non-regular workers, especially in the services sector with low wages, led to overall wage stagnation.

non-progressive sector.

Second, by decomposing aggregate labour productivity dynamics into three effects, we found that the PPGE typically leads to a change in aggregate labour productivity growth. This effect is mostly positive and determines aggregate labour productivity growth. On the contrary, the BE is mostly negative, by which aggregate labour productivity growth is restrained. This negative impact is especially large in the industry sector. Generally, the contribution of the DE is rather small except for 2005–2010.

Third, although it is not apparent in aggregate labour productivity dynamics, Baumol's growth disease is silently latent in the Japanese economy. If there was any movement in relative size in the industry and agriculture sectors, the resources are moving from sectors with high productivity growth to sectors with low productivity growth. In addition, the probability transition matrix shows that progressive sectors are more likely to lose their contribution than non-progressive sectors are to gain. Moreover, the FSGR shows that the Baumol growth effect for the agriculture and industry sectors is depressing, meaning that these sectors have been suffering from negative Baumol's growth disease, whereas this effect is partially positive in the services sector. Overall, the nominal value added weights, especially since 1985-1990, shift to reduce aggregate growth. Baumol's growth disease thus undermines the Japanese economy.

Fourth, the panel Granger causality test reveals that the growth rates of effective demand and the capital-labour ratio cause labour productivity growth. On the contrary, neither man-hour labour input nor capital input it-self causes labour productivity growth in Granger's sense. This result implies that the Keynesian effective demand and Kaldor's technological progress view are important as causes of labour productivity growth. The panel Granger causality test also suggests that labour productivity growth causes a change in the price, the unit labour cost, and labour, whereas it does not cause a change in the wage rate. This causality goes along with Baumol (1967)'s model since the dynamics of the unit labour cost, prices, and employment are a consequence of labour productivity dynamics, whereas the wage growth rate is not necessarily so.

Fifth, although it is difficult to find a relationship between productivity growth and price dynamics at the highest industrial classification during 1974–1997, PGRD deflation is apparent between industry and services after the end of the 1990s. However, a closer look at the within sectoral dynamics reveals that PGRD inflation is apparent in both the industry and the services sectors during 1974–1997 and that PGRD deflation is apparent in both sectors during 1997–2011. Thus, the consequences of productivity growth dynamics occur in a nested manner across sectors. Moreover, the consequences of productivity dynamics have been changing since the end of the 1990s, undermining the Japanese economy by way of deflation. Hence, Baumol's cost disease appears atypically as deflation in the recent Japanese economy.

Sixth, the econometric analysis reveals the following evidence. In the long run (1974–2011), labour productivity dynamics are the main determinant of price dynamics in most cases. Neither the wage rate nor sectorally different productivity impacts push price dynamics. By dividing the entire period into 1974–1997 and 1997–2011, we found contrasting evidence. During 1974–1997, both the wage growth rate and the labour productivity growth rate had a significant impact on price dynamics. The wage growth rate pushed the rate of change in prices, whereas the labour productivity growth rate restrained it. There was no sectorally different impacts of labour productivity growth on price dynamics. On the contrary, during 1997–2011, the wage growth rate lost a positive and significant impact in most cases, whereas the labour productivity growth rate still had a negative and significant impact on price dynamics. Moreover, there was a sectorally different impact of the labour productivity rate on price dynamics. Further, the decrease in prices was accelerated by the productivity growth rate in the industry sector, whereas it was decelerated by the productivity growth rate in the services sector. Thus, important heterogeneity between industry and services appeared during PGRD deflation.

On the basis of these six main findings, we conclude that Baumol's growth disease silently undermines Japanese economic growth and that the Japanese economy suffers from atypical Baumol's cost disease.

We focused on the Baumol (1967) model as a reference to investigate the sources and consequences of labour productivity growth dynamics and presented new evidence from the Japanese economy. This primitive model is thus useful to consider the essence of the sources and consequences of labour productivity growth dynamics. As we explained in the Introduction, the model has been extended to many fields such as services' role as an input, endogenous technological progress, and so on. These extensions generally show that the aggregate growth rate does not decline as Baumol's original model says. This paper does not take these extensions into consideration in a sufficient manner. Therefore, they are remaining issues for future research.

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Appendix

Decomposition method of labour productivity growth

A fixed-weight index and chained index are well-known methods for calculating real value in the economy. However, the fixed-weight index may overestimate (underestimate) the importance of industries with frequent price decreases (increases), while it tends to overestimate the real side of the economy, especially when the estimation year differs from the base year. The chained index method can minimise these problems by sequentially using the price structure of the previous year in the calculation; however, this method involves the problem of the non-additive issue. As the aggregate is defined by the sum of its components, traditional ways of computing industrial contributions to aggregate labour productivity growth based on the additivity of real output are no longer valid. The technique proposed by Tang and Wang (2004) and Dumagan (2013) decomposes aggregate labour productivity growth into industrial contributions to address these problems. The technique is exact for any long period, base-year invariant, and valid for all types of price index numbers. This technique thus enables us to measure pure productivity growth, the DE, and the BE regardless of the measure of real output or the behaviour of relative prices.

The technique of Tang and Wang (2004) and Dumagan (2013) is as follows. Consider an economy with n sectors, with aggregate real output X, aggregate labour input L, aggregate nominal output Y, and aggregate price index P. Aggregate labour productivity $q = X/L$ is defined as the real output per unit of labour input. As real output is measured by using deflated nominal output $X = Y/P$, aggregate labour productivity can also be expressed as $q = Y/PL$. By building up from nominal output at the sector level, aggregate labour productivity can be defined as

$$q = \frac{\sum_i Y_i}{PL}$$

Define $p_i = P_i/P$, which is the relative output price or real output price of sector i; $l_i = L_i/L$, the labour input share for sector i; and $s_i = p_i l_i$, the labour input share adjusted for its real output price, which is called here the relative size of sector i. The labour share is adjusted by the real output price because a change in the real output price also affects the importance of the sector in aggregate GDP. This in turn influences the contribution of the sector to aggregate labour productivity even when the sector's labour share and labour productivity remain constant. Aggregate labour productivity can be expressed as

$$q = \sum_i p_i l_i q_i = \sum_i s_i q_i,$$

meaning that aggregate labour productivity can be expressed as the weighted sum of sectoral labour productivities. The weight of each industry is equal to its relative size. On this basis, aggregate labour productivity growth over a period can be calculated over one year or more. In a simple case of the growth rate over one period from $t-1$ to t, this is as follows:

$$\hat{q}_t = \frac{\sum_i (s_{i,t} q_{i,t} - s_{i,t-1} q_{i,t-1})}{q_{t-1}}.$$

Define $\overline{q}_{i,t-1} = q_{i,t-1}/q_{t-1}$ as the labour productivity level of sector i relative to the aggregate labour productivity level at the beginning of the period, and $\Delta s_{i,t-1} = s_{i,t} - s_{i,t-1}$ as the change in the relative size of sector i from $t-1$ to t. Then, add and subtract $\sum_i \overline{q}_{i,t-1}(s_{i,t-1}\hat{q}_{i,t})$, leading to

$$\hat{q}_t = \sum_i \overline{q}_{i,t-1} \left[s_{i,t-1}\hat{q}_{i,t} + \Delta s_{i,t} + \Delta s_{i,t}\hat{q}_{i,t} \right].$$

Define $y_{i,t-1} = \overline{q}_{i,t-1} s_{i,t-1}$, which is equal to the nominal output share of sector i, $Y_{i,t-1}/Y_{t-1}$ at the beginning of the period. Then, equation (1) is derived.

Data source

The JIP database 2014 of RIETI is employed in this study. The original data source and construction of the variables in this paper are explained as follows:

- Labour productivity (used in most tables and figures) is defined as the ratio of real value added to man-hours. Real value added is taken from the Growth accounting table (sheet name V), evaluated at 2000 prices. Man-hours are taken from the Labour input table (sheet name 3–8).

- Nominal value added share (Tables 2 and 3, and Figures 1–3) is taken from the Growth accounting table (sheet name NV), evaluated at current prices.

- GDE (Table 7) is the sum of government consumption, nonprofit consumption, households consumption, changes in inventories, capital (public and private sectors), exports, and imports (negative). These items are taken from the Input-Output table, 7) Final demand by sector.

- Labour (employment) (Figures 4–6) is the number of workers by sector in the Labour input table (sheet name 3–7) to calculate these indices.

- Relative size (Tables 2–3) is evaluated by the product of the relative price and man-hours share in each sector. The relative price in each sector is calculated by dividing its price by the price at total sector level.

- Capital (Table 7): The capital stock variable is taken from the real net capital stock in the Growth accounting table (sheet name KT), evaluated at 2000 prices.

- The capital-labour ratio (Table 7) is defined as the ratio of real net capital to the number of workers introduced above.

- Wages (Tables 5–10 and Figures 4–6) are evaluated by dividing the nominal labour cost by man-hours. The nominal labour cost is taken from the Growth accounting table (sheet name WL).

- Prices (Tables 5–10 and Figures 4–6) are calculated by dividing the nominal value added by the real value added.

- The unit labour cost (Table 7 and Figures 4–6) is calculated by dividing the nominal labour cost by the real value added.

To calculate the growth rate of each variable, it is defined as its annual growth rate.