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# Missing Growth in the Lost Decade*

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Abstract

Standard measurement often impute innovation from creative destruction and new varieties using surviving products. This can lead to an understatement of growth, if surviving products improve less than creatively destroyed products and new varieties. This paper estimates this bias for Japan using establishment-level data from the Japanese Census which covers all private businesses. We find that the correction increases Japan's productivity growth by 0.39 percentage points per year between 1997 and 2009 with most of the missing growth coming from non-manufacturing industries. As this bias is smaller than the bias found for the U.S., our results imply 0.23 percentage points per year bigger difference between productivity growth rates in the U.S. and Japan. The larger difference mostly stems from a larger difference in productivity growth rates for non-manufacturing industries.

Keywords: inflation measurement, growth measurement, lost decade, creative destruction, productivity
JEL Classification: E31, O31, O47



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# 1. Introduction

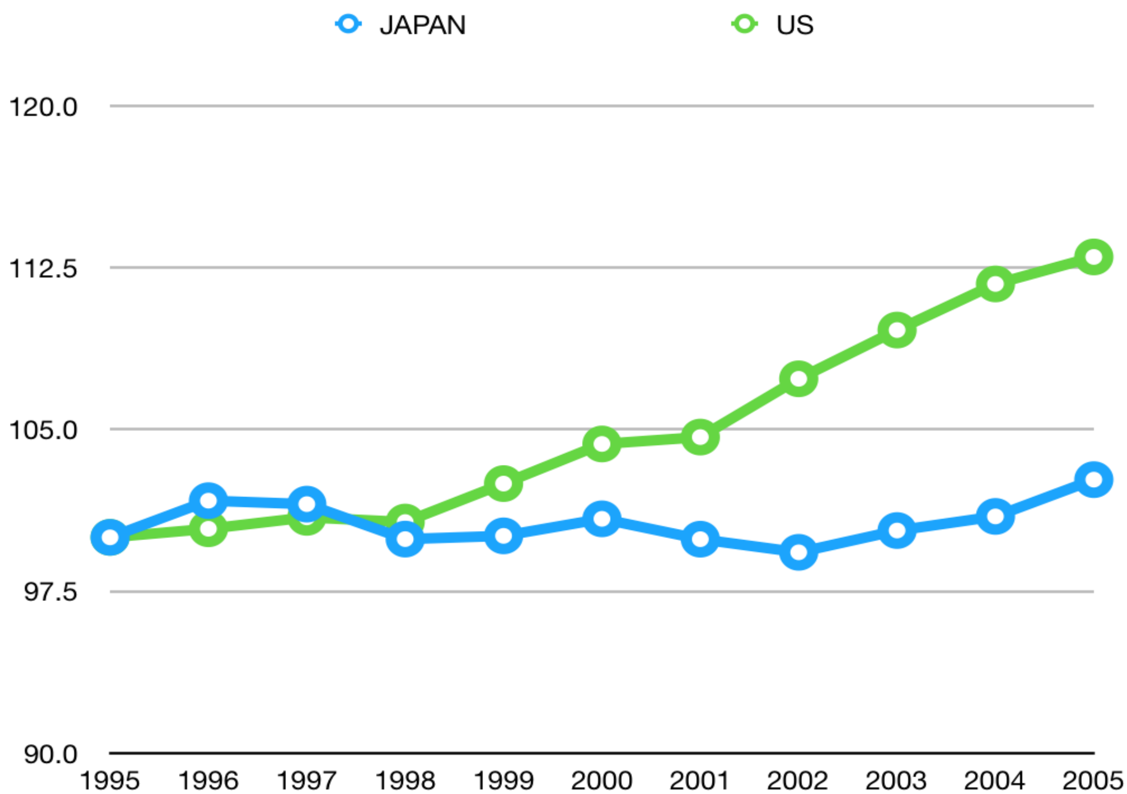
According to official statistics, Japan's aggregate productivity growth was abysmal between the late 1990's and early 2000's. Figure 1 compares the growth rate of total factor productivity in the U.S. and Japan. It shows that over the 10 years between 1995 and 2005, productivity in the U.S. grew cumulatively by 12.5% while productivity in Japan grew by less than 5%. This phenomenon is often referred to as "the Lost Decade". It has attracted the attention of policy makers and researchers.

A recent paper Aghion et al. (2019) shows that aggregate productivity growth in the U.S. is significantly understated because official measurements miss productivity growth due to innovation from creative destruction and new goods. This bias occurs because official statistics in the U.S. use imputation to estimate the inflation rate of disappearing goods. Taken at face value, this suggests that the true gap in U.S. and Japan growth rates is larger than suggested by official statistics. However, as we will argue in detail, imputation is also commonly used in Japan. Hence one needs to account for bias in both countries in order to quantify the true gap between U.S. and Japan's growth rates.

This paper applies the methodology of Aghion et al. (2019) to quantify missing growth in Japan. Our data comes from the Establishment and Enterprise Census in 1996, 2001, 2004, and 2006 and the Economic Census in 2009. These datasets cover all establishments in all industries in Japan. We ask 1) how large is missing growth in Japan, 2) which industries contribute to missing growth and 3) is the US-Japan productivity growth gap larger that previously thought.

We find on average 0.39 percentage points of missing growth per year in Japan. This is about 0.25 percentage points smaller than the missing growth found in the U.S. over the same time period suggesting that the US-Japan productivity growth gap is indeed larger than previous thought. If we take the 7.5% gap in Figure 1 as a benchmark, our results suggest that instead of a gap of 7.5%, Japan's productivity grew slower by 10% over 1995–2005. Finally, similar to

Figure 1: The Lost Decade




Source: TFPva_I series. EU KLEMS March 2008 Release. JIP.

Aghion et al. (2019)'s finding for the U.S., we find large missing growth in retail trade, accommodations and food services and little missing growth in manufacturing. Moreover, the larger gap is almost entirely due to non-manufacturing.

Our paper is related to the large literature on measuring TFP growth during the Lost Decade (see Table 1 of Fukao and Kwon (2006) for a summary of findings). There is a general consensus that TFP growth rate in Japan slowed down in during the 1990's. We contribute to this literature by showing that missing growth from creative destruction and new variety innovation imply that Japan's growth rate is even more depressed relative to the U.S. than previously thought. We are also relate to the literature that estimates the industrial origin of the U.S. and Japan productivity gap (e.g. Jorgenson and Nomura (2007)). Our results imply larger non-manufacturing contribution to the gap in growth between U.S. and Japan. There is an extensive literature on international price comparison.

Finally, we are part of the literature on the measurement of growth. We use the methodology of Aghion et al. (2019), which is also applied to France by Aghion et al. (2018). In addition to analyzing missing growth in Japan, we analyze how missing growth affects international comparison of growth rates. For Japan, Abe et al. (2018) studies measurement error in international price comparison between U.S. and Japan for service industries. We differ in that we compare productivity growth rates instead of levels.

The paper is organized in the following way. In section 2., we describe the framework we use to measure missing growth. In section 3. we describe the data and in section 4. the results. Section 5. concludes.

## 2. Model

This section lays out the framework of Aghion et al. (2019) to illustrates the sources of growth and mismeasurement.

## 2.1. Final goods producer

A final goods producer combines output from $M$ sectors into a final good using the following Cobb-Douglas production technology.

$$Y = \prod_{s=1}^{M} Y_s^{\theta_s} \tag{1}$$

where $\theta_s \in (0,1)$ and $\sum_s \theta_s = 1$. Cost minimization implies that demand for each sector's good is given by

$$\frac{P_s Y_s}{PY} = \theta_s$$

and the price of the final output $P$ is related to the price of sector's output by

$$P = \prod_{s=1}^{M} \left(\frac{P_s}{\theta_s}\right)^{\theta_s} \tag{2}$$

## 2.2. Sectoral output

In each sector there is a continuum of products $i \in [0, N_s]$. Output from each sector $Y_s$ is produced by combining varieties in each sector $y(i)$ using a CES production technology:

$$Y_s = \left[\int_0^{N_s} (q(i)y(i))^{\frac{\sigma-1}{\sigma}} di\right]^{\frac{\sigma}{\sigma-1}}. \tag{3}$$

where $\sigma > 1$ is the elasticity of substitution between different varieties and $q(i)$ is the quality of each variety. Output of the sector is produced according to (3) under perfect competition. As a result, demand for a variety that has price $p(i)$ is given by

$$y(i) = \left[\frac{P_s}{p(i)/q(i)}\right]^{\sigma} Y_s \tag{4}$$

Furthermore, the price for a unit of sectoral output is given by

$$P_s = \left(\frac{1}{N_s}\int_0^{N_s} (p(i)/q(i))^{1-\sigma} di\right)^{\frac{1}{1-\sigma}}. \tag{5}$$

## 2.3. Intermediate goods producers

Each variety $y(i)$ is produced by a monopolist using labor $l$ and technology

$$y(i) = l(i) \tag{6}$$

Facing demand function (4), each variety producer sets price to the profit maximimizing value

$$p(i) = W\frac{\sigma}{\sigma - 1} \tag{7}$$

where $W$ is the nominal wage.

### 2.3.1. Quality and variety growth

We assume exogenous growth. There are three types of innovation: 1) new variety, 2) creative destruction, 3) own innovation. At each point in time new varieties arrive exogenously with rate $\lambda_n \in [0, 1)$ that allows a new entrant to produce a new variety that has quality proportional to the average quality of existing varieties by a factor of $\gamma_n > 0$. With rate $\lambda_d \in [0, 1)$, an entrant can improve upon an existing product by a factor of $\gamma_d > 1$. When this occurs, the incumbent producer is pushed out of the market of that variety. In addition, if an incumbent producer survives, it has an exogenous arrival rate $\lambda_i \in [0, 1)$ of an innovation that improves the quality of its product by a factor of $\gamma_i > 1$.

## 2.4. Growth and inflation rate

Real growth in output of a sector $s$ is given by

$$\ln \frac{Y_{s,t+1}}{Y_{s,t}} = \ln \frac{E_{s,t+1}}{E_{s,t}} \frac{P_{s,t}}{P_{s,t+1}}. \tag{8}$$

where $E_{s,t}$ denotes the nominal output of a sector, that is, $P_{s,t}Y_{s,t}$. From the final output production function (1), real growth in aggregate output is given by

$$\ln \frac{Y_{t+1}}{Y_t} = \sum_s \theta_s \ln \frac{Y_{s,t+1}}{Y_{s,t}} \tag{9}$$

In practice, $\theta_s$ can by estimated by expenditure shares of sector $s$. Similarly, from (2), the inflation rate is given by the weight average of sectoral inflation rate.

$$\ln \frac{P_{t+1}}{P_t} = \sum_s \theta_s \ln \frac{P_{s,t+1}}{P_{s,t}} \tag{10}$$

where the inflation rate of a sector is given by

$$\frac{P_{s,t+1}}{P_{s,t}} = \frac{W_{t+1}}{W_t}\left[1 + \lambda_d\left(\gamma_d^{\sigma-1} - 1\right) + (1-\lambda_d)\lambda_i\left(\gamma_i^{\sigma-1} - 1\right) + \lambda_n\gamma_n^{\sigma-1}\right]^{\frac{1}{1-\sigma}}. \tag{11}$$

Equation (11) shows that the true inflation rate is the difference between the growth rate of money supply and the rate of innovation. In principle, the inflation rate can differ across sectors due to differences in the rate of innovation across sectors. Aggregate inflation rate is the average of sector inflation rate, weighed by each sector's share of expenditure.

### 2.4.1. Statistical office

In Figure 1, we compared the growth rate of U.S. and Japan using KLEMS data. In this dataset, the price deflator for the U.S. comes mostly from the Bureau of Labor Statistics (BLS). Aghion et al. (2019) documents that imputation is a common procedure used by the BLS. For Japan, prices deflators mostly come from unpublished data by the Cabinet Office, Department of National Accounts ESRI[1]. According to the SNA Handbook from ESRI, price deflators are constructed from the PPI and CSPI by the Bank of Japan (BOJ) and the CPI by Ministry of In-

[1]See KLEMS sources p173 , http://www.euklems.net/data/EUKLEMS_Growth_and_Productivity_Accounts_Part_II_Sources.pdf and Jorgenson, Ho and Stiroh (2005), p414, http://www.nber.org/chapters/c10627.pdf

ternal Affairs and Communications. For the CPI, the Bureau of Statistics states that both assumption with no price change and imputation are used when the price of an outgoing product is missing[2]. For the PPI, the SNA handbook states that when the price of a good is missing or when the quality change can not be determined, the BOJ tends to assume no price change. For the 2015 CGPI, quality changes could not be determined for 61% of the goods. Similarly, for 2008, quality change could not be determined for 43% of the products in the PPI and 65% of the products in the CSPI. For these goods where quality change could not be determined, the BOJ in principle assumes no price change.[3]

We model the measurement of inflation and growth in a very stylized way. First, we assume that the statistical offices measures the inflation rate of surviving products perfectly and use this to impute the inflation rate of creatively destroyed products. We assume that they miss new varieties all together. Under these assumption, the measured inflation rate is just the inflation rate of the surviving products. In the model, this yields the following measured inflation rate for each sector:

$$\widehat{\frac{P_{s,t+1}}{P_{s,t}}} = \frac{W_{t+1}}{W_t} \left[1 + \lambda_i \left(\gamma_i^{\sigma-1} - 1\right)\right]^{\frac{1}{1-\sigma}} . \tag{12}$$

We assume the statistical offices measure nominal output growth $\frac{E_{t+1}}{E_t}$ correctly and estimate output growth in each sector by deflating nominal expenditure growth by the measured inflation rate and then aggregate across sectors using sector expenditure shares. This means measured sectoral growth is

$$\widehat{\frac{Y_{s,t+1}}{Y_{s,t}}} = \left[1 + \lambda_i \left(\gamma_i^{\sigma-1} - 1\right)\right]^{\frac{1}{\sigma-1}} . \tag{13}$$

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[2] http://www.stat.go.jp/data/cpi/2015/kaisetsu/pdf/3-2.pdf, p18.

[3] For 2015, see BOJ report https://www.boj.or.jp/statistics/outline/exp/pi/cgpi_2015/data/excgpi15a.pdf Table 7-28 (in Japanese). For 2008, see Figure 6 of BOJ report https://www.boj.or.jp/research/brp/ron_2009/data/ron0910a.pdf (in Japanese). According to the 2008 report, the BOJ chose to assume zero inflation out of concern of imputation bias.

and measured aggregate growth is

$$\ln \frac{\widehat{Y_{t+1}}}{Y_t} = \sum_s \theta_s \ln \left[1 + \lambda_i \left(\gamma_i^{\sigma-1} - 1\right)\right]^{\frac{1}{\sigma-1}}. \tag{14}$$

#### 2.4.2. Missing growth

Within our model of true growth and measurement, we can calculate missing growth, which is the difference between true output growth and measured output growth.

$$\ln \frac{Y_{t+1}}{Y_t} - \ln \frac{\widehat{Y_{t+1}}}{Y_t} = \sum_s \frac{\theta_s}{\sigma - 1} \ln \frac{1 + \lambda_d \left(\gamma_d^{\sigma-1} - 1\right) + (1-\lambda_d)\lambda_i \left(\gamma_i^{\sigma-1} - 1\right) + \lambda_n \gamma_n^{\sigma-1}}{1 + \lambda_i \left(\gamma_i^{\sigma-1} - 1\right)} \tag{15}$$

The right hand side of (15) is approximately equal to

$$\sum_s \frac{\theta_s}{\sigma - 1} \left[\lambda_d \left(\gamma_d^{\sigma-1} - 1\right) - \lambda_d \lambda_i \left(\gamma_i^{\sigma-1} - 1\right) + \lambda_n \gamma_n^{\sigma-1}\right] \tag{16}$$

That is, missing growth is larger when creative destruction and new variety innovation are large relative to incumbent's own innovation. Missing growth can growth if expenditure shares $\theta_s$ shifts toward sectors with larger missing growth.

#### 2.4.3. Using market shares to infer missing growth

As in Aghion et al. (2019), we infer missing growth in each sector using the growth rate of incumbent's market share[4]. More precisely, missing growth in a sector in the model is equal to

$$-\frac{1}{\sigma - 1} \frac{S_{s,t+1}}{S_{s,t}} \tag{17}$$

where $S_{s,t+1}$ and $S_{s,t}$ measure the incumbents market share in $t+1$ and $t$, respectively. The equation shows that missing growth is positive when incumbent

[4]This is the same approach as Feenstra (1994).

producer's market share shrinks. Next, we describe how we evaluate (17).

## 3. Data

Our data comes from the Statistics Bureau, Ministry of Internal Affairs and Communications. We use the Establishment and Enterprise Census which was conducted in 1996, 2001, 2004 and 2006. In 2009, the data was replaced by the Economic Census. Hereafter, we call both datasets the Census. The Census is designed to cover the universe of establishments in Japan[5]. For each establishment, we have counts of several categories of workers. We use the count of regular workers (*joyo koyo*), which are employed persons with open-ended contract or contracts exceeding 1 months. The data also contains self-reported year of establishment, which we use to measure age. The establishments are categorized as companies (*hojin kigyo*) and sole-proprietors (*kojin kigyo*). To faciliate comparison with the U.S., we restrict the sample to companies. Each establishment reports its industry using the JSIC industry codes.

Unlike the U.S. Longitudinal Business Data or the Census, the Japanese Census does not contain establishment identifiers. We create longitudinal links using survey number. During each Census survey, every plants is assigned a unique survey number. The Census Bureau maintains a record of the survey number assigned to each plant in each year. In each year of our data, we see the current year survey number and the previous Census's survey number (if there is one). We use this to link plants between consecutive Censuses. New plants and exiting plants are those without numbers in both Censuses.

We implement equation (17) in the following steps. First, as in Aghion et al. (2019) we drop plants that are 5 years old and under to account for time to

[5]The government statistics bureau cautions that the coverage of establishments may have changed between 2006 and 2009 due to changes in data collection methodologies. http://www.stat.go.jp/data/e-census/2009/kakuho/riyou.html. The aim of the Censuses is to cover all establishments in Japan. However, unlike the U.S., tax records cannot be used for statistic purposes. Before 2009, establishments are identified by signage and appearance. In 2009, the Ministry of Justice incorporation data was added to identify more establishments.

accumulate market share and other frictions. We identify the operating years of plants using each plant's self report year of establishments. Next, we link consecutive Censuses by survey numbers as described in the preceding paragraph. Since we calculate industry level missing growth, we need to create industry samples. After linking consecutive Censuses, for each industry, we create a sample of plants that report that industry code in either Census. This means we dropped plants that do not have industry codes in both Censuses. Then we classify a plant as continuing when it has a survey number in both Censuses. We then calculate the share of regular employment by these continuing plants in the two Censuses. The Censuses are conducted twice every five years and have varying lags. We calculate annual percent of missing growth by

$$\frac{1}{\Delta}\frac{1}{\sigma-1}\ln\frac{S_{s,t+\Delta}}{S_{s,t}} \tag{18}$$

where $\Delta$ is the number of years between two Censuses. For all our results, we use $\sigma = 4$ to facilitate comparison with the U.S.

## 4. Results

Table 1 reports missing growth in Japan by consecutive Census years and the average over 1997–2009. The unit is percentage points of missing growth over one year. We find that on average, 0.39 percentage points of growth was missed [6]. There are some time variation in missing growth. Unlike the U.S. where missing growth has been relatively constant over 1983–2013, we find large variation in missing growth in Japan between 1997 and 2009. However, the change in surveying methodology between 2006 and 2009 may have led to an expansion of coverage that overstates missing growth in 2007-2009. Hence, we do not take a stand on the time variation in missing growth.

Column 2 in Table 2 displays missing growth in the U.S. for comparison. We

[6]This figure is calculated applying 1 digit industry classification. The numbers are basically robust when 2 and 3 digit industry classifications are applied

Table 1: Missing Growth in Japan

| | |
|---|---|
| **1997–2009** | **0.39** |
| 1997–2001 | 0.16 |
| 2002–2004 | 0.61 |
| 2005–2006 | -0.50 |
| 2007–2009 | 1.17 |

Calculated from the Census. The unit of measurement is percentage points per year

obtain the U.S. results from Aghion et al. (2019). Their benchmark results used heterogeneous $\sigma$ across sectors. As we do not have such an estimate for Japan, we modify their results to use the same $\sigma = 4$ across sectors so that we can compare their results to Japan. We find on average 0.23 percentage points gap in the U.S. and Japan productivity growth rate. According to Figure 1, the TFP growth rate gap is higher in U.S. by 0.75 percentage point per year. Our results pushes the gap up by 30%, a significant increase. This gap will be larger if we use a lower value of $\sigma$ and smaller if we use a larger value of $\sigma$. The missing growth in Japan over 2006–2009 may be overstated due to changes in Census methodologies. Hence the actual bias in the U.S. and Japan growth gap may be larger than our estimates.

Motivated by debates about the industry origin of the Lost Decade, we also examined the industrial contribution to missing growth. First, Table 3 displays missing growth in manufacturing and it contribution to total missing growth for Japan and the U.S. The first row is total missing growth, the second row is missing growth in manufacturing and the last row is the contribution of manufacturing to aggregate missing growth. The difference between the first and last row is the contribution of non-manufacturing. In both countries, aggregate missing growth largely comes from non-manufacturing. The additional growth rate difference that we have uncovered can be mostly attributed to a larger gap in the growth rate in non-manufacturing productivity. That is, the US-Japan

Table 2: Missing Growth in Japan

| | Japan | U.S. | US - Japan |
|---|---|---|---|
| **1997–2009** | **0.39** | **0.62** | **0.23** |
| 1997–2001 | 0.16 | 0.50 | 0.34 |
| 2002–2004 | 0.61 | 0.43 | -0.18 |
| 2005–2006 | -0.50 | 0.88 | 1.38 |
| 2007–2009 | 1.17 | 0.80 | -0.37 |

Calculated from the Census. U.S. numbers are from Aghion et al. (2019). The unit of measurement is percentage points per year

Table 3: Missing Growth, Manufacturing vs Non-manufacturing

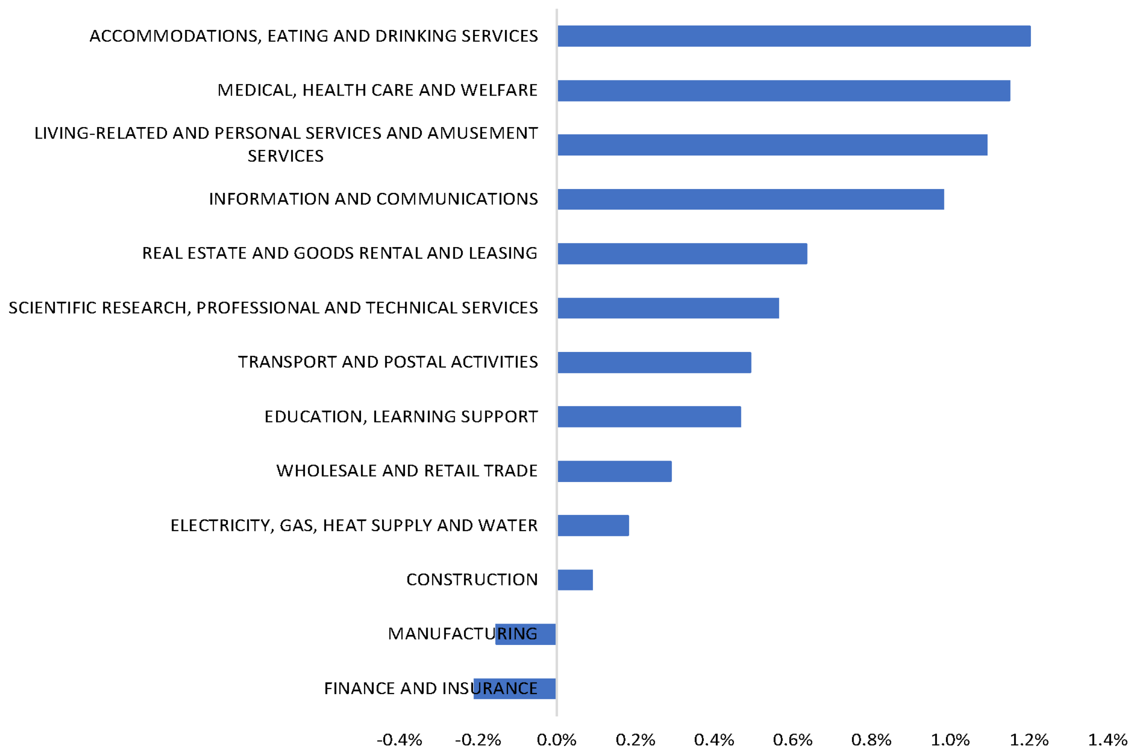
| | Japan | U.S. | US - Japan |
|---|---|---|---|
| Aggregate MG | 0.39 | 0.62 | 0.23 |
| Manufacturing MG | -0.15 | -0.04 | -0.15 |
| Contribution | -0.04 | -0.00 | **0.04** |

Calculated from Establishment and Enterprise Census and Economic Census 2009. U.S. numbers are from Aghion et al. (2019). The unit of measurement is percentage points per year. The time period is 1997–2009.

productivity growth rate gap is larger than official statistics because the official statistics understates the growth rate gap in non-manufacturing.

Finally, we delved deeper into the source of missing growth. Figure 2 displays average missing growth per year over 1997–2009 in each JSIC one digit industry. Like the U.S., we uncover large missing growth in accommodations and food services, various service industries and wholesale and retail trade. It is interesting that we find similar ranking as the U.S. despite differences in data collection methodologies between U.S. and Japan. From the perspective of our model, this suggests heterogeneous innovation processes across sector.

Figure 2: Missing Growth by Industry




Calculated from the Census. U.S. numbers are from Aghion et al. (2019). The unit of measurement is percentage points per year. Average over 1997–2009. JSIC 1-digit industries.

## 5. Conclusion

In this paper, we calculate missing growth from creative destruction and new goods for Japan and compare to the U.S. We find that official statistics may significantly understate the difference between TFP growth rate in the U.S. and Japan because they understate the gap in growth rate for the non-manufacturing industries. This suggests that non-manufacturing industries may have contributed more to Japan's relative slowdown than previously found.

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