Accounting for Japan’s Lost Score

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Motivation

Between the 2nd W.W. and 1991, Japan was a quintessential example of a “growth miracle” country.

- Japan was rapidly “catching up” in GDP per person with richer countries by growing faster and, especially, with the United States.
- United States, the “global technology frontier” and “trend-growth rate” setter.

In 1991, *everything changed.*

- Growth in Japan’s GDP, GDP per person, and GDP per unit of labor slowed substantially.
- GDP per person growth fell below “trend” for *20 years* – the “lost score” – and *never* recovered to 1980s values.

Motivation

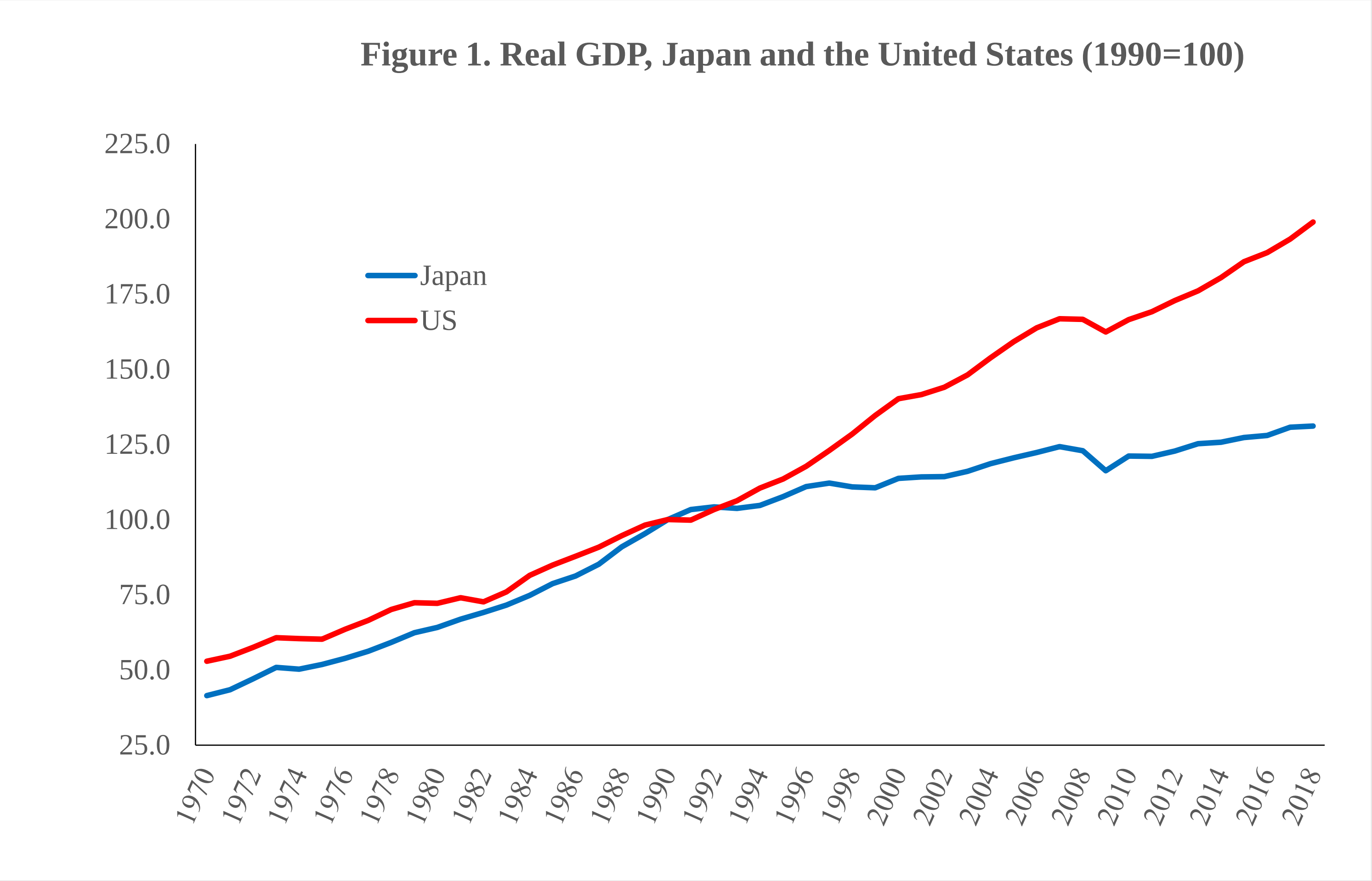

Figure 1. Real GDP, Japan and the United States (1990=100)
225.0
200.0
175.0
150.0
125.0
100.0
75.0
50.0
25.0
Japan
US
1970
1972
1974
1976
1978
1980
1982
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Motivation

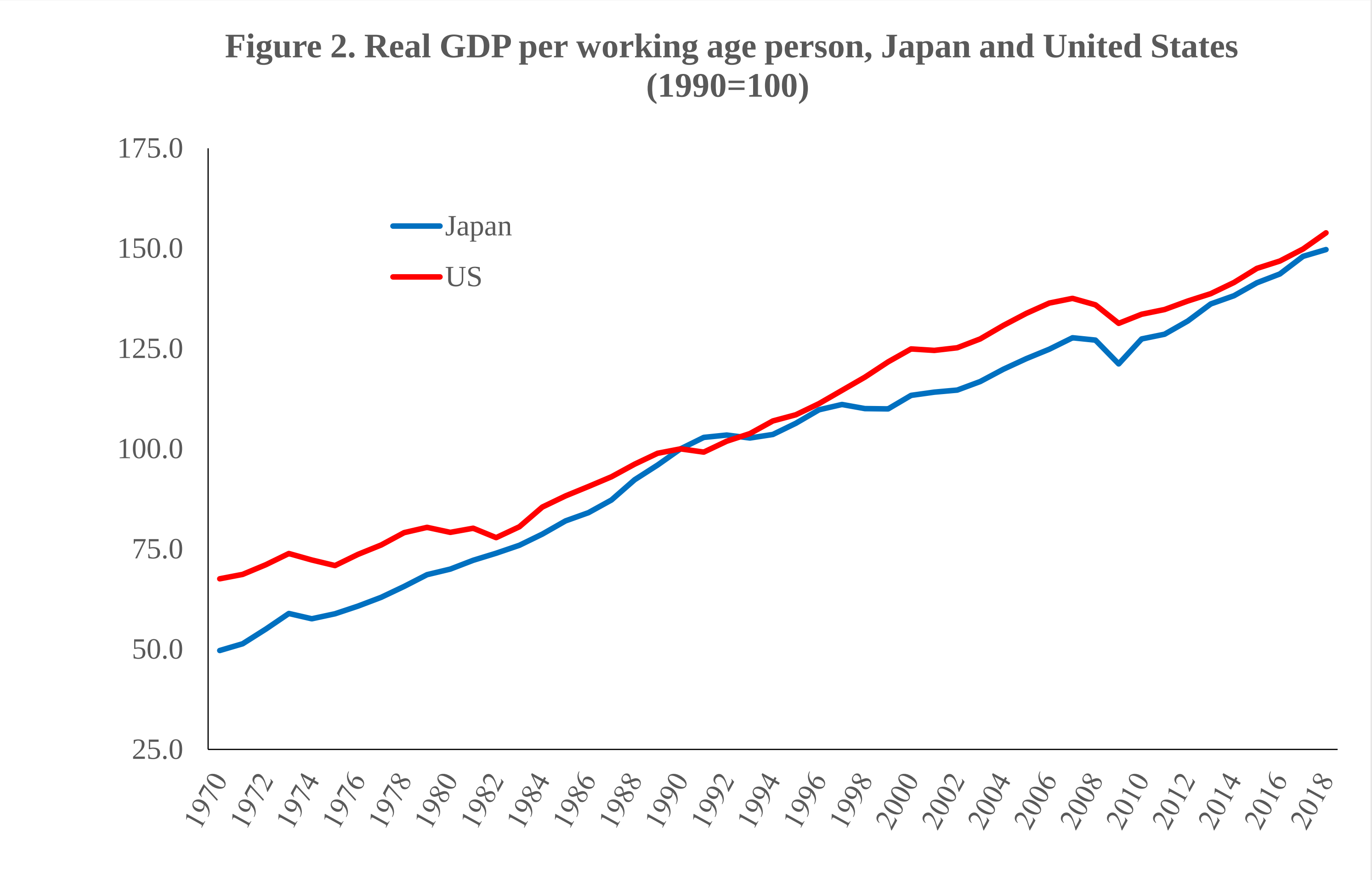

Figure 2. Real GDP per working age person, Japan and United States (1990=100)
175.0
150.0
125.0
100.0
75.0
50.0
25.0
Japan
US
1970
1972
1974
1976
1978
1980
1982
1984
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2016
2018

Motivation

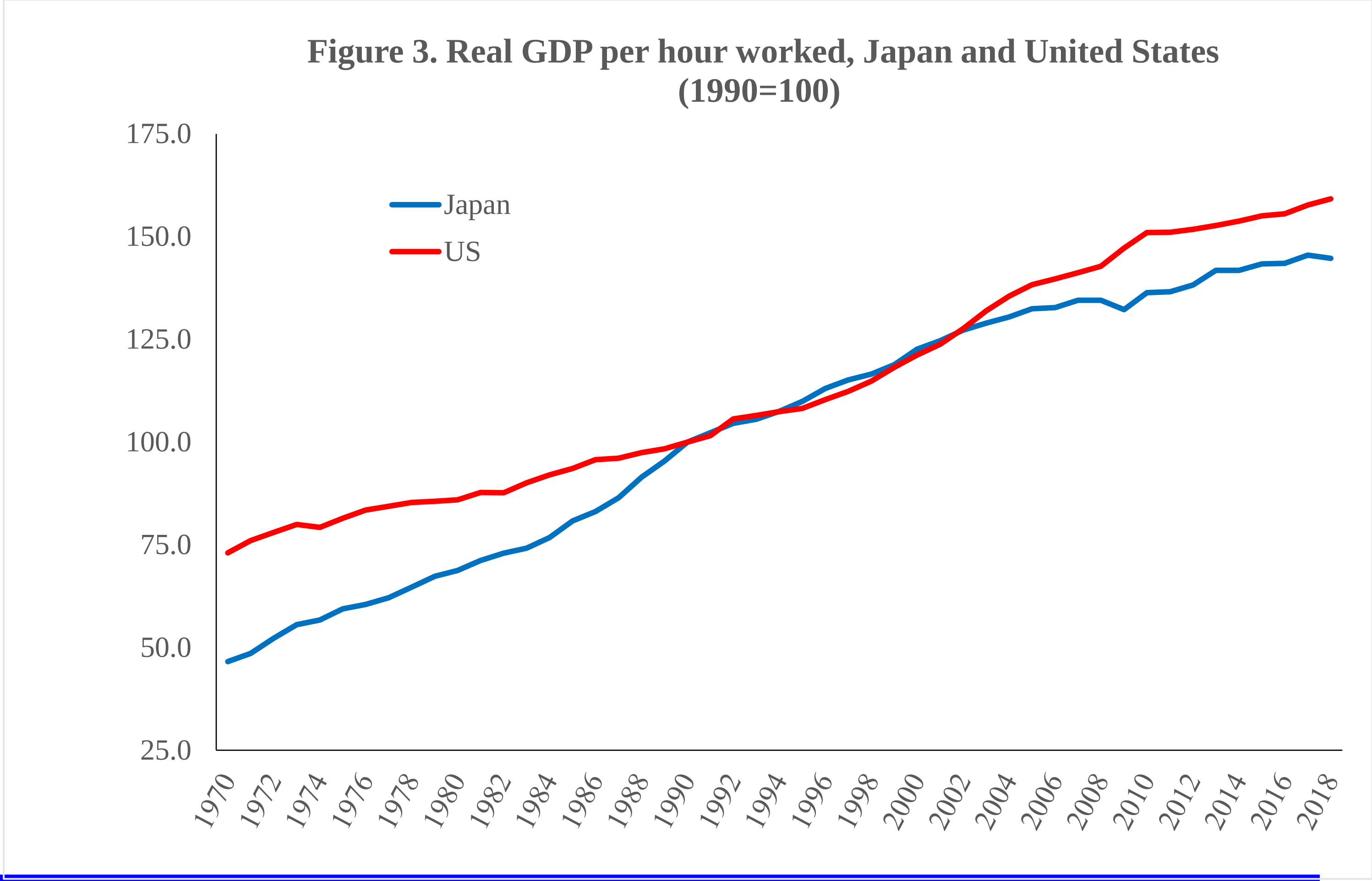

Figure 3. Real GDP per hour worked, Japan and United States
(1990=100)
175.0
150.0
125.0
100.0
75.0
50.0
25.0
Japan
US
1970
1972
1974
1976
1978
1980
1982
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Motivation

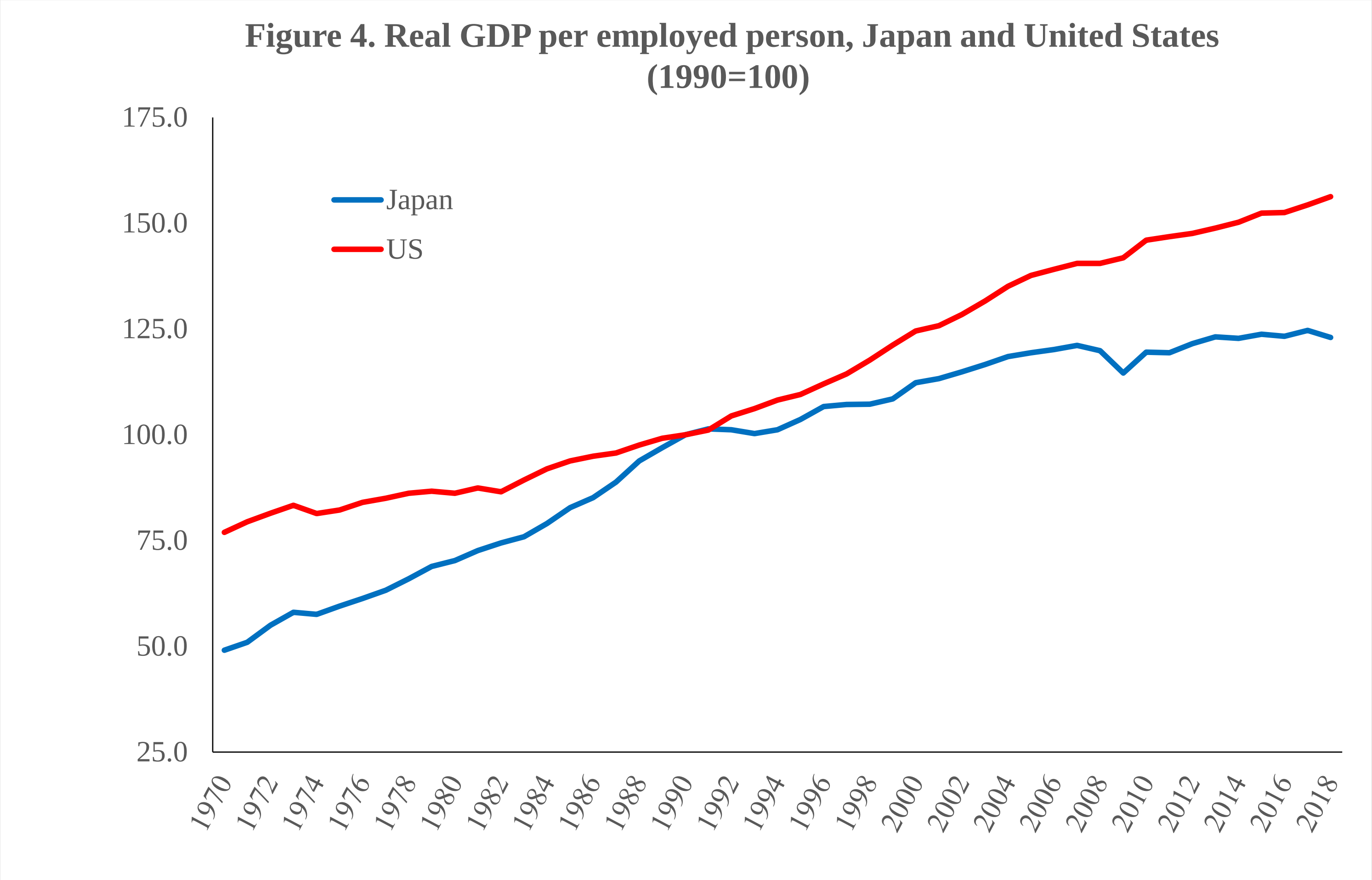

Figure 4. Real GDP per employed person, Japan and United States (1990=100)
175.0
150.0
125.0
100.0
75.0
50.0
25.0
Japan
US
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
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1994
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1998
2000
2002
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2018

Question

WHY?

Question

The collapse of Japan's real estate bubble (late 1980s through 1990) in 1991 seems an obvious answer to why growth slowed in the 1990s – lots of papers on this.

- However, Hayashi and Prescott (2003) showed slower aggregate total factor productivity (TFP) growth was the largest source of slower GDP per person growth in the 1990s.
- Lower hours worked per working age person a secondary factor.
- They found no evidence of financial constraints resulting from the real estate collapse precluding firms from obtaining credit for real investment.

It also seems *improbable* that a collapsing bubble in 1991 would be causing slower growth in GDP per person and labor productivity to this day. Then why?

Overview

This research project is a modest attempt to better understand the sectoral and underlying behavioral origins of Japan's lost score of GDP per person growth and three decades of slower labor productivity growth using the simplest possible framework.

- 1. Empirically, which factors are quantitatively important in accounting for GDP per person and labor productivity growth in Japan from 1991–2018 relative to the 1980s? (Growth accounting, replicating and updating Hayashi and Prescott.)

- 2. Empirically, what were the *sectoral* origins of GDP per person and productivity growth slowdown in Japan? (Sectoral decompositions of growth accounting variables).

- 3. Is Japan's slowdown consistent with optimal household and firm responses to exogenous sectoral and aggregate engines of growth – sectoral TFP, for e.g. – in a frictionless multi-sector neoclassical growth model? Or do we need frictions, financial constraints, etc.?

Main results

Main results.

1. Japan's "lost score" of GDP per working age person growth, and three decade-long decline in labor productivity growth, can be fully accounted for empirically by a *large aggregate TFP growth slowdown persisting through 2018, with temporary decline in hours per working age person seen during the 1990s.*

2. The aggregate TFP growth slowdown can be largely accounted for, empirically, by *slower TFP growth in the manufacturing and service sectors after 1990 and after 2000, respectively.*

3. The temporary 1990s hours per working age person *decline occurred in the manufacturing sector, with somewhat slower growth in services.*

Main results

4. The time-series of observed TFP and GDP per working age person in Japan from 1980-2018, and sectoral contributions to TFP and GDP per working age person, can be *closely replicated by (the implied aggregates of) a multi-sector neoclassical growth model.*

5. A multi-sector neoclassical growth model with exogenous growth due to sectoral TFP can account for *100% of the GDP per working age person, hours per working age person, and TFP slowdown in the lost score years relative to the 1990s…*

6. Counterfactual exercises show that

a) expansionary fiscal policy after 1990 marginally reduced the magnitude of the growth slowdown in the model;

b) slowing working population growth after 1990 significantly reduced the magnitude of the growth slowdown;

c) smaller manufacturing and aggregate trade surpluses after 1990 had negligible effects for Japan’s lost score;

d) slower TFP growth in manufacturing and services is by far the largest source of Japan’s lost score.

Main results

Are these interesting findings?

- TFP, after all, although assumed to reflect exogenous technological progress in this and other models, is not a directly observable metric of productivity.

Empirically, it is estimated or inferred by the distance between real GDP and a production function of factor inputs – for example, capital and hours worked.

- TFP is the “Solow residual” or “a measure of our ignorance”.

Main results

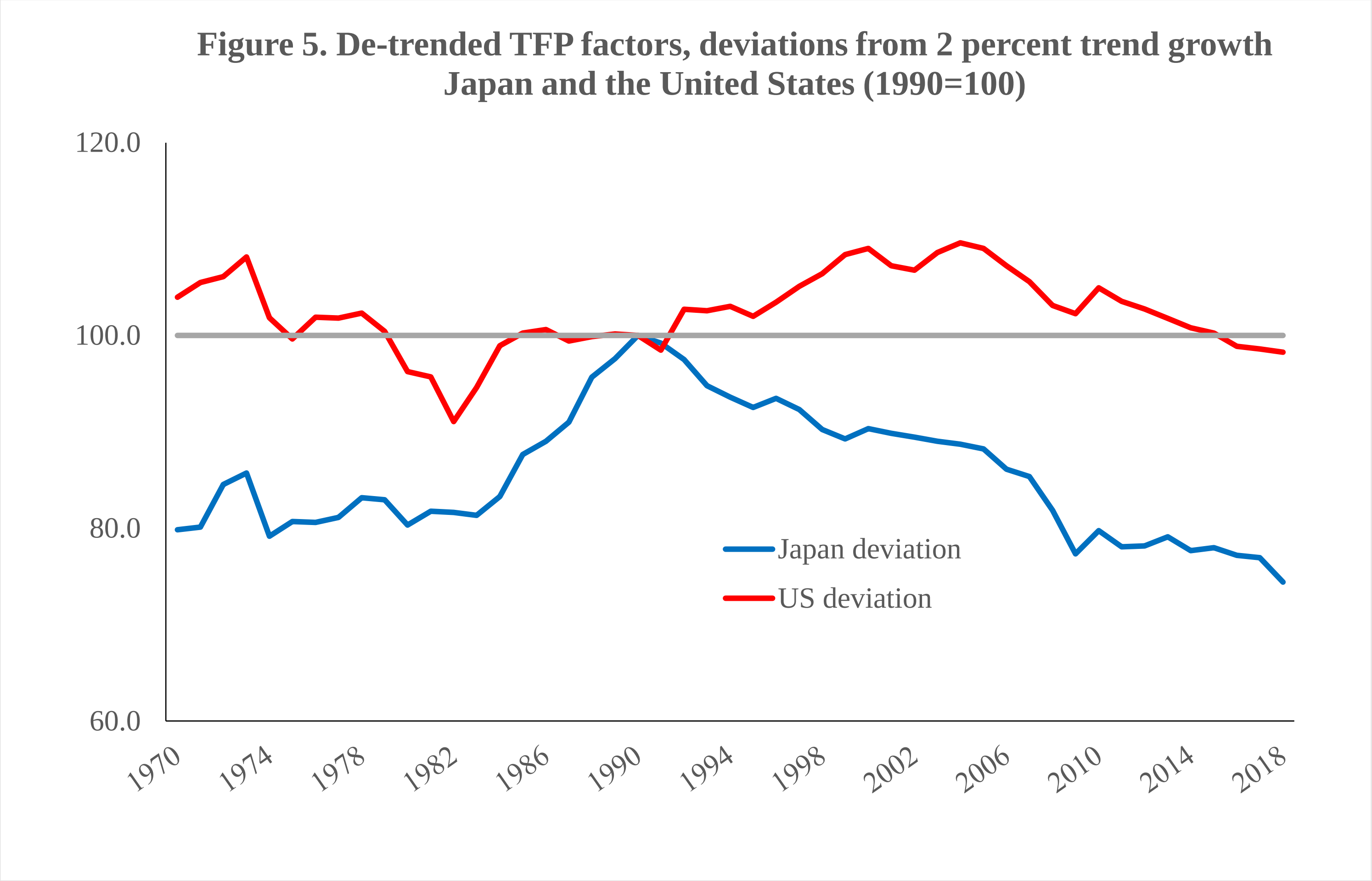
Let’s simply look at the *implication of slower TFP growth over thirty years for Japan’s current level of aggregate TFP.*

- How much output can Japan produce, hence consume and invest, from given capital and labor inputs – relative to the global technology-frontier?

Compare aggregate TFP in the United States and Japan, after de-trending by 2 percent.

- 2 percent is the long-run US growth rate of GDP per person and TFP – in principle, the globally attainable growth rate of technology at the frontier.

Main results



Main results

A massive US-Japan TFP differential has resulted – could take decades of faster TFP growth in Japan to eliminate. (Additional OECD Comparison.)

- It's as big or larger than the productivity differential observed prior to and in 1970, during Japan's "catchup" period.

If the United States is the technology frontier country, this implies that Japan is massively inefficient in using globally available frontier technology.

- Due to domestic policies, practices, and institutions that deviate from those in the United States: What are these and how can we model them?

Outline

- 1. Aggregate growth accounting results
- 2. Sectoral decomposition results
- 3. Model
- 4. Calibration
- 5. Results and counterfactual results
- 6. Conclusion

Aggregate growth accounting: Framework

Assume Cobb-Douglas aggregate production function for GDP in Hicks-neutral technological progress, TFP, capital services, and hours worked by employees:

$$Y_t = A_t K_t^{\alpha} H_t^{1-\alpha}, \quad (1)$$

- **Note:** For a model economy with this aggregate production function to have a (feasible) balanced growth path (BGP) requires long-run technological change is labor-augmenting. Define TFP as

$$A_t \equiv \Gamma_t \gamma^{t(1-\alpha)};$$

$$Y_t = \Gamma_t K_t^{\alpha} (\gamma^t H_t)^{1-\alpha}.$$

  - γ is the long-run/BGP/trend gross growth rate of technology at the frontier, e.g. 1.02.
  - Γ_t is a country-specific technology *level* (local policies, institutions, etc.) that's constant on a BGP, $\Gamma_t = \Gamma_0$, but can result in large deviations from trend growth off a BGP.

Aggregate growth accounting: Framework

Write the production function for GDP per hour worked by solving for hours worked as a function of output, TFP, capital services:

$$H_t = A_t^{-1/(1-\alpha)} K_t^{-\alpha/(1-\alpha)} Y_t^{1/(1-\alpha)},$$

$$\frac{Y_t}{H_t} = A_t^{\frac{1}{1-\alpha}} \left(\frac{K_t}{Y_t}\right)^{\frac{\alpha}{1-\alpha}}.$$

- GDP per working age person is thus representable by the product of a "TFP factor", "capital factor", and an "hours factor",

$$\frac{Y_t}{N_t} = A_t^{\frac{1}{1-\alpha}} \left(\frac{K_t}{Y_t}\right)^{\frac{\alpha}{1-\alpha}} \left(\frac{H_t}{N_t}\right);$$

$$(H_t/N_t) = \left(\frac{H_t}{E_t}\right) \left(\frac{E_t}{N_t}\right).$$

Aggregate growth accounting: Framework

Taking logs and time-derivatives on each side of the equation yields the instantaneous growth rate accounting model for output per working age person:

$$\frac{d(Y_t/N_t)/dt}{Y_t/N_t} = \left(\frac{1}{1-\alpha}\right)\left(\frac{dA_t/dt}{A_t}\right) + \left(\frac{\alpha}{1-\alpha}\right)\left(\frac{d(K_t/Y_t)/dt}{K_t/Y_t}\right) + \frac{d(H_t/N_t)/dt}{H_t/N_t}. \qquad (2)$$

- In empirical work, instantaneous growth rates are replaced by discrete time (net) growth rates.
- Notice that on a BGP (defined empirically by Kaldor's growth facts or in a growth model) capital and output grow at the same rate, total hours and the working population grow at the same rate, and *the only source of growth in output per working age person is tech/TFP factor growth.*

Aggregate growth accounting: Data

Annual data from 1980 through 2018 to calibrate and measure the observables in the production function:

$$\frac{Y_t}{N_t} = A_t^{\frac{1}{1-\alpha}} \left(\frac{K_t}{Y_t}\right)^{\frac{\alpha}{1-\alpha}} \left(\frac{H_t}{N_t}\right).$$

- $Y_t =$ real GDP (a Laspeyres chain) from Japan System of National Accounts (JSNA), also available from OECD NIPA data.

- $\alpha = 0.362$ (Hayashi and Prescott (2003), Chen, Imrohoroglu, and Imrohoroglu (2006)).

- $H_t =$ total hours worked by employees, constructed from JSNA data on average hours per employee $\left(\frac{H_t}{E_t}\right)$ and JSNA data on total employees, (E_t), linked across sub-periods.

Aggregate growth accounting: Data

Annual data from 1980 through 2018 to calibrate and measure the observables in the production function:

$$\frac{Y_t}{N_t} = A_t^{\frac{1}{1-\alpha}} \left(\frac{K_t}{Y_t}\right)^{\frac{\alpha}{1-\alpha}} \left(\frac{H_t}{N_t}\right).$$

- $\left(\frac{K_t}{Y_t}\right) = \left(\frac{K_t P_{k,t}}{Y_t P_{y,t}}\right)$nominal net capital stock from OECD divided by nominal GDP from JSNA, OECD.
  - Not ideal as it captures movements in the relative price of capital to GDP.
  - There are no superior alternatives for which sectoral equivalents are available which permit sectoral decomposition of this growth factor.

- $N_t =$ population of Japan aged from 16 to 65 years of age constructed from UN Population estimates database.

Aggregate growth accounting: Data

The aggregate TFP factor and its growth rate are measured as residuals, based on these metrics of the observable growth accounting variables :

$$A_t^{\frac{1}{1-\alpha}} = \frac{\frac{Y_t}{N_t}}{\left(\frac{K_t}{Y_t}\right)^{\frac{\alpha}{1-\alpha}}\left(\frac{H_t}{N_t}\right)}.$$

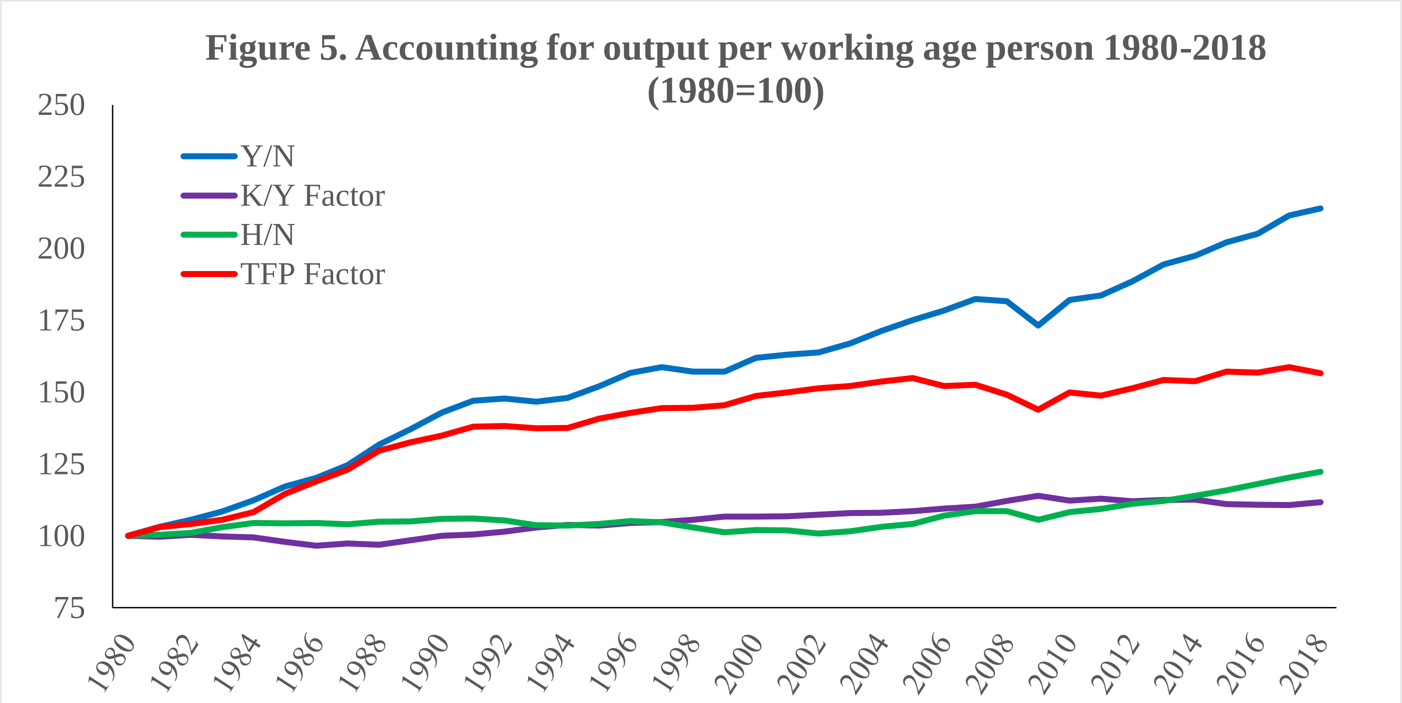
$$\left(\frac{1}{1-\alpha}\right)\left(\frac{A_{t+1}-A_t}{A_t}\right)$$

$$= \frac{(Y_{t+1}/N_{t+1})-(Y_t/N_t)}{(Y_t/N_t)} - \left(\frac{\alpha}{1-\alpha}\right)\left(\frac{(K_{t+1}/Y_{t+1})-(K_t/Y_t)}{(K_t/Y_t)}\right) - \frac{(H_{t+1}/N_{t+1})-(H_t/N_t)}{(H_t/N_t)}.$$

Aggregate growth accounting: Results

Results for growth accounting in levels. Notice, Japan remains far from a BGP in 2018.

1. *Slower* growth in GDP per working age person from 1991-2000 is closely associated with slower TFP factor growth, and with *falling* H/N; 2001-2010, slower TFP factor growth.
2. *Faster* growth in GDP per working age person after 2010 is associated with slower TFP factor growth, *increasing* H/N.



Aggregate growth accounting: Results

Growth accounting for decennial average annual growth rates TFP actor growth collapses in 1990s and never recovers. There is fast positive hours factor growth on average. Fast, positive hours factor growth 2001-2018.

Table 1. Aggregate growth accounting 1981-2018

Period	Y/N	$A^{\frac{1}{1-\alpha}}$	$(K/Y)^{\frac{\alpha}{1-\alpha}}$	H/N
1981–1990	**3.64**	3.05	0.01	0.58
1991-2010	**1.24**	0.54	0.59	0.12
1991–2000	1.27	0.98	0.65	-0.36
2001–2010	1.21	0.09	0.52	0.60
2011–2018	**2.04**	0.55	-0.06	1.54
1981-2018	**2.04**	**1.20**	**0.30**	**0.54**

Sectoral growth accounting

What are the sectoral origins of the decline in TFP factor growth and the decline and subsequent increase in the hours factor?

- 1. Sectoral growth accounting, using the same growth accounting production function, and framework, yields metrics of sectoral TFP and sectoral growth factors including H/N: info about *each sector's* growth experience.

But to measure sectoral contributions to aggregate TFP and aggregate H/N:

- 2. Decompose each observable aggregate growth accounting variable into sectoral contributions using aggregation of sectoral data used to publish aggregate variables, and back out implied sectoral contributions to aggregate TFP growth.

Sectoral growth accounting: Framework

1. Sectoral growth accounting Use the sectoral analogue of aggregate production function, obtain metrics of measurable sectoral growth factors including $\left(\frac{H_{i,t}}{N_t}\right)$, back out TFP factors $A_{i,t}^{\frac{1}{1-\alpha_i}}$.

$$\frac{Y_{i,t}}{N_t} = A_{i,t}^{\frac{1}{1-\alpha_i}} \left(\frac{K_{i,t}P_{i,k,t}}{Y_{i,t}P_{i,t}}\right)^{\frac{\alpha_i}{1-\alpha_i}} \left(\frac{H_{i,t}}{N_t}\right), i = ag, ind, ser. \qquad (3a)$$

$$A_{i,t}^{\frac{1}{1-\alpha_i}} = \frac{\frac{Y_{i,t}}{N_t}}{\left(\frac{K_{i,t}P_{i,k,t}}{Y_{i,t}P_{i,t}}\right)^{\frac{\alpha_i}{1-\alpha_i}} \left(\frac{H_{i,t}}{N_t}\right)}, i = ag, ind, ser. \qquad (3b)$$

Sectoral decomposition of aggregate growth accounting variables: Framework

2. Sectoral decompositions of growth accounting variables Use the fact that nominal aggregate variables are exactly equal to the sum of nominal sectoral analogues:

$$Y_t P_t = \sum_i Y_{i,t} P_{i,t} \,,$$

$$K_t P_{k,t} = \sum_i K_{i,t} P_{i,k,t} \,.$$

And, aggregate hours are exactly the sum across sectors of sectoral hours

$$H_t = \sum_i H_{i,t} \,.$$

Sectoral decomposition of aggregate growth accounting variables: Framework

2. Then sectoral decompositions of observable growth accounting variables, letting $s_{x,i,t} \equiv \frac{X_{i,t}}{\sum_i X_{i,t}}$:

$$\frac{\left(\frac{Y_{t+1}}{N_{t+1}}\right)-\left(\frac{Y_t}{N_t}\right)}{\left(\frac{Y_t}{N_t}\right)} \equiv \sum_{i=a,m,s}\left(\frac{\left(\frac{Y_{i,t+1}}{N_{t+1}}\right)}{\left(\frac{Y_{i,t}}{N_t}\right)} \times \frac{\left(\frac{P_{i,t+1}}{P_{t+1}}\right)}{\left(\frac{P_{i,t}}{P_t}\right)} - 1\right) s_{y,i,t}\,, \qquad (4a)$$

$$\frac{\left(\frac{H_{t+1}}{N_{t+1}}\right)-\left(\frac{H_t}{N_t}\right)}{\left(\frac{H_t}{N_t}\right)} \equiv \sum_{i=a,m,s}\left(\frac{\left(\frac{H_{i,t+1}}{N_{t+1}}\right)-\left(\frac{H_{i,t}}{N_t}\right)}{\left(\frac{H_{i,t}}{N_t}\right)}\right) s_{h,i,t}\,. \qquad (4b)$$

Sectoral decomposition of aggregate growth accounting variables: Framework

2. Sectoral decompositions of observable growth accounting variables letting $s_{x,i,t} \equiv \frac{X_{i,t}}{\sum_i X_{i,t}}$:

$$\left(\frac{\alpha}{1-\alpha}\right)\left(\frac{\left(\frac{K_{t+1}P_{k,t+1}}{Y_{t+1}P_{t+1}}\right)-\left(\frac{K_tP_{k,t}}{Y_tP_t}\right)}{\left(\frac{K_tP_{k,t}}{Y_tP_t}\right)}\right)$$

$$\equiv \left(\frac{\alpha}{1-\alpha}\right)\sum_{i=a,m,s}\left(\frac{\left(\frac{K_{i,t+1}P_{i,k,t+1}}{Y_{i,t+1}P_{i,t+1}}\right)s_{y,i,t+1}-\left(\frac{K_{i,t}P_{i,k,t}}{Y_{i,t}P_{i,t}}\right)s_{y,i,t}}{\left(\frac{K_{i,t}P_{ik,t}}{Y_{i,t}P_{i,t}}\right)s_{y,i,t}}\right)s_{k,i,t}. \qquad (4c)$$

Sectoral decomposition of aggregate growth accounting variables: Framework

2. Implied sectoral decomposition of aggregate TFP factor growth :

$$\frac{1}{1-\alpha}\left(\frac{A_{t+1}-A_t}{A_t}\right)$$

$$=\sum_{i=a,m,s}\left(\frac{\left(\frac{Y_{i,t+1}}{N_{t+1}}\right)}{\left(\frac{Y_{i,t}}{N_t}\right)}\times\frac{\left(\frac{P_{i,t+1}}{P_{t+1}}\right)}{\left(\frac{P_{i,t}}{P_t}\right)}-1\right)s_{y,i,t}-\sum_{i=a,m,s}\left(\frac{\left(\frac{H_{i,t+1}}{N_{t+1}}\right)-\left(\frac{H_{i,t}}{N_t}\right)}{\left(\frac{H_{i,t}}{N_t}\right)}\right)s_{h,i,t}$$

$$-\left(\frac{\alpha}{1-\alpha}\right)\sum_{i=a,m,s}\left(\frac{\left(\frac{K_{i,t+1}P_{ik,t+1}}{Y_{i,t+1}P_{i,t+1}}\right)s_{y,i,t+1}-\left(\frac{K_{i,t}P_{ik,t}}{Y_{i,t}P_{i,t}}\right)s_{y,i,t}}{\left(\frac{K_{i,t}P_{ik,t}}{Y_{i,t}P_{i,t}}\right)s_{y,i,t}}\right)s_{k,i,t}. \qquad (4d)$$

Sectoral decomposition of aggregate growth accounting variables: Framework

Notice how each sector's contribution to aggregate TFP factor growth differs from its own TFP factor growth rate:

$$\frac{1}{1-\alpha_i}\left(\frac{A_{i,t+1}-A_{i,t}}{A_{i,t}}\right)$$

$$=\left(\frac{\left(\frac{Y_{i,t+1}}{N_{t+1}}\right)-\left(\frac{Y_{i,t}}{N_t}\right)}{\left(\frac{Y_{i,t}}{N_t}\right)}\right)-\left(\frac{\left(\frac{H_{i,t+1}}{N_{t+1}}\right)-\left(\frac{H_{i,t}}{N_t}\right)}{\left(\frac{H_{i,t}}{N_t}\right)}\right)-\frac{\alpha_i}{1-\alpha_i}\left(\frac{\left(\frac{K_{i,t+1}P_{ik,t+1}}{Y_{i,t+1}P_{i,t+1}}\right)-\left(\frac{K_{i,t}P_{ik,t}}{Y_{i,t}P_{i,t}}\right)}{\left(\frac{K_{i,t}P_{ik,t}}{Y_{i,t}P_{i,t}}\right)}\right). \quad (5)$$

In the paper, I decompose each sector's total TFP factor growth contribution into a "weighted sectoral TFP" and a "residual sectoral" component (relative output price, capital income share, and value-added share adjustments).

Sectoral analysis: Data

Annual data from 1980 through 2018.

$$\frac{Y_{i,t}}{N_t} = A_{i,t}^{\frac{1}{1-\alpha_i}} \left(\frac{K_{i,t}}{Y_{i,t}}\right)^{\frac{\alpha_i}{1-\alpha_i}} \left(\frac{H_{i,t}}{N_t}\right), i = ag, ind, ser.$$

- $Y_{i,t}$ = real value added by sector (a Laspeyres chain) from OECD Structural Analysis (STAN) data (via JSNA) .

- $\alpha_{ag} = 0.71;\ \alpha_{ind} = 0.37;\ \alpha_{ser} = 0.33;$ using 1980 OECD STAN data on labor compensation and value added by sector.

- $H_{i,t}$ = sectoral hours worked by employees, constructed from linked JSNA data on sectoral average hours per employee $\left(\frac{H_{i,t}}{Ei_{,t}}\right)$ and JSNA data on sectoral employees, $(E_{i,t})$, linked across sub-periods.

Sectoral analysis: Data

Annual data from 1980 through 2018.

$$\frac{Y_{i,t}}{N_t} = A_{i,t}^{\frac{1}{1-\alpha_i}} \left(\frac{K_{i,t}}{Y_{i,t}}\right)^{\frac{\alpha_i}{1-\alpha_i}} \left(\frac{H_{i,t}}{N_t}\right), i = ag, ind, ser.$$

- $\frac{K_{i,t}P_{i,k,t}}{Y_{i,t}P_{i,t}} =$ nominal net capital stock from OECD divided by nominal value added from OECD, via JSNA.
  - Not ideal as it captures relative price of capital to value added movements, but nominal sectoral capital stocks aggregate to the total nominal capital stock.

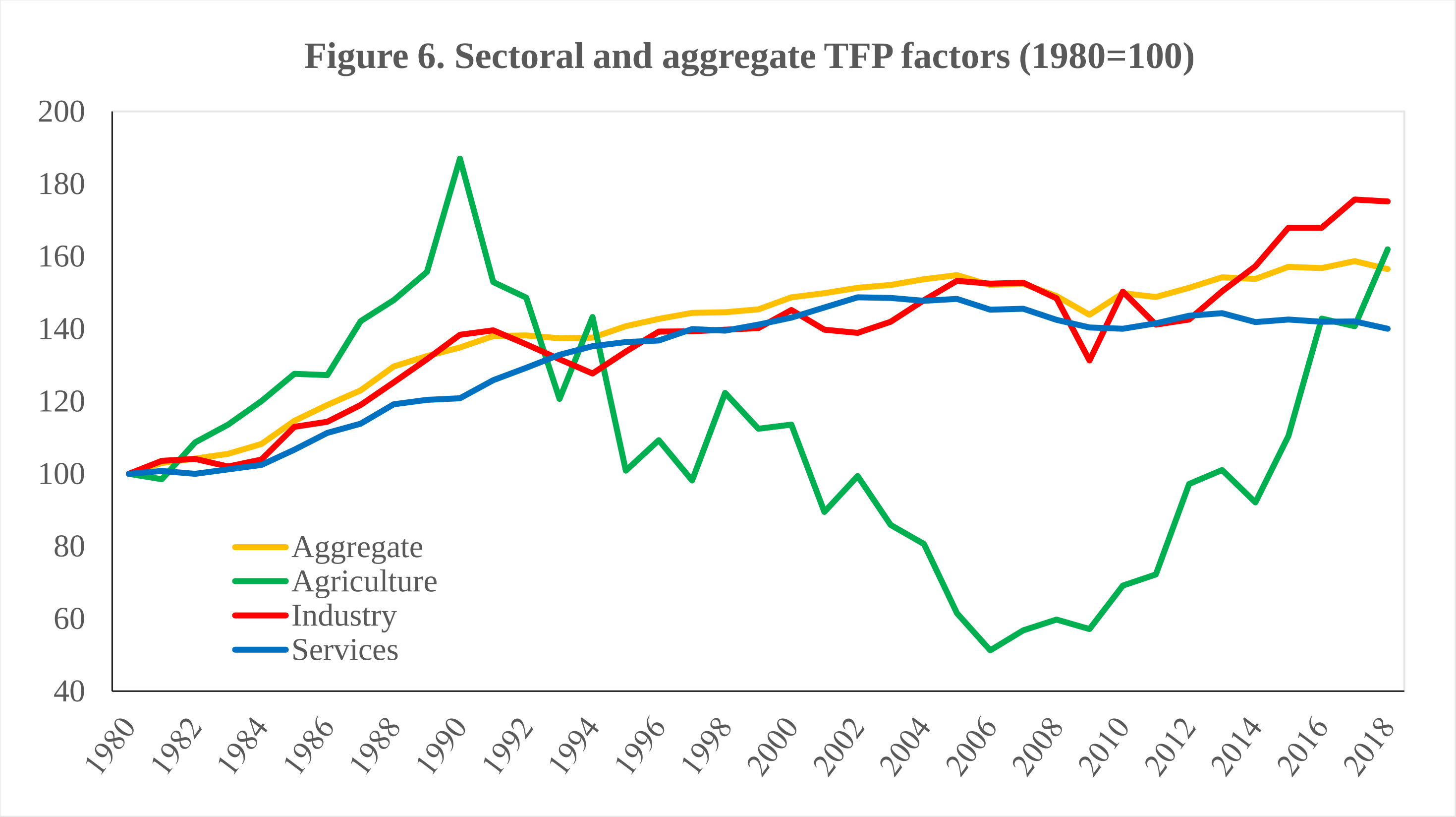
- $N_t =$ population of Japan aged from 16 to 65 years of age constructed from UN Population estimates database.

Sectoral TFP measured as:

$$A_{i,t}^{\frac{1}{1-\alpha_i}} = \frac{\frac{Y_{i,t}}{N}}{\left(\frac{K_{i,t}P_{i,k,t}}{Y_{i,t}P_{i,t}}\right)^{\frac{\alpha_i}{1-\alpha_i}}\left(\frac{H_{i,t}}{N_t}\right)}.$$

Sectoral growth decomposition

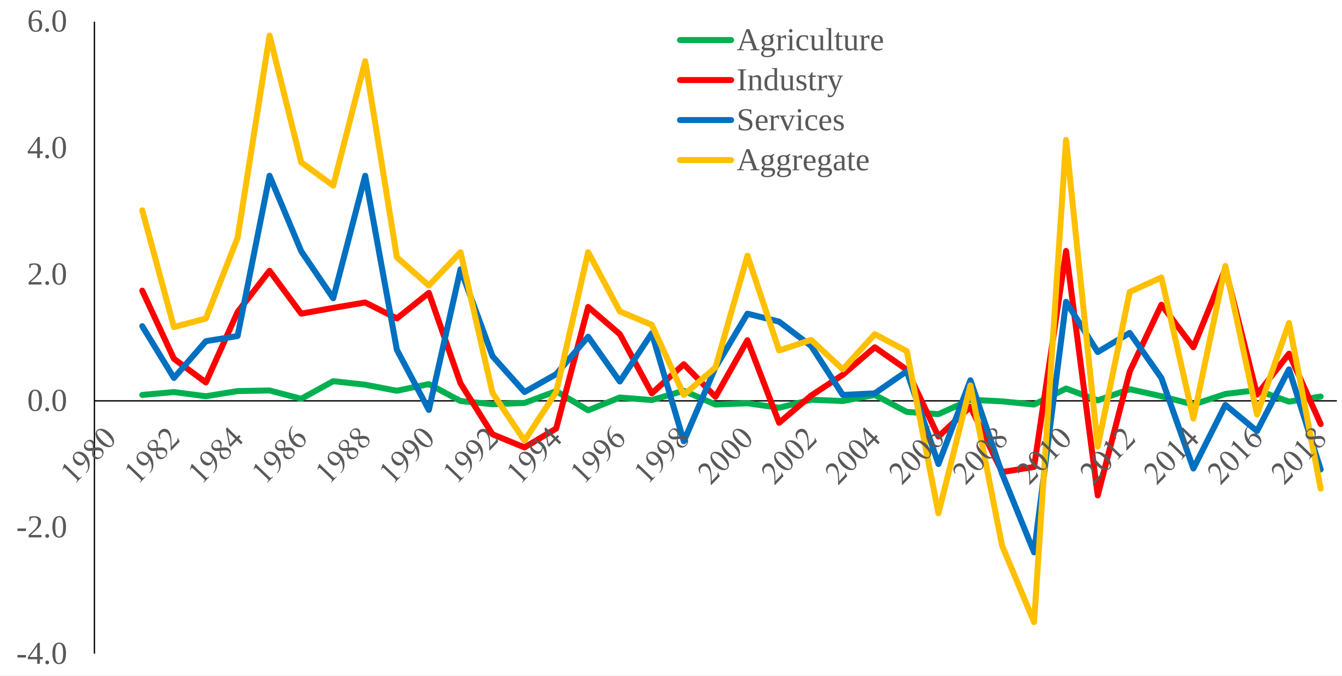
Sectoral and aggregate TFP factors, measured via sectoral and aggregate growth accounting
Aggregate TFP factor tracks that of industry until 1990, services from 1990-2000s; then services TFP factor growth ceases completely. Agriculture's TFP is wild, but the sector's too small for it to matter.



Sectoral growth decomposition

Sectoral contributions to aggregate TFP factor growth: Aggregate TFP factor growth driven by both industry and services' early in the sample, higher correlation with services. More closely correlated with industry's contributions after 1995; services' contribution declines with its own TFP growth.

Figure 7. Sectoral contributions to aggregate TFP factor growth (percentage points)



Sectoral growth decomposition

Table 2. Sectoral and aggregate TFP factor growth

Period	Aggregate	Agriculture	Industry	Services
1981–1990	**3.05**	6.02	3.33	1.93
1991–2010	**0.54**	-5.36	0.45	0.76
1991–2000	**0.98**	-5.47	0.47	1.72
2001–2010	**0.09**	-5.26	0.44	-0.20
2011–2018	**0.55**	10.12	1.92	0.02
1981–2018	**1.20**	**0.89**	**1.52**	**0.91**

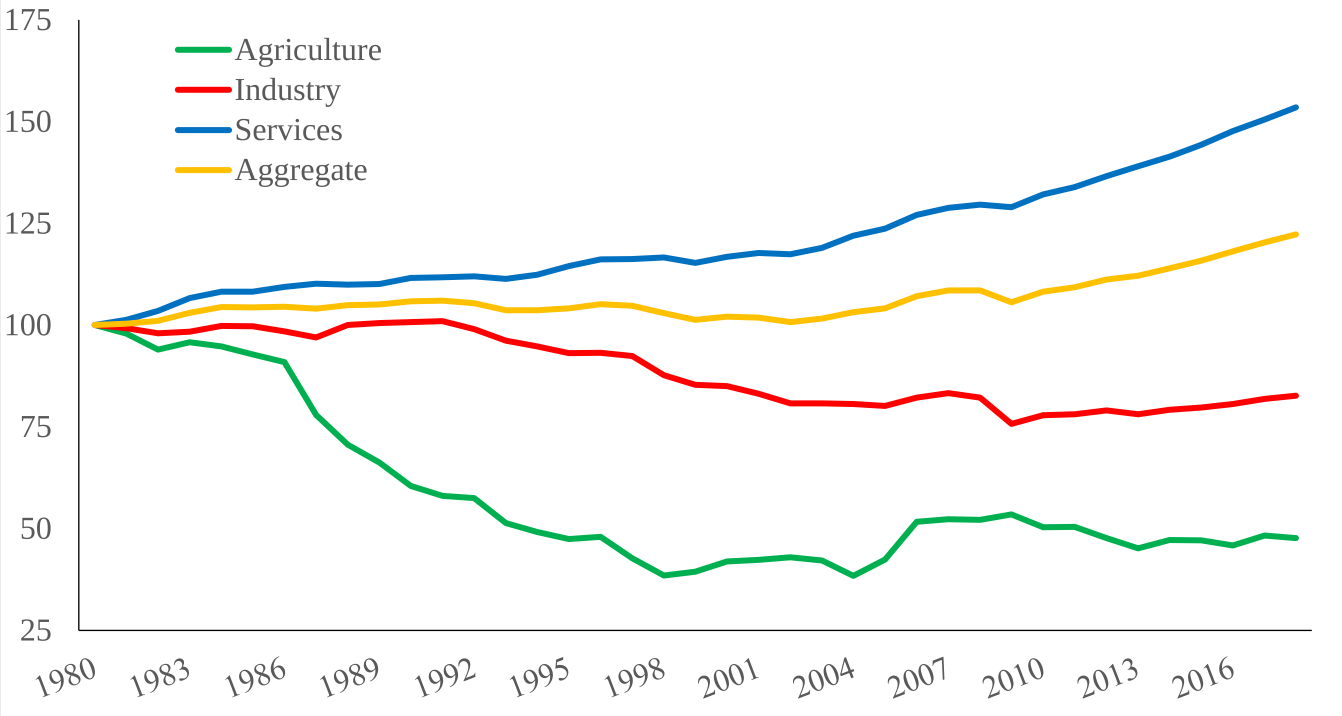
Table 3. Sectoral contributions to aggregate TFP factor growth

Period	Aggregate	Agriculture	Industry	Services
1981–1990	**3.05**	0.16	1.36	1.53
1991–2010	**0.54**	-0.01	0.19	0.36
1991–2000	**0.98**	0.00	0.28	0.70
2001–2010	**0.09**	-0.03	0.10	0.01
2011–2018	**0.55**	0.07	0.49	0.00
1981-2018	**1.20**	**0.05**	**0.56**	**0.59**

Sectoral growth decomposition

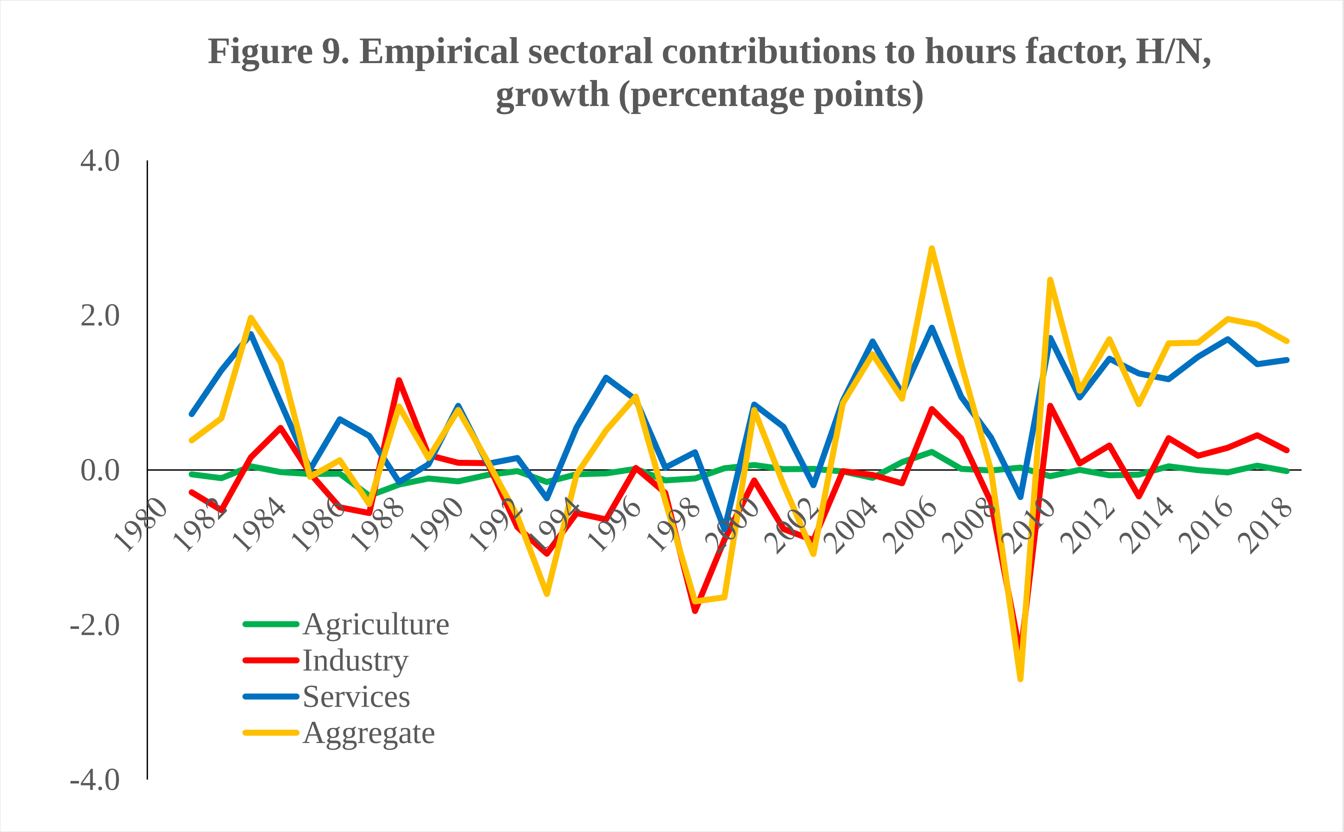
Sectoral and aggregate hours factors measured via sectoral and aggregate growth accounting
Aggregate H/N factor tracks that of services, much the largest sector by hours share, especially in 2000s and 2010s. Industry H/N falls in 1990s and much of 2000s.

Figure 8. Sectoral and aggregate hours' factors, H/N (1980=100)



Sectoral growth decomposition

Sectoral *contributions* to aggregate hours factor growth: Services dominate fluctuations and levels except during 1990s decline in industry's H/N and 2008-2009 recession. High aggregate H/N growth post 2000 is almost entirely due to service sector H/N growth.



Sectoral growth decomposition

Table 4. Sectoral contributions to aggregate H/N growth

Period	Aggregate	Agriculture	Industry	Services
1981–1990	**0.58**	-0.10	0.03	0.65
1991–2010	**0.12**	-0.01	-0.44	0.57
1991–2000	**-0.36**	-0.05	-0.60	0.29
2001–2010	**0.60**	0.02	-0.27	0.85
2011–2018	**1.54**	-0.01	0.21	1.34
1981-2018	**0.54**	**-0.27**	**-0.23**	**0.46**

Summary of empirical results

1. Declines in industrial and, to a smaller extent, service sector contributions dramatically reduced aggregate TFP factor growth and GDP per working age person growth in the 1990s.

Industry's due to slower within-sector TFP growth.

Services was due to smaller residual contributions. (Slower rate of relative price increase, growth in its VA share, increasing the negative aggregate TFP growth impact of the sector's capital deepening.)

2. A further substantial decline in service sector contributions in the 2000s aggravated the decline in aggregate TFP factor growth - almost to 0% - relative to the 1990s and reduced further GDP per working age person growth.

All of this was due to within-service sector TFP growth decline.

Summary of empirical results

3. After 2010, industrial sector TFP growth contributions increased somewhat with its “own” TFP growth rate.

Services’ TFP growth rate and contributions to aggregate TFP factor growth were basically zero, *suppressing growth in GDP per working age person.*

4. Large decline in industrial sector contributions – and smaller service sector contributions – to aggregate hours factor growth significantly contributed to 1990s slowing of GDP per working age person growth.

But after 2000, faster service sector hours factor growth contributions *mitigated the effects of the productivity growth slowdown.*

Multi-sector growth model

Can these aggregate growth and sectoral decomposition findings be replicated by the endogenously determined variables in a multi-sector neoclassical growth model?

- Exogenous variables in the model (which will be data inputs in model simulations)

  - sectoral TFP growth rates
  - working population growth rate
  - net exports by sector (aggregate "forced savings", closed economy for simplicity)
  - government spending share of GDP
  - capital income tax rate

Multi-sector growth model

Representative household

Maximizes lifetime utility, choosing consumption per working age person and leisure per working age person:

$$(c,l) = \sum_{t=0}^{\infty} \beta^t U\left(\left(\frac{C_t}{N_t}\right), \left(1 - \frac{n_t}{N_t}\right)\right) N_t, \qquad (5a)$$

where the number of household members is equal to the size of the working age population, N_t, and grows exogenously. Period utility is log:

$$U\left(\left(\frac{C_t}{N_t}\right), \left(1 - \frac{n_t}{N_t}\right)\right) = \phi\ ln\left(\frac{C_t}{N_t}\right) + (1-\phi)\ln\left(1 - \frac{n_t}{N_t}\right). \qquad (5b)$$

Multi-sector growth model

Representative household

Consumption is a CES composite of three types of final good: $j = ag, ind, ser$.

Has CES price index $P_{c,t}$.

$$C_t = \left(\sum_j \omega_{j,c}^{\frac{1}{\varepsilon_c}} \left(c_{j,t} - \bar{c}_j\right)^{1-\frac{1}{\varepsilon_c}} \right)^{\frac{\varepsilon_c}{\varepsilon_c - 1}}. \qquad (5c)$$

$\bar{c}_{ag} > 0$ (subsistence consumption level)
$\bar{c}_{ind} = 0.$
$\bar{c}_{ser} < 0$ (endowment of services, nonmarket)

Multi-sector growth model

Representative household

The household maximizes lifetime utility subject to sequence of budget constraints; non-negativity of consumption, leisure, and capital; an adding up constraint that labor and leisure equal the total hours' endowment (normalized to one hour per working age person); and taking as given the initial capital stock:

$$\sum_j p_{j,t} c_{j,t} + P_{x,t}(K_{t+1} - (1-\delta)K_t) + NX_t \leq (r_t - \delta)\left(1 - \tau_{k,t}\right)K_t + w_t n_t + T_t, \qquad (6)$$

where $$\sum_j p_{j,t} c_{j,t} \equiv P_{c,t} C_t + (p_{ag,t}\bar{c}_{ag} + p_{ser,t}\bar{c}_{se}),$$

$$(K_{t+1} - (1-\delta)K_t) = X_t.$$

Multi-sector growth model

Firms

Perfectly competitive producer of final good $j = ag, ind, ser$ maximizes profits, taking prices as given:

$$max_{\left\{\{m_{j,i,t}\}_{i=ag}^{ser}, k_{j,t}, n_{j,t}\right\}} \left(p_{j,t}\, y_{j,t} - \sum_{i=ag,ind,ser} m_{j,i,t} p_{i,t} - r_t\, k_{j,t} - w_t\, n_{j,t} \right). \qquad (7)$$

Multi-sector growth model

Firms

This is subject to the production technology for final good $j = ag, ind, ser$:

$$y_{j,t} = \left(\omega_{j,y}^{1/\varepsilon_y} m_{j,t}^{1-1/\varepsilon_y} + (1-\omega_{j,y})^{1/\varepsilon_y} v_{j,t}^{1-1/\varepsilon_y}\right)^{\varepsilon_y/(\varepsilon_y-1)}, \quad (8a)$$

$$m_{j,t} = \left(\sum_{i=1}^{J} \omega_{j,i,m}^{1/\varepsilon_m} m_{j,i,t}^{1-1/\varepsilon_m}\right)^{\varepsilon_m/(\varepsilon_m-1)}, \quad (8b)$$

$$v_{j,t} = \Delta_{j,v} A_{j,t} (k_{j,t})^{\alpha_j} (n_{j,t})^{1-\alpha_j}. \quad (8c)$$

Multi-sector growth model

Firms

In the value-added bundle, exogenous sector-specific TFP growth is given by

$$\frac{A_{j,t+1}}{A_{j,t}} = \frac{\Gamma_{j,t+1}}{\Gamma_{j,t}} \gamma^{(1-\alpha_j)} = 1 + \sigma_{A,j,t}\,, \forall t, j, \qquad (9a)$$

taken from the sectoral growth accounting. On a BGP (send the model to this in program)

$$\frac{\Gamma_{j,t+1}}{\Gamma_{j,t}} = 1 \forall t, j, \qquad (9b)$$

$$\left(\frac{A_{j,t+1}}{A_{j,t}}\right)^{1/(1-\alpha_j)} = \gamma, \forall j. \qquad (9c)$$

Multi-sector growth model

Firms

Perfectly competitive producer of the final investment good CES composite, X_t, maximizes profits by choice of inputs of goods $j = ag, ind, ser$, subject to non-negativity of inputs and taking gross output prices as given:

$$max_{\left\{\{x_{j,t}\}_{j=ag}^{ser}\right\}} P_{x,t}X_t - \sum_j p_{j,t}x_{j,t}, \qquad (10a)$$

subject to the production function/aggregator

$$X_t = \Delta_x \left(\sum_j \omega_{j,x}{}^{1/\varepsilon_x}\left(x_{j,t}\right)^{1-1/\varepsilon_x}\right)^{\varepsilon_x/(\varepsilon_x-1)}, \qquad (10b)$$

Multi-sector growth model

Government

Maximizes a CES consumption composite, G_t, by choice of inputs of outputs $j = ag, ind, ser$, subject to a budget constraint, a policy rule $P_{g,t}G_t = \overline{g_t}Y_t$ for total spending as a fraction of total value added, and non-negativity of inputs, taking output prices as given:

$$max_{\{g_{j,t}\}}\, G_t = \left(\sum_{j=ag,ind,ser} \omega_{j,g}^{1/\varepsilon_g} \left(g_{j,t}\right)^{1-1/\varepsilon_g} \right)^{\varepsilon_g/(\varepsilon_g-1)}, \qquad (11a)$$

$$Y_t = \sum_{j=ag,ind,ser} P_{j,v,t} v_{j,t}\,, \qquad (11b)$$

$$P_{g,t}G_t \le T_t + \tau_{k,t}(r_t - \delta)k_t. \qquad (11c)$$

Multi-sector growth model

Equilibrium

1. Non-negative static and dynamic allocations of consumption of $j = ag, ind, ser$, and leisure maximize household lifetime utility subject to budget constraint.
2. Non-negative static allocations of intermediate and primary inputs maximize final output firms' profits subject to production function(s).
3. Non-negative static allocation of sectoral inputs maximizes investment good producer's profits subject to production function/aggregator.
4. Static allocations of sectoral inputs maximizes government consumption subject to policy rule and transfers that satisfy the budget constraint.
5. Final goods markets clear. Labor market clears. Capital services market clears.

Calibration of parameters

1. Calibration of production function and government consumption parameters, weights on consumption and leisure in the period utility function: calibrate to match Japan's 1980 input-output and NIPA data.

- Take the first order conditions for optimal static allocations, for example:

$$\frac{p_{j,t}(c_{j,t}+\bar{c}_j)}{p_{j',t}(c_{j',t}+\bar{c}_{j'})} = \left(\frac{\omega_{j,c}}{\omega_{j',c}}\right)\left(\frac{p_{j',t}}{p_{j,t}}\right)^{\varepsilon_c - 1}, \forall t.$$

$$N_t - H_t = \left(\frac{1-\psi}{\psi}\right)\left(\frac{P_{c,t}C_t}{w_t}\right), \forall t.$$

- Assign CES elasticity parameters and subsistence/endowment parameters from extant literature.
- Choose weights in the function (and scaling parameters) so that the FOC are satisfied by 1980 (symmetrized, RAS'd) Japan input-output intermediate and final expenditure data, setting all 1980 prices equal to 1.

Calibration of parameters

2. Calibration of the discount factor in lifetime utility function.

- Take the first order conditions for dynamic optimal consumption allocations: intertemporal consumption Euler equations

$$\frac{\beta P_{c,t} C_t / N_t}{P_{c,t+1} C_{t+1} / N_{t+1}} = \frac{1}{(1 - \delta(1 - \tau_k)) + r_{t+1}(1 - \tau_k)}, \forall t.$$

- Choose discount factor consistent with these equations on a BGP, conditional on depreciation rate of capital and a long-run average annual interest rate taken from the data.

Calibration of parameters

3. Calibration of the initial capital stock, K_{1980}, levels of 1980 variables, and the depreciation rate for the capital stock.

- Take nominal aggregate Japan capital stock data from OECD in 1980.
- Recall nominal = real in 1980, prices equal 1.
- Normalize 1980 Japan GDP to equal 100, which conveniently scales all endogenous variables.
- Calculate the nominal capital-nominal GDP ratio from OECD data for Japan in 1980: about 2.71.
- Set $K_{1980} = 2.71 \times 100 = 271.$

Calculate depreciation rate using 1980 Japan data on capital consumption expenditure and divide by initial capital stock:

- $\delta = \frac{KCONS_{1980}}{K_{1980}} = 0.062.$

Calibration of parameters

4. Calibration of exogenous time-series.

- Sectoral TFP initial levels and growth rates at each date taken from the data (estimated); $A_{j,t}, \forall j, t$.
- Working population initial level and growth rate at each date taken from UN Population Estimates; $N_t, \forall t$.
- Government share of GDP, from JSNA NIPA data; $\bar{g}_t, \forall t$.
- From OECD and JSNA NIPA and sectoral data; $NX_{j,t}, \forall t$.
- From Chen et al. (2006) updated with corporate tax rate data; $\tau_{k,t}$.

Calibration of parameters

Parameter	Value	Source/target
Technology: output		
$\omega_{ag,y}, \omega_{in,y}, \omega_{se,y}$	0.554, 0.674, 0.353	JSNA input-output table (1980)
$\omega_{ag,ag,m}, \omega_{ag,in,m}, \omega_{ag,se,m}$	0.265, 0.559, 0.176	JSNA input-output table (1980)
$\omega_{in,ag,m}, \omega_{in,in,m}, \omega_{in,se,m}$	0.047, 0.740, 0.213	JSNA input-output table (1980)
$\omega_{se,ag,m}, \omega_{se,in,m}, \omega_{se,se,m}$	0.047, 0.360, 0.593	JSNA input-output table (1980)
α	0.362	Hayashi and Prescott (2002)
$\alpha_{ag}, \alpha_{in}, \alpha_{se}$	0.708, 0.372, 0.335	OECD (STAN), JSNA (1980)
$A_{ag,1980}, A_{in,1980}, A_{se,1980}$	5.376, 112.958, 132.063	OECD (STAN), JSNA (1980)
$\Delta_{ag,v}, \Delta_{in,v}, \Delta_{se,v}$	0.082, 0.008, 0.007	JSNA sectoral value added (1980)
Technology: investment		
$\omega_{ag,x}, \omega_{in,x}, \omega_{se,x}$	0.036, 0.666, 0.297	JSNA input-output (1984)
Δ_x	1.250	JSNA fixed investment (1980)
δ	0.062	JSNA capital consumption (1980)
k_0	271.940	JSNA capital-GDP ratio (1980)
Technology: productivity		
γ	1.012	Sample average TFP growth rate (BGI
$\sigma_{A,ag,t}, \sigma_{A,in,t}, \sigma_{A,se,t}$	Data appendix	JSNA and OECD (STAN)

Calibration of parameters

Household: preferences		
β	0.989	WDI, long-run real interest rate
ϕ	0.327	JSNA, labor 1/3 total time (1980)
$\omega_{ag,c}, \omega_{in,c}, \omega_{se,c}$	0.015, 0.250, 0.735	JSNA input-output (1980)
Δ_c	1.000	JSNA consumption spending (1980)
Household: size and NX		
$\sigma_{n,t}$	Data appendix	UN Population Estimates
$nx_{ag,t}, nx_{in,t}, nx_{se,t}$	Data appendix	JSNA input-output (1980), OECD
Government: policies		
$\omega_{ag,g}, \omega_{in,g}, \omega_{se,g}$	0.018, 0.129, 0.853	JSNA input-output (1980)
Δ_g	1.000	JSNA government spending (1980)
$\tau_{k,t}$	Data appendix	Chen et al. (2006), corporate tax rate
$\overline{g}_t$	Data appendix	JSNA (NIPA) government share of GI
Elasticities		
$1/\sigma$	1.000	Herrendorf et al. (2014)
ε_c	0.650	Atalay (2017)
ε_g	0.650	Kehoe et al. (2018)
ε_x	1.000	Bems (2011), Kehoe et al. (2018)
ε_m	0.420	Atalay (2017, appendix, Japan)
ε_y	0.790	Atalay (2017, appendix, Japan)
$1/\theta$	1.000	Kehoe and Prescott (2002

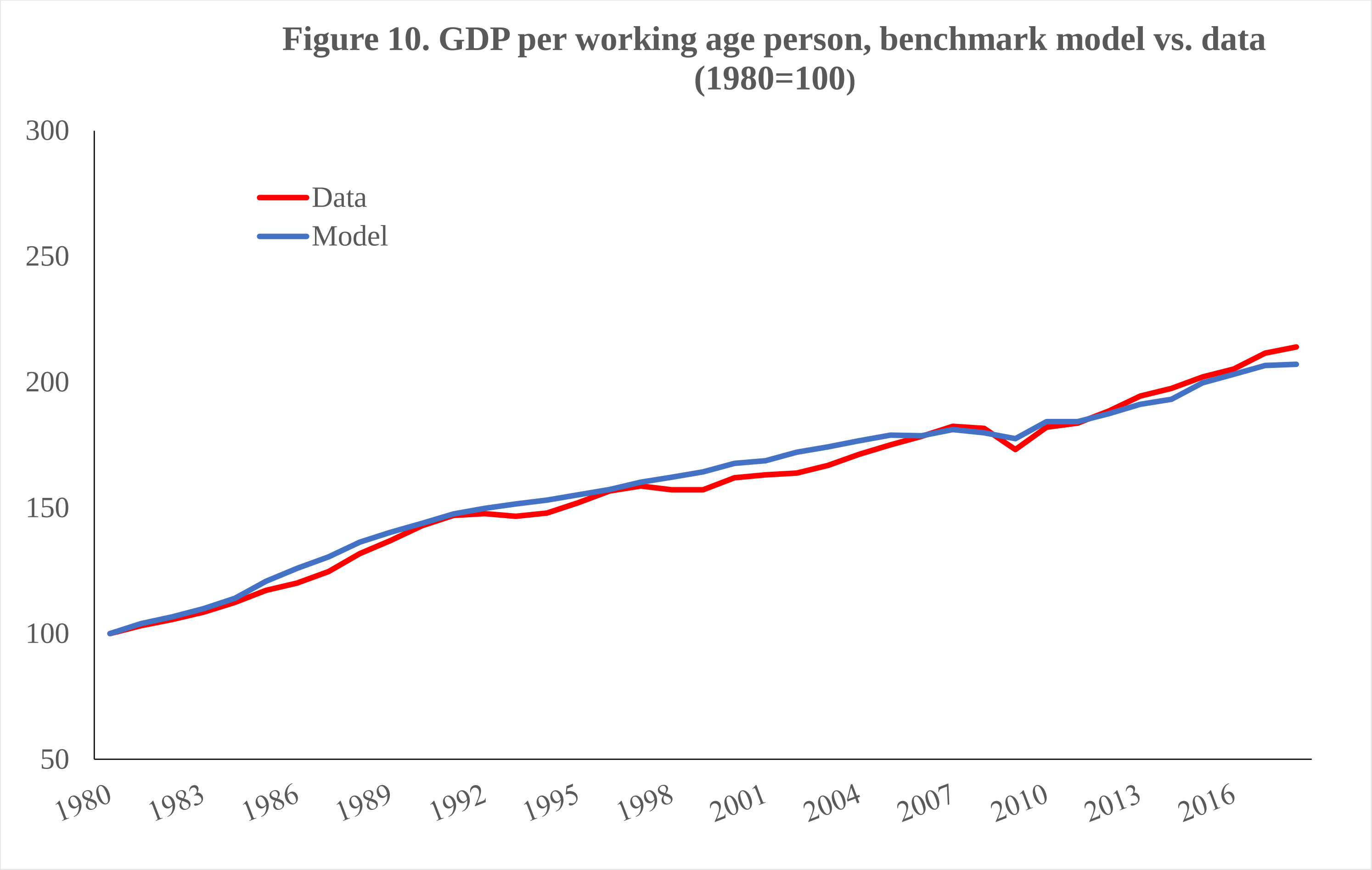
Results

1. Evaluate the performance of the benchmark model in capturing sectoral contributions to aggregate growth accounting variables facts.

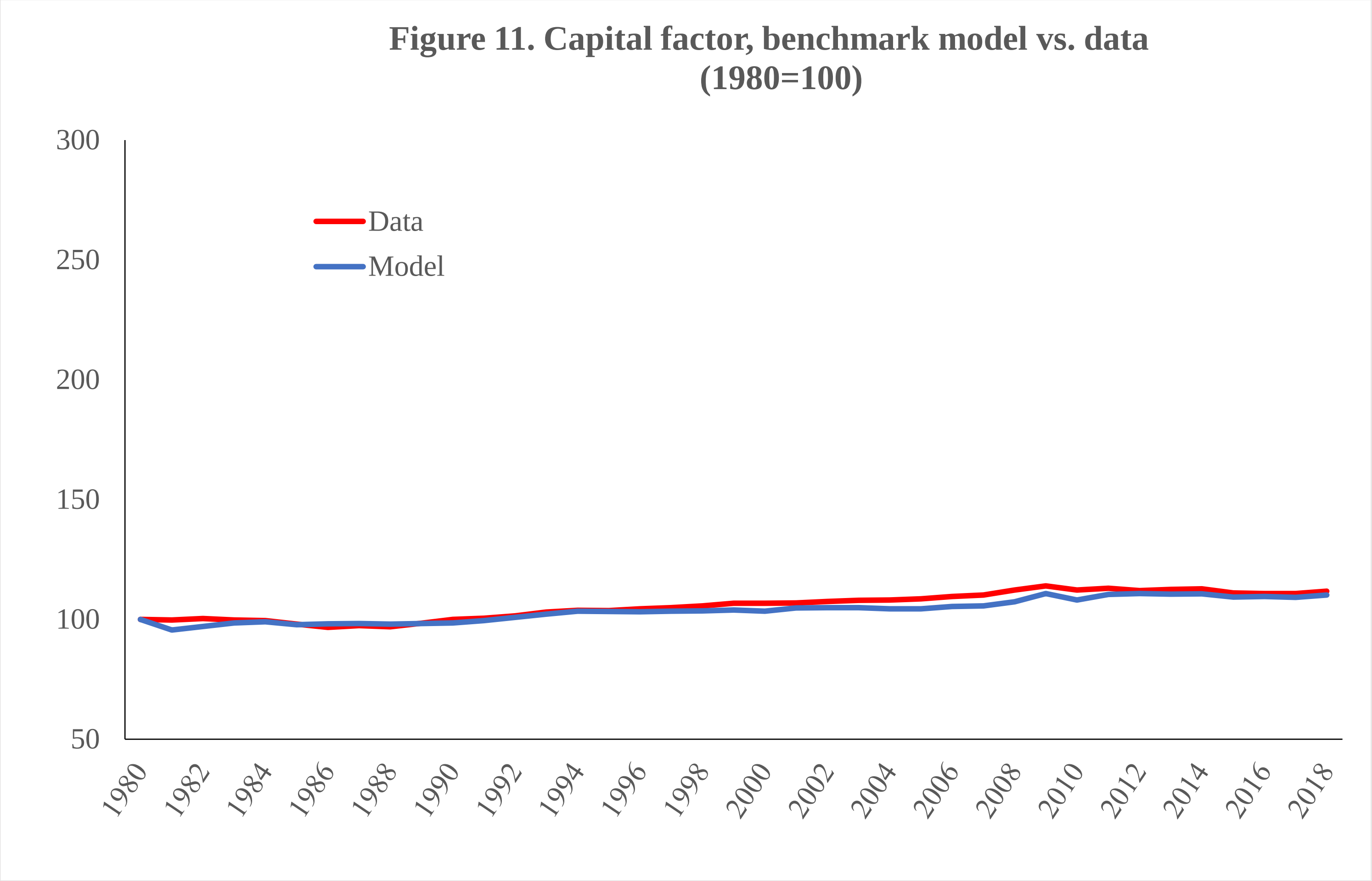
2. Aggregate across sectors and evaluate the performance of the benchmark model in capturing aggregate growth accounting facts.

- Calculate aggregate variables by "re-constructing" exactly the sectoral contributions (predicted by the model) to each aggregate variable that were characterized in exact sectoral decompositions of the data.

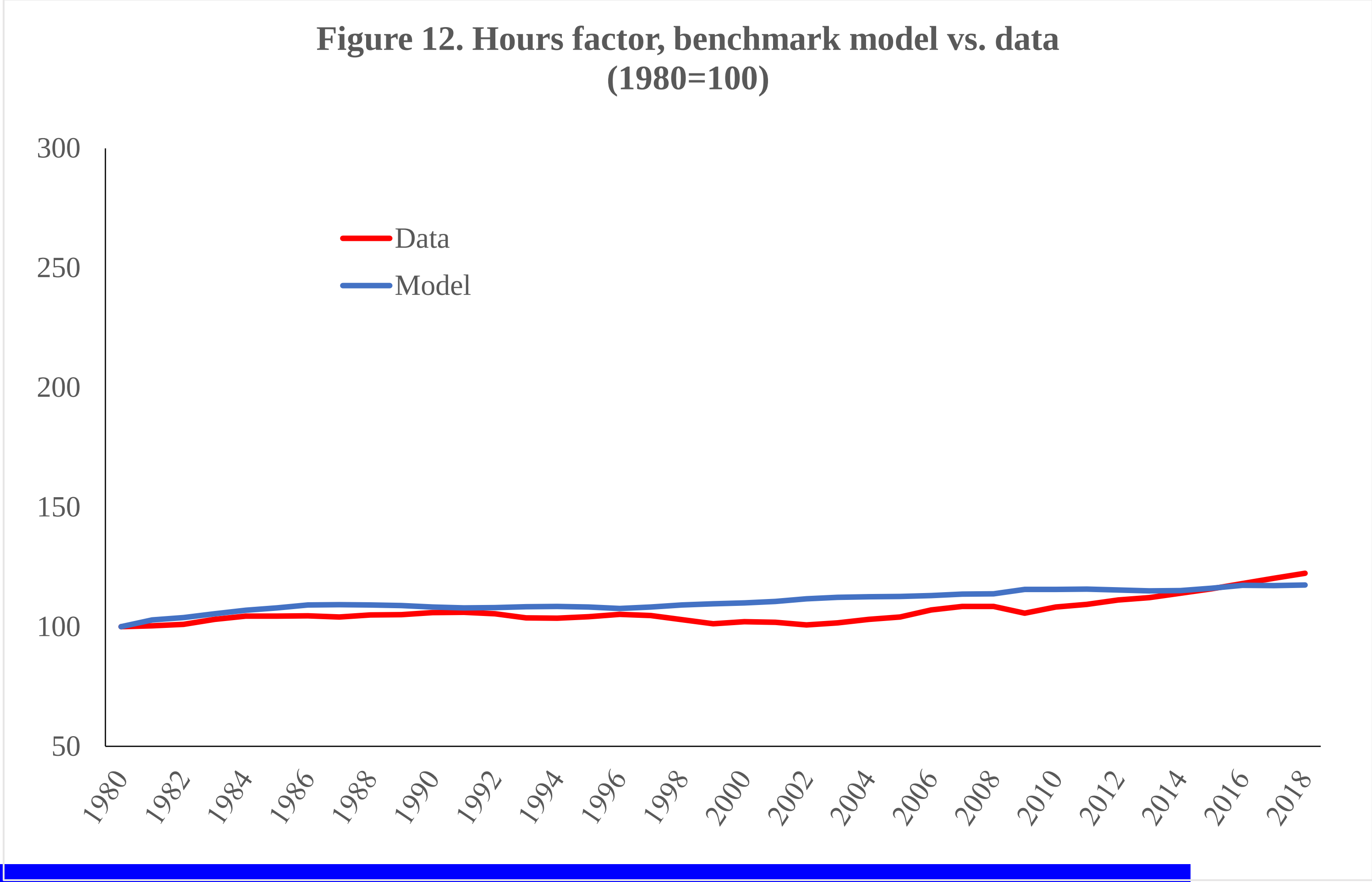
Benchmark model vs. data (aggregate)



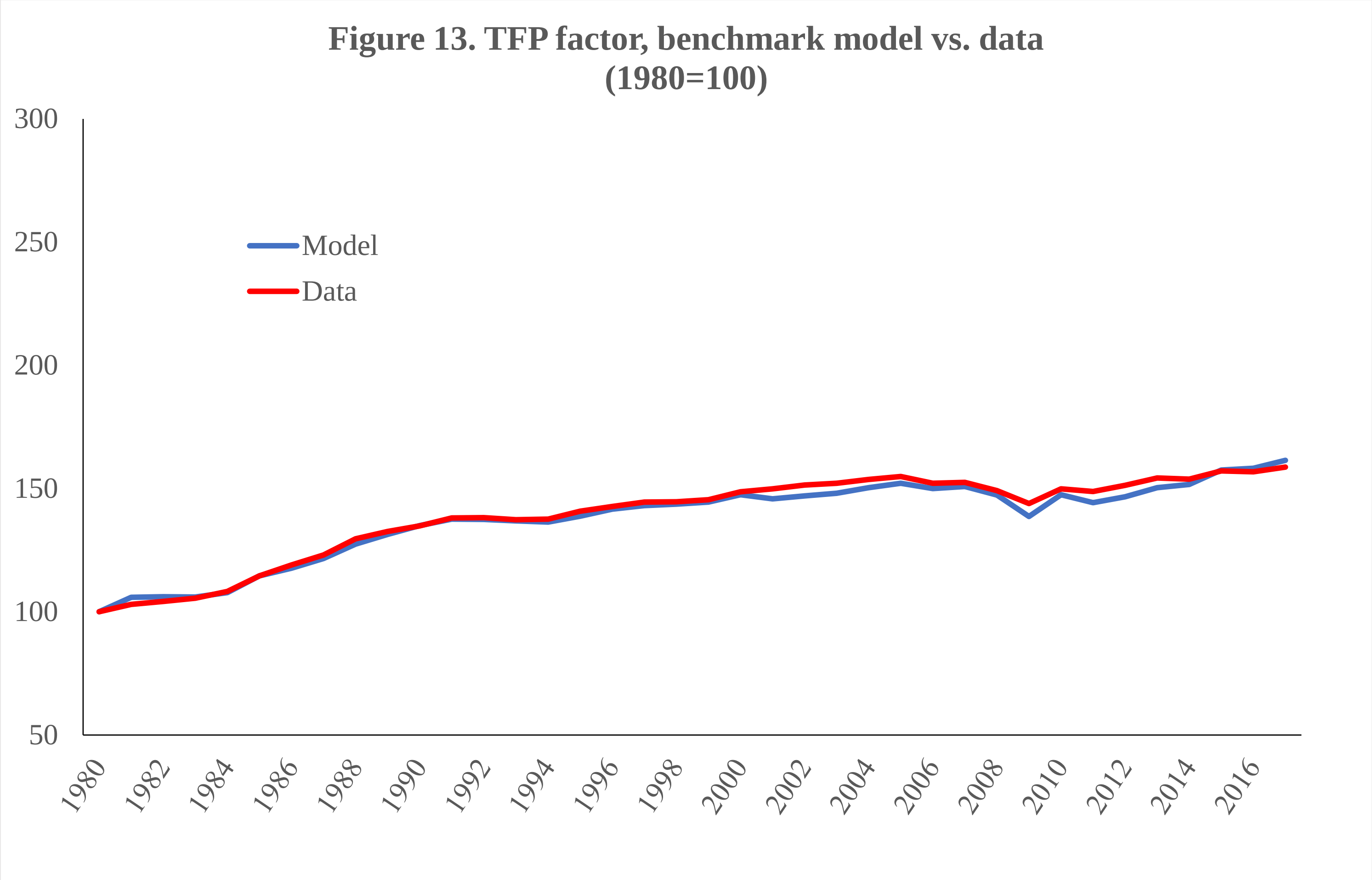
Benchmark model vs. data (aggregate)



Benchmark model vs. data (aggregate)



Benchmark model vs. data (aggregate)



Benchmark model vs. data (aggregate)

Table 5. Growth accounting for GDP per working age person, benchmark model vs. data (data in parentheses)

Period	**Y/N**	$A^{\frac{1}{1-\alpha}}$	$(K/Y)^{\frac{\alpha}{1-\alpha}}$	**H/N**
1981–1990	**3.71 (3.64)**	3.04 (3.05)	-0.13 (0.01)	0.80 (0.58)
1991–2010	**1.25 (1.24)**	0.44 (0.54)	0.48 (0.59)	0.33 (0.12)
1991–2000	1.54 (1.27)	0.89 (0.98)	0.50 (0.65)	0.16 (-0.36)
2001–2010	0.96 (1.21)	-0.00 (0.09)	0.46 (0.54)	0.51 (0.60)
2011–2018	**1.47 (2.04)**	1.04 (0.55)	0.24 (-0.06)	0.19 (1.54)
1981-2018	**1.96 (2.04)**	**1.25 (1.20)**	**0.27 (0.30)**	**0.43 (0.54)**

Benchmark model vs. data (aggregate)

Even when average growth rates *within* decades are inaccurate, changes in average growth rates *between the lost* score and 1980s are close. Specifically:

1. The benchmark model accounts for 102% of the fall in av. Y/N growth during 1991-2010 relative to the 1980s, and 92% of that during 1991-2000.
2. The benchmark model accounts for 103% of the fall in av. TFP factor growth during 1991-2010 relative to the 1980s, and 104% of that during 1991-2000.
3. The benchmark model accounts for 100% of the fall in av. H/N growth during 1991-2010 relative to the 1980s, but only 68% of that during 1991-2000.
4. The benchmark model accounts for 105% of the rise in av. K factor growth during 1991-2010 relative to the 1980s, and 98% of that during 1991-2000.

Benchmark model vs. data (aggregate)

Summary of aggregate growth accounting performance

1. It’s a *good* model for capturing the aggregate downturn in Japan relative to the 1980s, except the temporary decline in H/N during the 1990s.

2. It’s a *bad* model for capturing the upturn in the 2010s, relative to 1991-2010, due to rapid H/N growth.

Policy interventions in labor markets not captured by the model can account for both of these weaknesses.

Benchmark model vs. data (sectoral)

Table 7. Sectoral contributions to TFP factor growth, benchmark model vs. data (data in parentheses)

Period	Aggregate/ Sum	Agriculture	Industry	Services
1981–1990	**3.04** **(3.05)**	0.17 (0.16)	1.28 (1.36)	1.59 (1.53)
1991–2010	**0.44** **(0.54)**	-0.00 (0.04)	0.17 (0.19)	0.27 (0.36)
1991-2000	**0.89** **(0.65)**	0.01 (-0.01)	0.36 (0.11)	0.52 (0.55)
2001-2010	**-0.00** **(0.52)**	-0.01 (-0.03)	-0.01 (0.12)	0.02 (0.43)
2011–2018	**1.04** **(0.55)**	0.03 (0.07)	0.41 (0.49)	0.60 (0.00)
1981-2018	**1.25** **(1.20)**	**0.05** **(0.05)**	**0.52** **(0.56)**	**0.68** **(0.59)**

Benchmark model vs. data (sectoral)

Table 8. Sectoral contributions to H/N growth, benchmark model vs. data (data in parentheses)

Period	Aggregate/ sum	Agriculture	Industry	Services
1981–1990	**0.80** **(0.58)**	-0.01 (-0.10)	0.06 (0.03)	0.74 (0.65)
1991–2010	**0.33** **(0.12)**	0.01 (-0.01)	0.07 (-0.44)	0.26 (0.57)
1991-2000	**0.16** **(-0.36)**	0.01 (-0.05)	0.02 (-0.60)	0.13 (0.29)
2001-2010	**0.51** **(0.60)**	0.01 (0.02)	0.11 (-0.27)	0.39 (0.85)
2011–2018	**0.19** **(1.54)**	-0.01 (-0.01)	-0.09 (0.21)	0.30 (1.34)
1981-2018	**0.43** **(0.54)**	**0.00** **(-0.03)**	**0.03** **(-0.18)**	**0.39** **(0.75)**

Benchmark model vs. data (sectoral)

Summary of sectoral contributions to important downturn growth factors

1. The model does a very good job of capturing sectoral contributions to aggregate TFP factor changes that drive Japan’s lost score (less so the 1990s and 2000s separately).

1. It does *not* do such a good job of capturing sectoral contributions to aggregate H/N decline in the 1990s, although its matches the decline in aggregate H/N growth 1991-2010 relative to the 1980s.

   - It overstates average hours growth in industry in the 1980s, 1990s, and 2000s.
   - It understates average hours growth in services in the 1990s, 2000s, 2010s.
   - It *cannot capture the decline* in industry hours growth between the 1980s and 1990s.

Benchmark model vs. data (sectoral)

Notes: The decline in aggregate H/N growth in the 1990s was driven by declining average hours per employee which partly reflects a mandated reduction in the length of the working week from 44 to 40 hours discussed by Hayashi and Prescott (2003), although there is also a trend throughout the sample period of falling average hours.

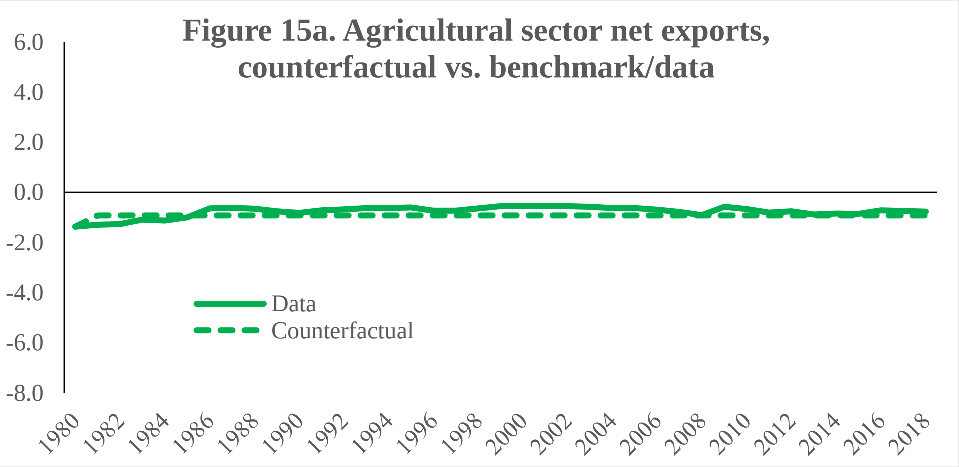
- Suggests that industrial sector-specific labor market policy may have contributed to this 1990s decline.
- Was the mandated reduction in average hours concentrated on workers in this sector?

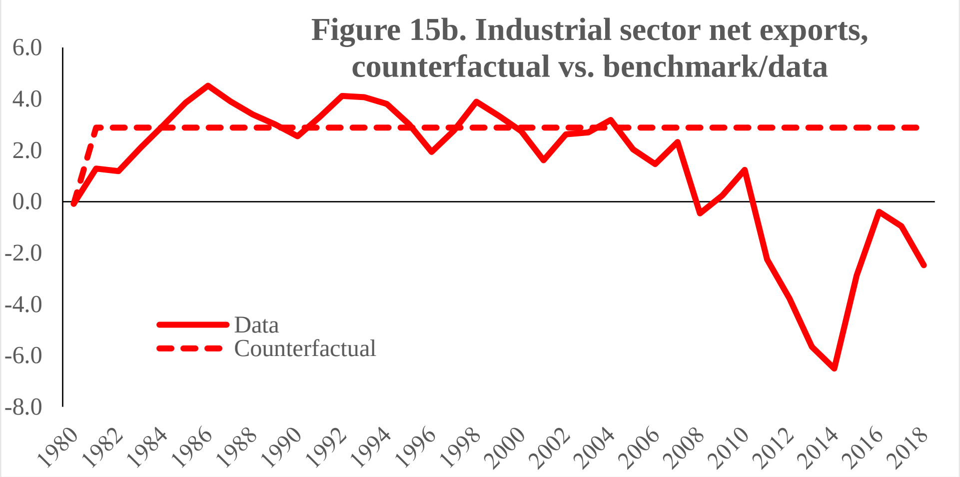
Counterfactuals

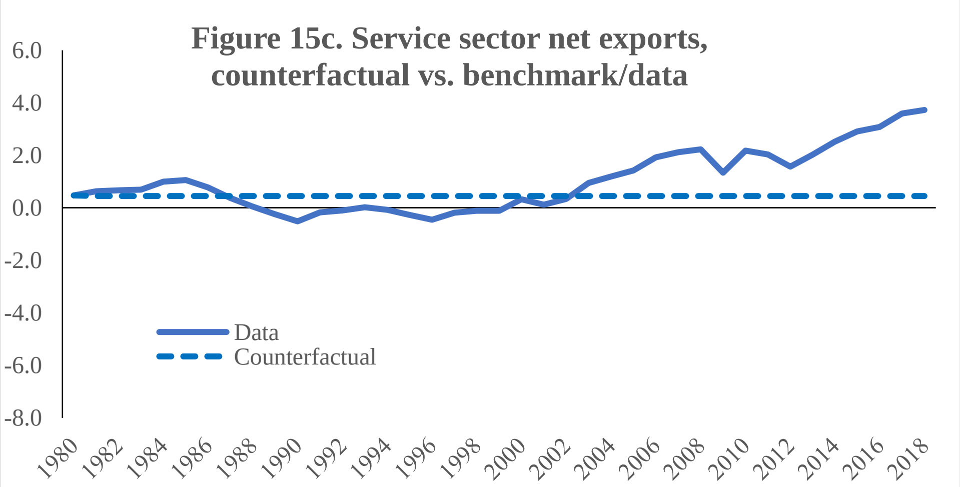
Since the model replicates well the reduction in Japan's GDP per working age person growth and its aggregate sources, I use it to conduct counterfactual exercises designed to evaluate the quantitative importance of alternative exogenous factors in accounting for that downturn.

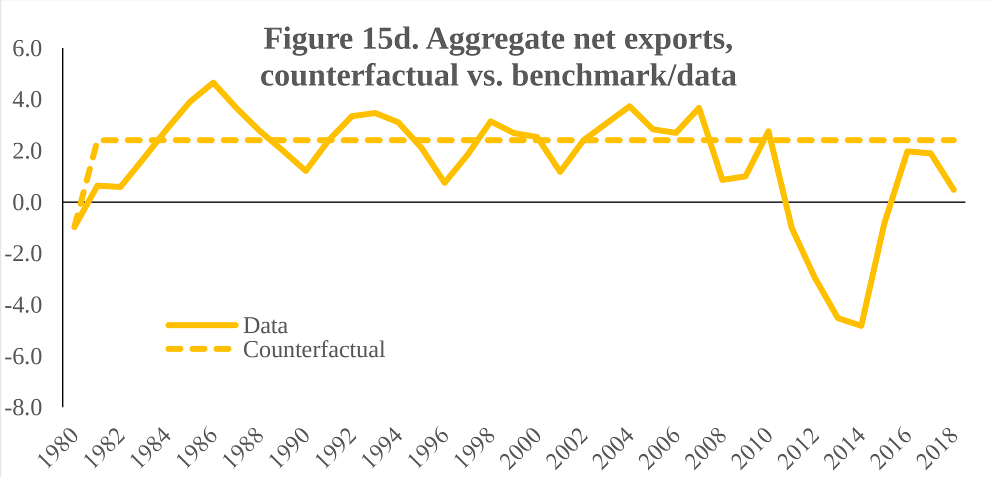
- Net exports.
- Government spending share of GDP.
- Working population growth rate.
- Sectoral TFP growth rates.

Counterfactuals: 1980s average net exports

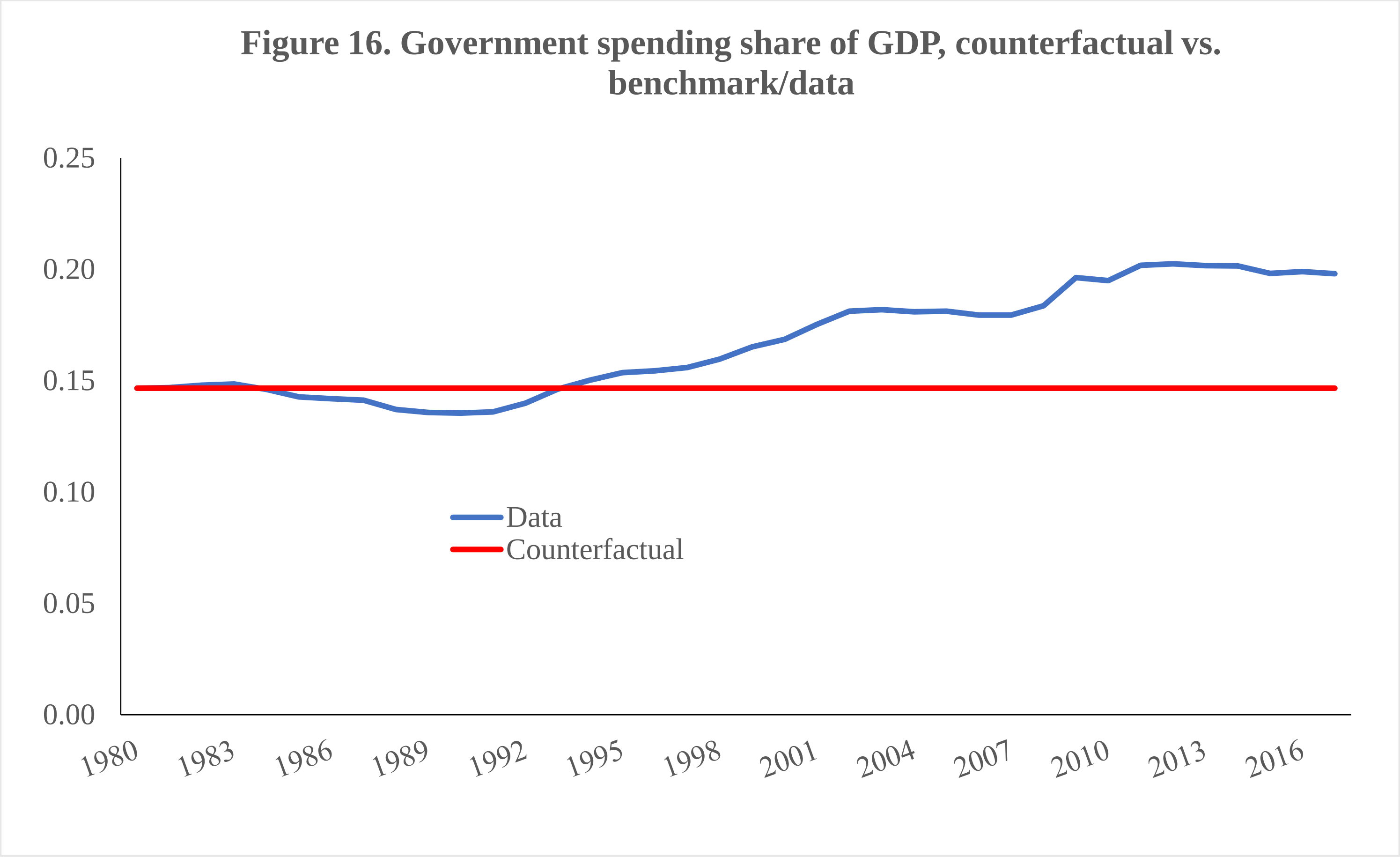




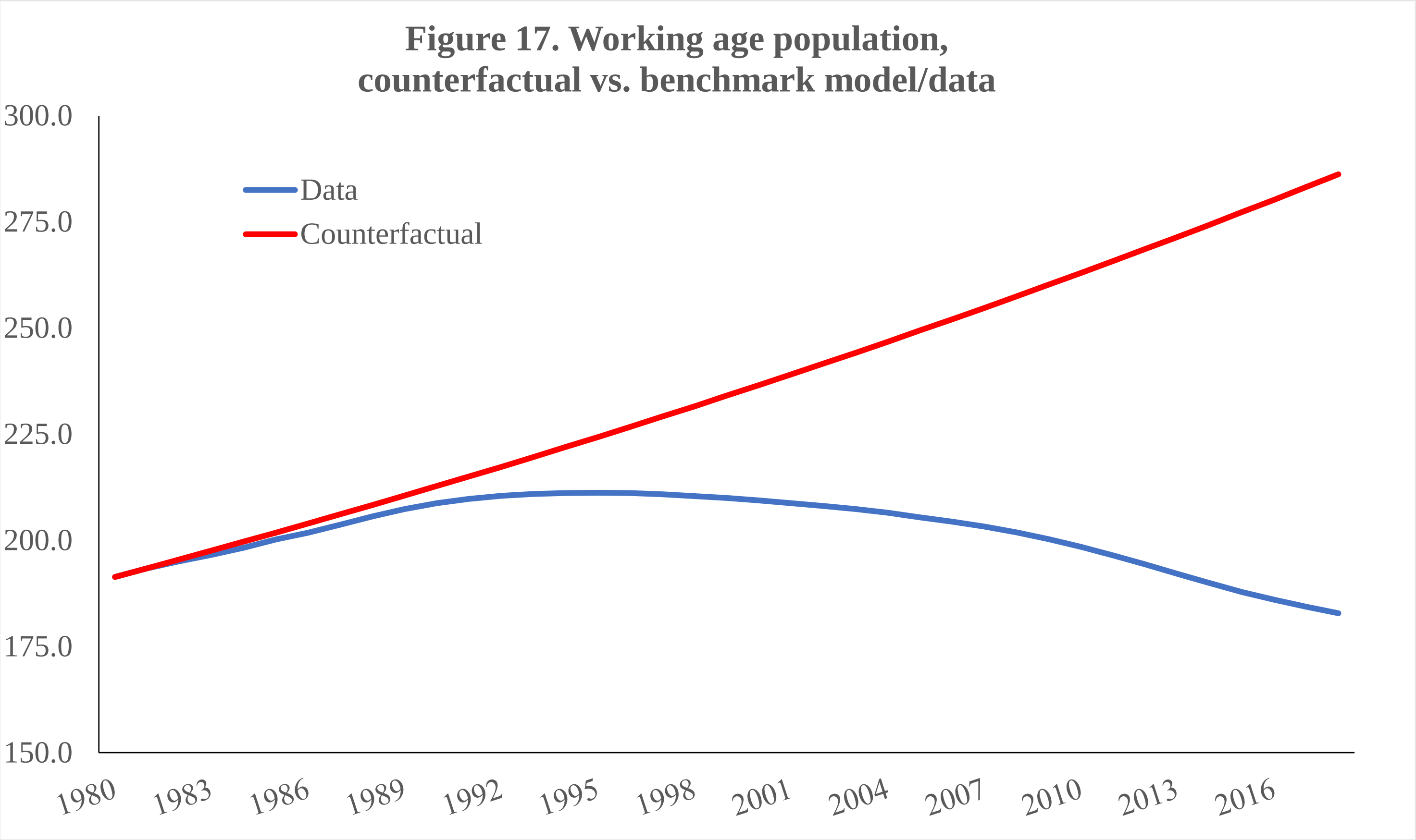




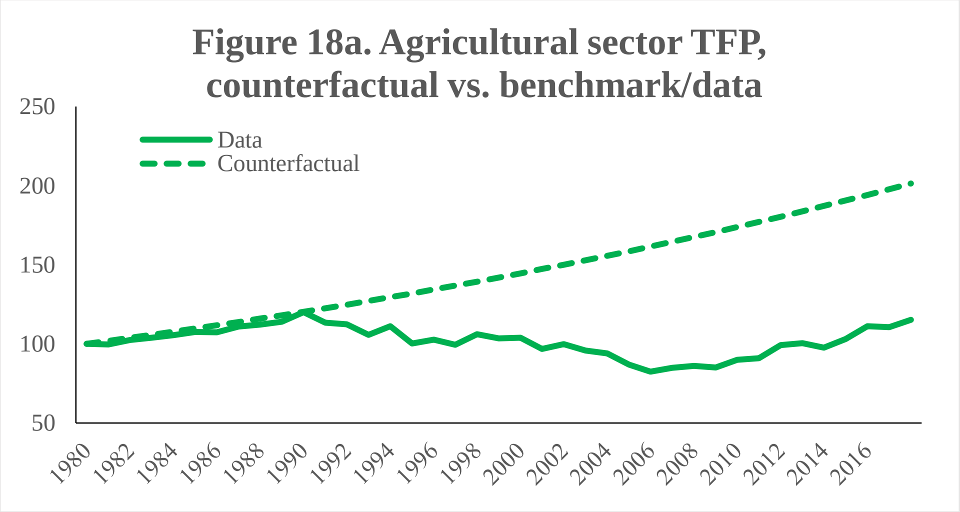
Counterfactuals: 1980 government GDP share

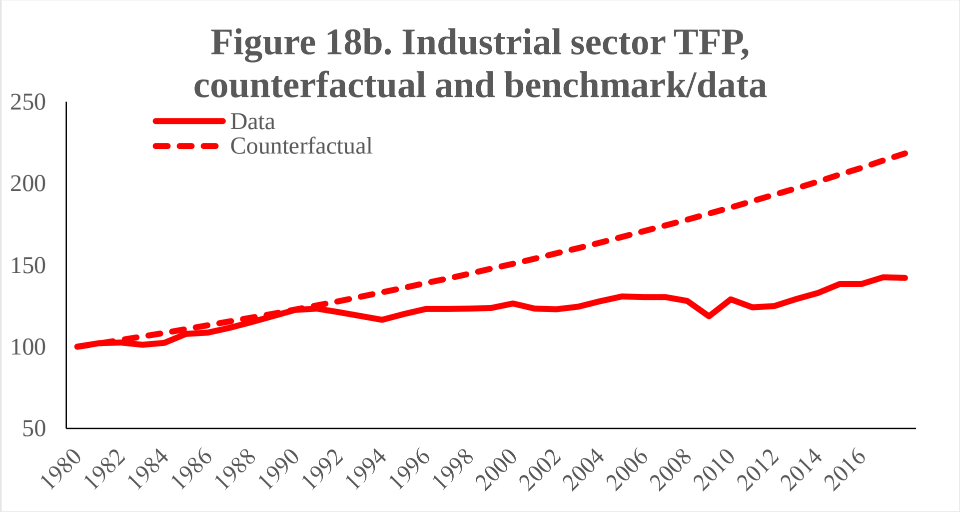


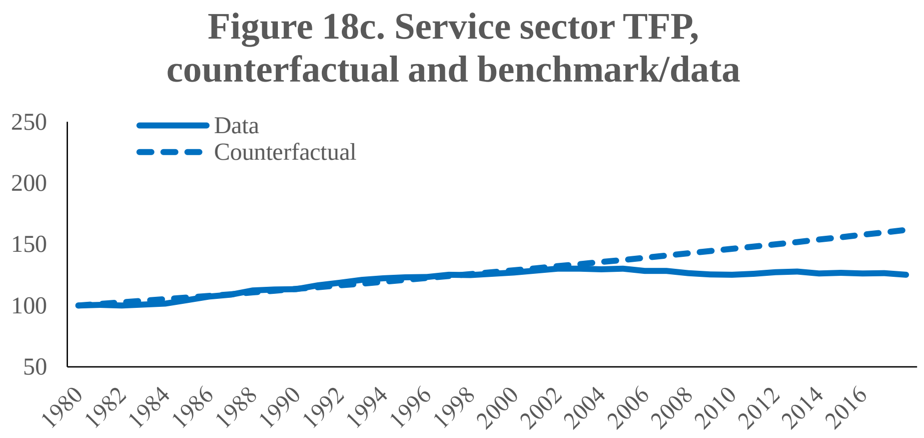
Counterfactuals: 1980-81 population growth



Counterfactuals: 1980s sectoral TFP growth

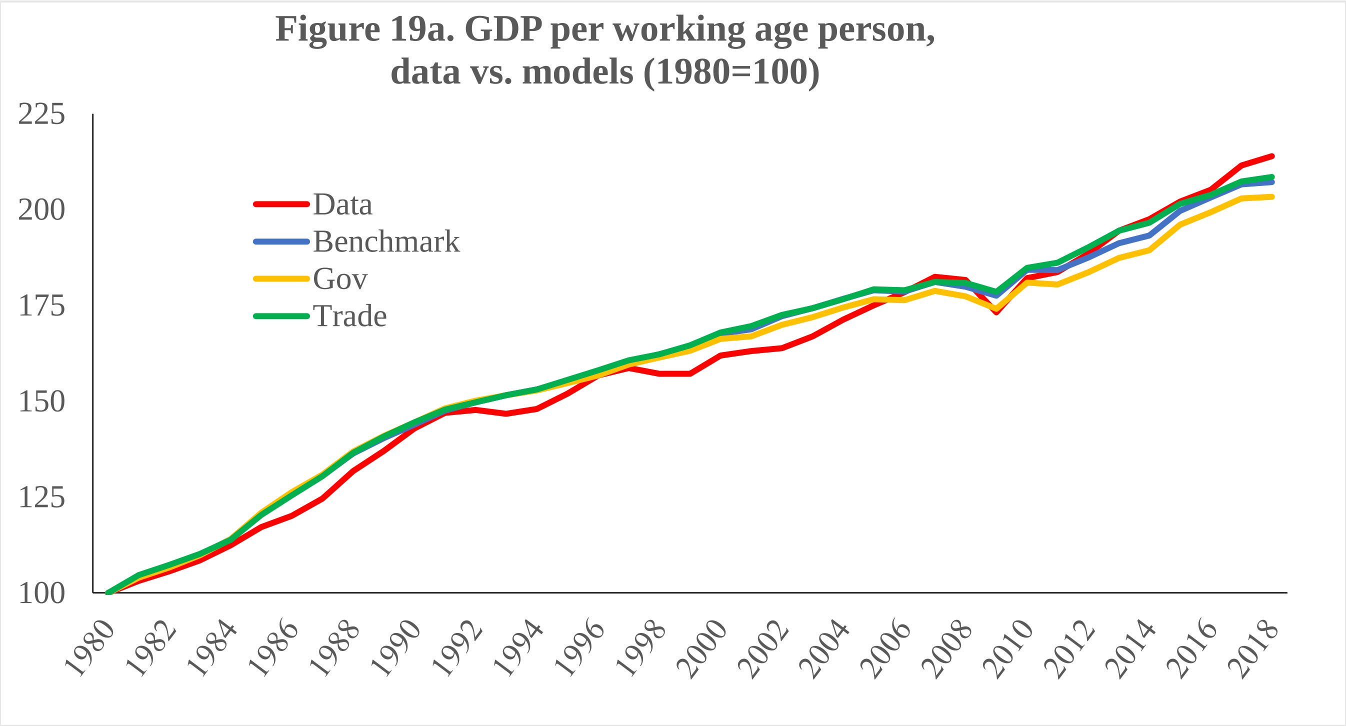






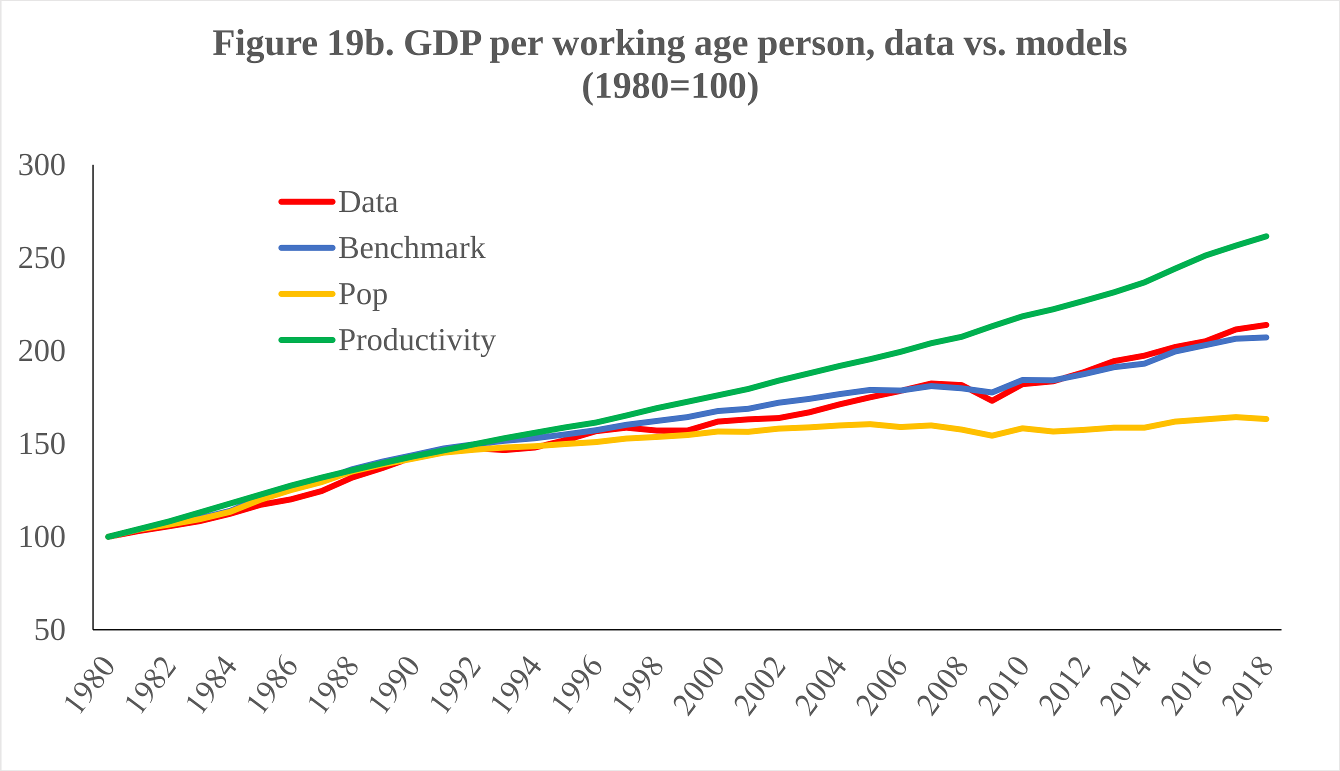
Counterfactuals: effect for GDP per person

- 1980s average net exports implies marginally faster growth than benchmark economy only in mid-2010s, and hence marginally higher level thereafter – otherwise no change.
- 1980 GDP share of government consumption implies marginally slower growth after 1994, and hence marginally lower GDP level – fiscal policy helped a little bit!



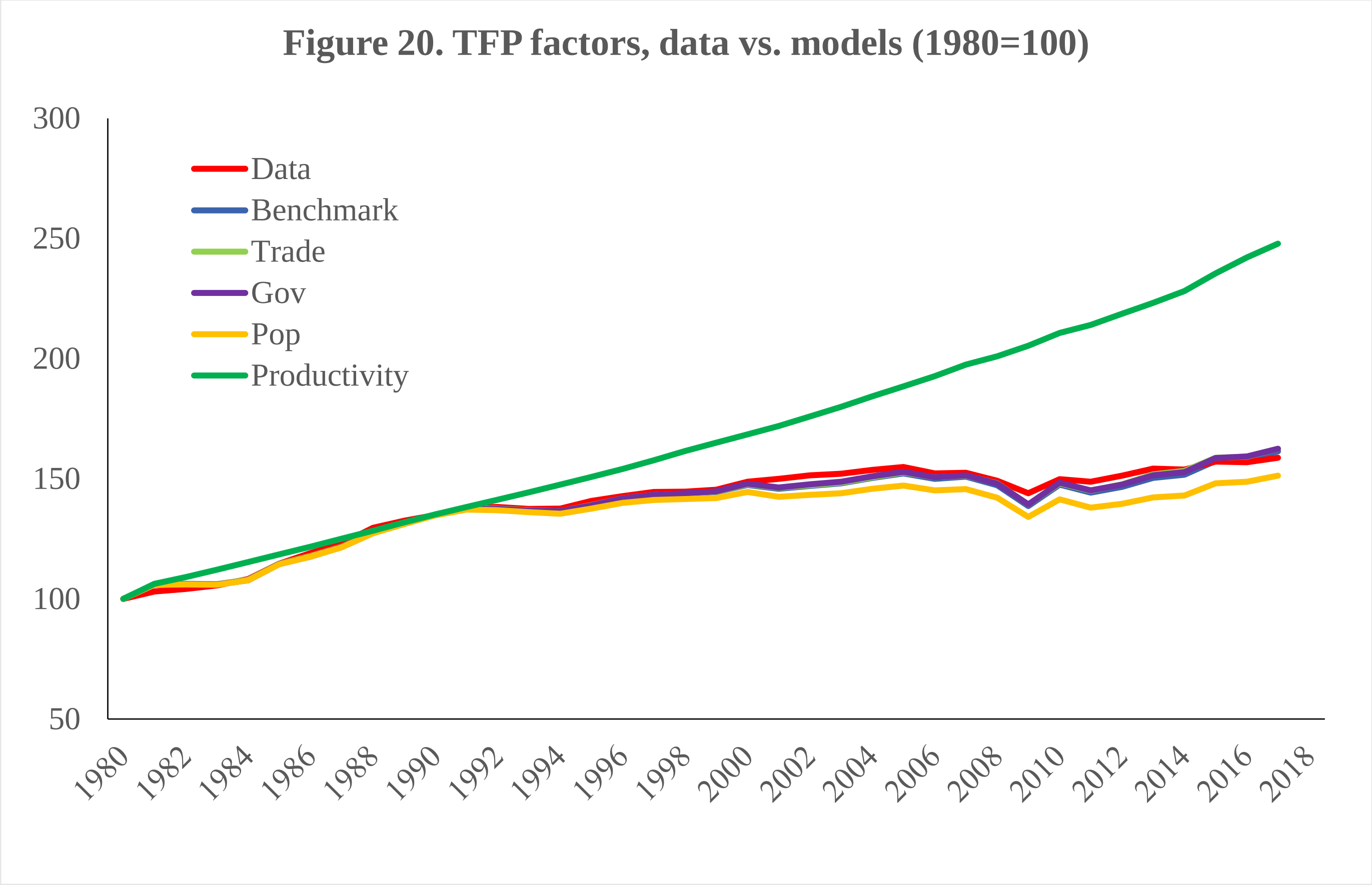
Counterfactuals: effect or GDP per person

- 1980-81 rapid population growth rate implies much *slower* growth and hence lower level than in the benchmark model or data after 1995: declining working population helped!
- 1980s average TFP growth rates imply much *faster* growth and hence higher level than in the benchmark model or data after 1995, modest slowing only in 1990s (due to H/N).



Counterfactuals: effect for aggregate TFP

- 1980s average TFP growth rates imply much *faster* aggregate TFP factor growth than in the benchmark model or data after 1990.



Counterfactuals

Period	Y/N	$A^{\frac{1}{1-\alpha}}$	$(K/Y)^{\frac{\alpha}{1-\alpha}}$	H/N
1981–1990				
1980 pop	3.58	2.41	0.41	0.76
1980 gov	3.75	3.03	-0.16	0.87
1980 NX	3.75	3.05	-0.14	0.84
1980s TFP	3.66	3.05	-0.15	0.76
Benchmark	**3.71**	**3.04**	**-0.13**	**0.80**
Data	**(3.63)**	**(3.05)**	**(0.01)**	**(0.58)**
1991–2010				
1980 pop	0.55	0.35	0.00	0.20
1980 gov	1.14	0.48	0.55	0.12
1980 NX	1.24	0.45	0.48	0.31
1980s TFP	2.14	2.24	-0.25	0.14
Benchmark	**1.25**	**0.44**	**0.48**	**0.33**
Data	**(1.24)**	**(0.54)**	**(0.58)**	**(0.12)**
2011–2018				
1980 pop	0.40	0.58	-0.19	0.02
1980 gov	1.47	1.05	0.27	0.16
1980 NX	1.52	1.09	0.18	0.25
1980s TFP	2.27	2.30	-0.14	0.10
Benchmark	**1.47**	**1.04**	**0.24**	**0.19**
Data	**(2.04)**	**(0.55)**	**(-0.06)**	**(1.54)**

Counterfactuals: effects for H/N

Even with rapid TFP growth in all three sectors, H/N drops sharply in the 1990s in the model.

- The only way to reduce this drop in hours per working age person in the model is to assume there are no income effects/non-homothetic terms in preferences which shift resources into services (and out of agriculture).

Income effects: Rapid TFP and hence aggregate income growth in 1980s causes resources/hours to shift into services and out of agriculture. Declining TFP and income growth in 1990s slows this process.

Relative price effects: Agriculture TFP growth is fastest in 1980s, services' the slowest: rising relative price of services, with gross complementarity in preferences, raises service share of hours relative to agriculture and industry.

- With both effects, hours in services – the largest sector, and hence in aggregate – grow relatively rapidly in 1980s, and there is a big decline in 1990s in the model (but not in industry!).

- Shut down income effects, services' hours grow less quickly in 1980s, and the decline is smaller.

Conclusions

Counterfactual exercises suggest we can interpret Japan's lost score of growth in GDP per working age person as the outcome of optimal household and firm responses to:

Declining TFP growth in the industrial and service sectors,

somewhat offset by

Declining working population growth.

Failure of the model to account well for sectoral contributions to slowing hours growth in the 1990s (large role for industry) and faster hours in the 2010s (large role for services) suggests these are responses to policy.

Conclusions

TFP growth in manufacturing and services in Japan remains stagnant after 2010 through 2018 – unlikely to see any sustained improvement in growth of living standards until this changes.

- Growth theory implies that the partial growth rate improvement after 2010 due to hours factor growth is *not* sustainable in the long-run.

Research and policy now need to focus on determining the sources of sectoral productivity slowdown – the policies and institutions in these sectors that prevent efficient use of frontier technology.

Appendix: Additional OECD Comparison

Figure A.1. De-trended TFP factors, richest twenty OECD countries (1990=100)