Hidden Stagflation

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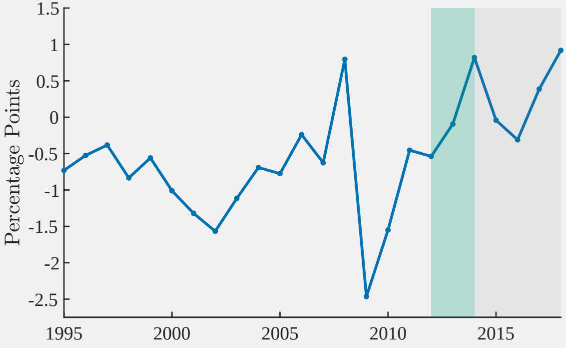
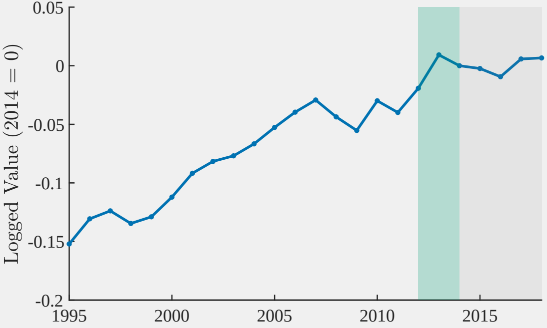
Motivation : Rise in Prices and Decline in Quantities?

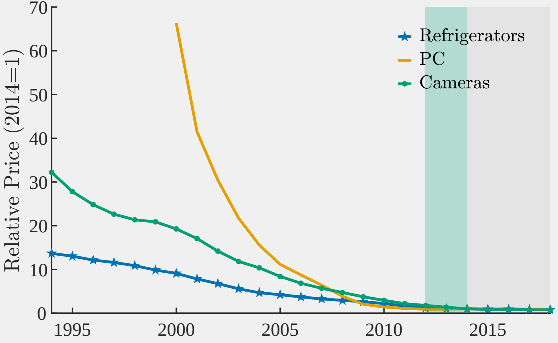


Aggregate Inflation Rate

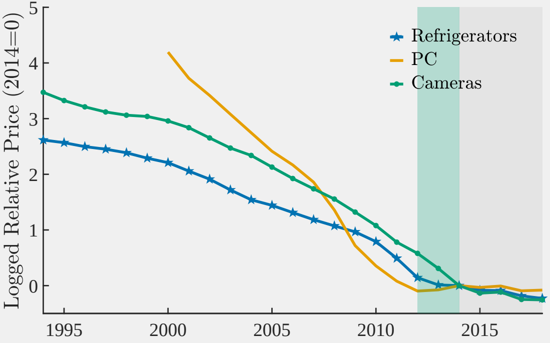


Real Consumption

A Glance at Disaggregated Price Series



Level



Logged Level

- During the same period, the prices of typical durable consumption goods stopped falling.

What We Do and Find in This Paper

- Documents facts about Japanese economy.
  - Give evidence the economy has experienced tech slowdown in durable and ICT goods sectors.
- Constructs an accounting model.
  - Our model can explain the facts about the Japanese economy together.
- Quantifies the effect on inflation of the technology stagnation.
  - The technological stagnation accounts for a sizable fraction of the rise in inflation and the stagnation of consumption since 2014.
- Explore the implication for European countries.
  - We uncover a version of hidden stagflation.
- Provide extension and various robustness exercises.

Empirical Context

Main Datasets : JSNA and KLEMS

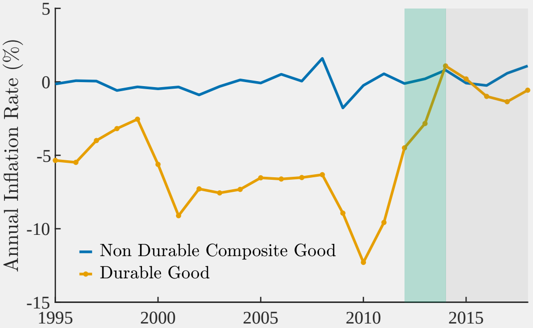
- National accounts of Japan (JSNA 2011)
  - Sample Period : 1994-2018.
  - Variables: consumption expenditure, deflators, capital stock, and GDP.
  - Types of consumption ($\mathcal{C}$) : [food + service (excl. imputed rents) + other nondurable goods] and durable (D).
    - Exclude the effects on inflation from VAT hikes implemented in year 1997 and 2014.
  - [Used Later] Types of capital stock ($\mathcal{I}$): (1) total non-residential investment (structure); (2) transportation equipment; (3) information and communication technology equipment (ICT); (4) other equipment; (5) weapons; (6) cultivated assets; (7) R&D; (8) other intellectual property products; (9) computer software.
  - Use (chain-linked) PCE deflator as our measure for the inflation. ▸ CPI-VS-Consumption
- The labor service sequence in JIP2021 (KLEMS) is used as labor input.
  - JIP2021 adjusts the quality of labor by the same method as the EU-KLEMS.
- We exclude housing from our analysis.

Fact 1' : Decomposition of Aggregate Inflation

- Recall the statistical relation: ‣ VAT Hike

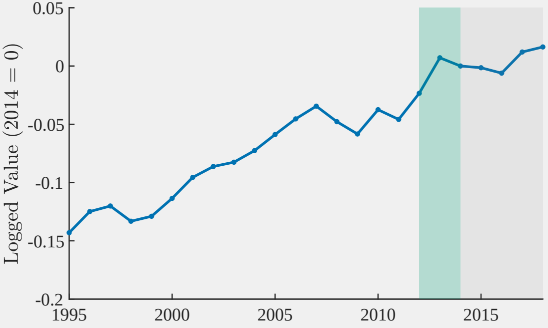
$$\pi_t = \sum_i \underbrace{s_{i,t-1}}_{\text{Nominal Share}} \times \underbrace{g_{P_{i,t}}}_{\text{Inflation by good}} .$$

	Average Inflation		
	-2011	2014-	Change
Aggregate	−0.82%	0.35%	1.18%
Non Durable	−0.13%	0.42%	0.56%
Durable	−6.71%	−0.32%	−6.39%

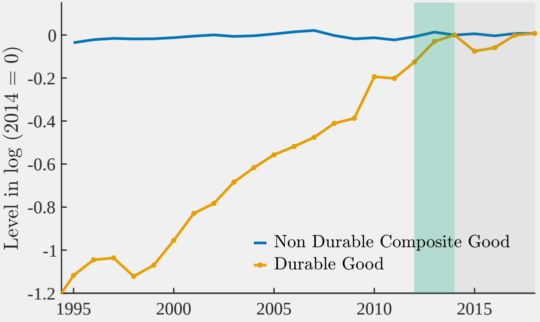


Inflation by Subcategory

Fact 2 : Weak Consumption Puzzle (Hausman and Wieland (2015))



Real Consumption per Capita g_{C_t}



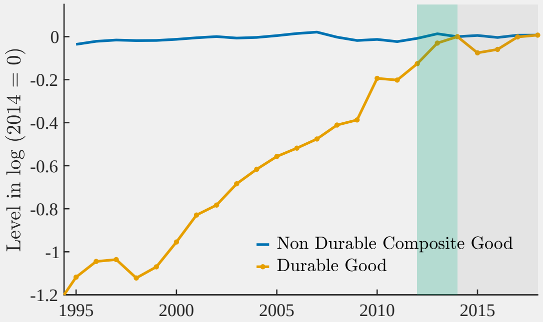
Real Consumption per Capita by Subcategory $g_{C_{i,t}}$

Fact 2' : Weak Consumption Due to Durable Consumption Stagnation

- Recall the statistical relation:

$$g_{C_t} = \sum_i s_{i,t-1} g_{C_{i,t}}.$$

	Average Growth		
	-2011	2014-	Change
Aggregate	0.70%	0.18%	−0.52%
Non Durable	0.03%	0.11%	0.08%
Durable	6.19%	0.74%	−5.45%



Real Consumption per Capita by Subcategory $g_{C_{i,t}}$

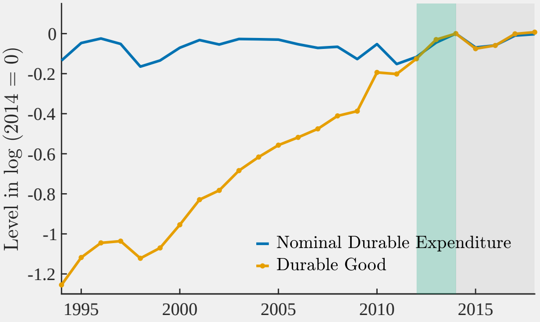
- The decline of the growth entirely comes from one for the durable good.

Fact 2 : Weak Consumption in Durable Good Is Due to the Deflator

- Recall the accounting identity:

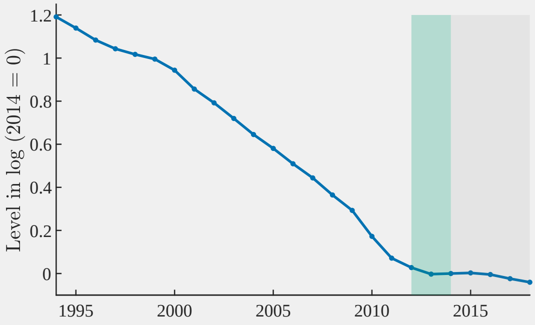
$$g_D = g_{P_D D} - \pi_{P_D}.$$

	Average Growth		
	-2011	2014-	Change
Real	6.19%	0.74%	−5.45%
Nominal	−0.11%	0.83%	0.94%
Deflator	−6.30%	0.09%	−6.39%

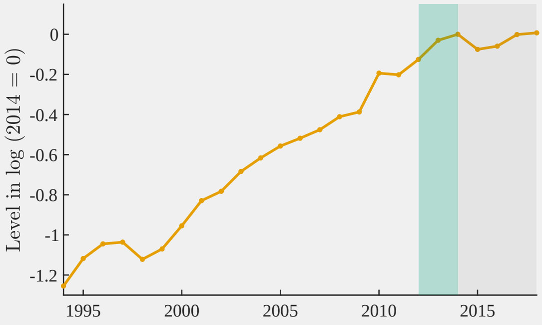


Real Consumption per Capita and Deflator

Fact 3 : Technology Stagnation Specific to Durable Good



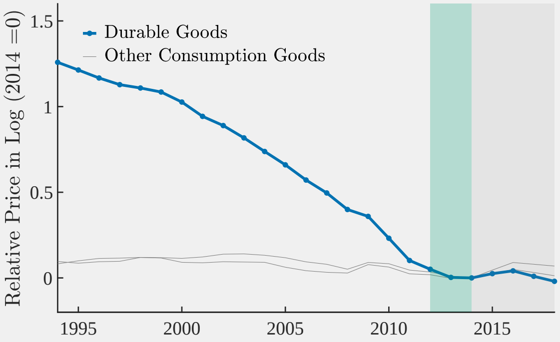
Relative Durable Deflator



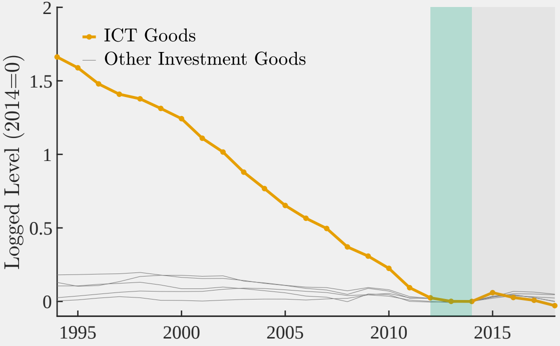
Real Consumption per Capita

- There had been a directed technology progress specific to the durable good (Hulten (1992)).
- Since 2014, the technology progress significantly slowed down.

Fact 3' Is Not Specific to Durable Good, but ICT Goods



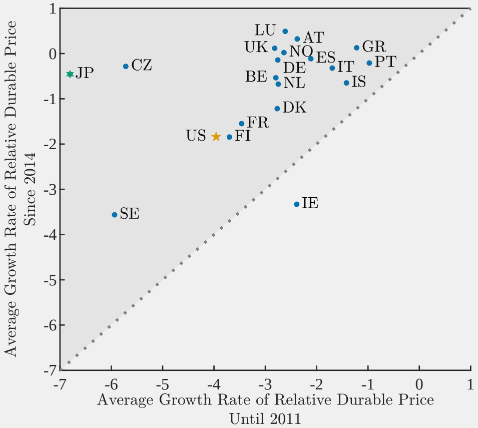
Consumption Goods



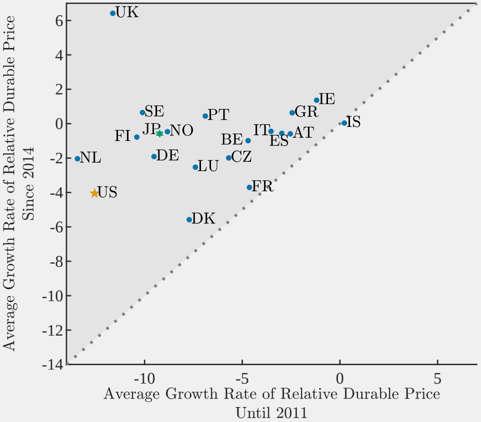
Investment Goods

- The declines in the relative prices reflect specific TFP improvement (Greenwood et al. (1997)).

Fact 3' Is Not Specific to Japan, but Common Across Developed Countries



Durable Goods

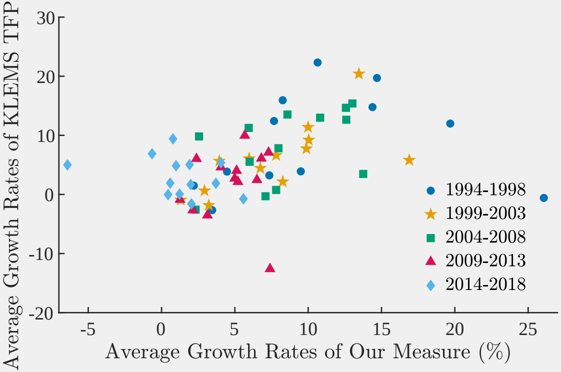


ICT (Computer Hardware) Goods

Fact 3' : Our Measure Correlates with The TFP Estimates by KLEMS

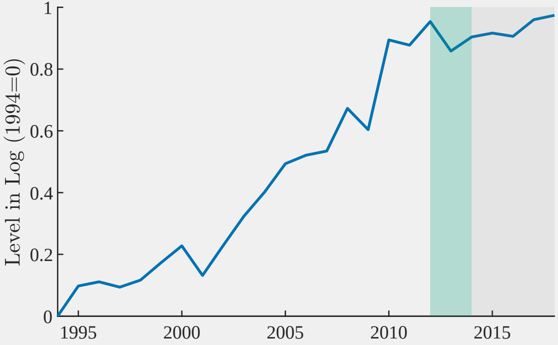
- The literature often interprets the secular decline of the relative prices as sector-specific technology improvement.
- But, the final good prices might not reflect technology correctly. (E.g. import, export, and exchange rate...) ▸ Exchange Rate
- KLEMS (JIP) directly estimates sectoral TFP growth rates with a general CRS production F.

$$Y_{n,t} = A_{n,t} F\left(K_{n,t}, L_{n,t}, M_{n,t}\right).$$

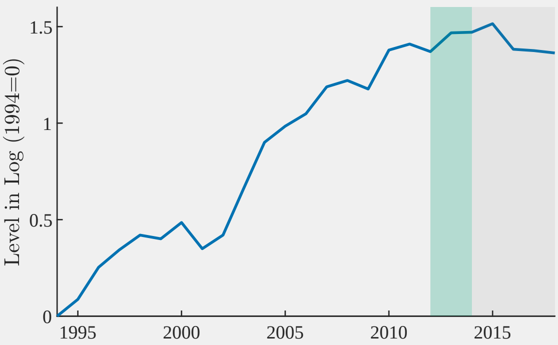


- The naive regression gives a significant and positive slope (.51).

Fact 3' : The TFP Estimates by KLEMS Also Exhibits Stagnation



Durable Goods

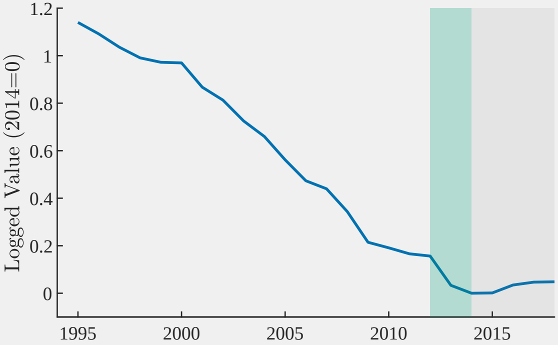


ICT Goods

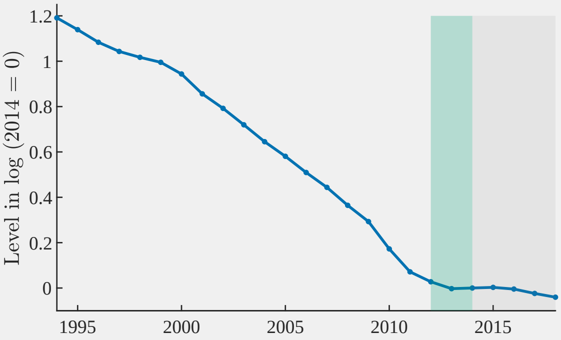
- We aggregate the sectoral TFP estimates by using consumption and investment weights.

Fact 3' : Imported Computer Hardware Price Exhibits Stagnation

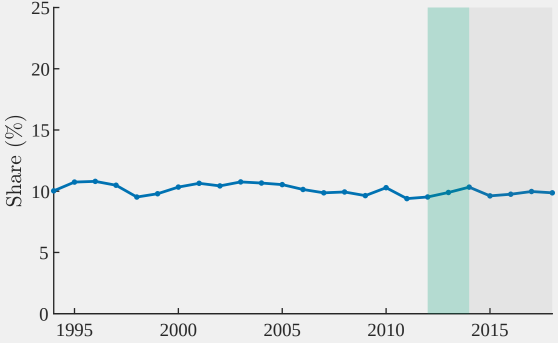
- Import price of "computers and peripheral equipment" relative to the other "electric and electronic equipment" shows the same pattern.
- Computer hardware price used to decline significantly, but stopped doing so.
- N.B. the computer hardware used to decline faster than **other electronic equipment**.
  - The rise/decline of China arguably affects both sequences.



Fact 4 : Unit Elasticity of Demand



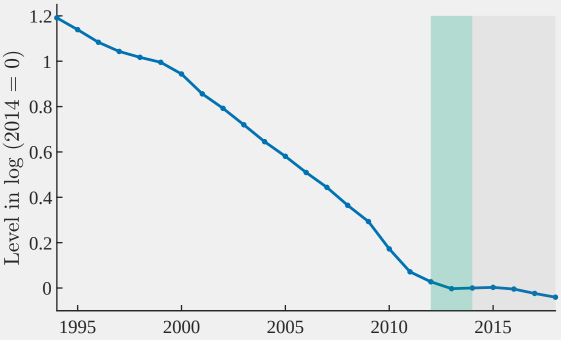
Relative Durable Deflator



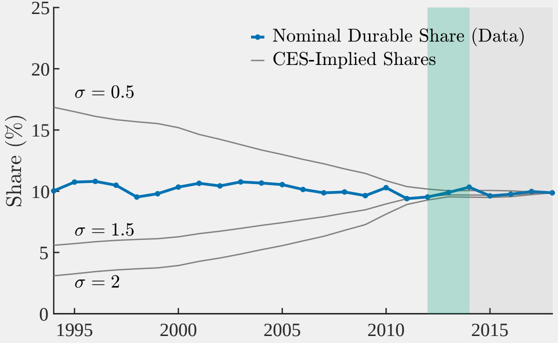
Nominal Durable Consumption Share

- The relative price of durable goods declined consistently.
- But the relative share in consumption has stayed stable. From 1980

Fact 4 : Unit Elasticity of Demand



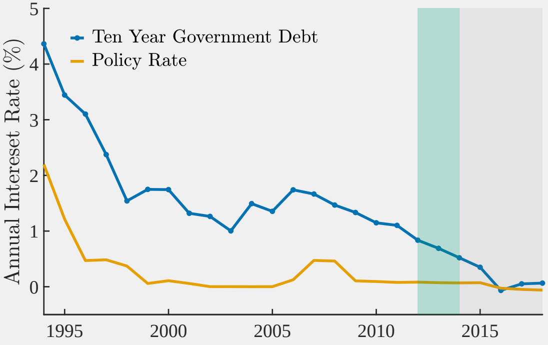
Relative Durable Deflator



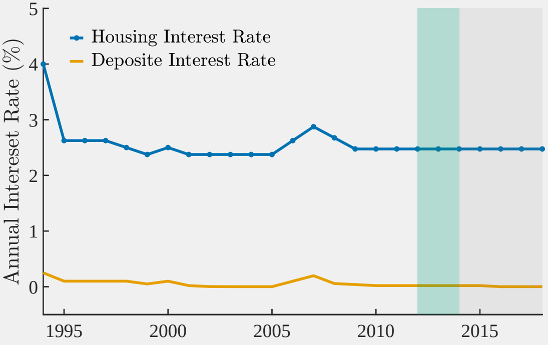
Nominal Durable Consumption Share

- The relative price of durable goods declined a lot.
- But the relative share in consumption has stayed stable. $\rightarrow$ The demand is roughly Cobb-Douglass.

Fact 5 : Effective Lower Bound



Policy and Government Debt Interest Rate



Housing and Deposit Interest Rates in Japan

Taking Stock

- The inflation rate in Japan has shifted since around 2011.
- The real side of the economy has stagnated since around 2011.

- The growth rate of the durable and ICT good productivity suddenly has declined since around 2011.

- We examine how much we can explain these facts based on the shock to the growth rate.
  - Need a model which connects the technology stagnation with inflation, consumption, and GDP.
- The primal goal is to quantitatively explain the dynamics of inflation and consumption, and their respective long-run shifts.,

$$\mathbf{d}\pi = \underset{t \geq 2014}{\text{average}}\left(\pi_t\right) - \underset{t \leq 2011}{\text{average}}\left(\pi_t\right) = 1.18\%$$

$$\mathbf{d}g_C = \underset{t \geq 2014}{\text{average}}\left(g_{C_t}\right) - \underset{t \leq 2011}{\text{average}}\left(g_{C_t}\right) = -0.52\%$$

Frictionless Monetary Model

Overview of the Model

- Extend the frictionless monetary model by incorporating many goods.
  - There are many consumption and investment goods.
  - The consumption goods can be durable.
- A representative household owns capital stocks and rent them to firms.
- Firms produce one of the investment goods or consumption goods.
- The government sets its interest rate.

Graphical Overview of the Model

Main Players : Households and Firms

Consumption Good : Non-Durable

$$Y_t = A_{C,t} \prod_{j \in \mathcal{I}} K_{j,t}^{\theta_j \alpha} L_t^{1-\alpha}$$

Non-Durable Good Market

$$Y_t = \underbrace{C_t}_{\text{HH's Demand}} + \underbrace{\sum_{j \in \mathcal{I}} M_{j,t} + M_{D,t}}_{\text{Intermediate Demand}}$$

Investment Good : ICT

$$I_{j,t} = A_{j,t} M_{j,t}$$

⋮

Investment Good : Structure

$$I_{j',t} = A_{j',t} M_{j',t}$$

Households

$$U = \sum_{t=0}^{\infty} \frac{1}{1-\sigma} \left(C_t^{\gamma} D_t^{1-\gamma} \right)^{1-\sigma}$$

$$P_{C,t} C_t + P_{D,t} D_t + \sum_{j \in \mathcal{I}} P_{j,t} I_{j,t} + B_{t+1} = \sum_{j \in \mathcal{I}} r_{j,t} K_{j,t} + w_t L_t + R_{t-1} B_t$$

Consumption Good : Durable

$$D_t = A_{D,t} M_{D,t}$$

Representative Household's Problem

- The maximization problem for the household is

$$\max_{(C_t, D_t, K_{j,t+1}, B_t)\geq 0} \quad \sum_{t=0}^{\infty} \beta^t \frac{1}{1-\sigma} \left(C_t^{\gamma} X_t^{1-\gamma} \right)^{1-\sigma}$$

$$s.t. \quad \sum_{i\in\mathcal{C}} P_{i,t} C_{i,t} + \sum_{j\in\mathcal{I}} P_{j,t} K_{j,t+1} + \frac{B_t}{R_t} \leq \sum_{j\in\mathcal{I}} \left(r_{j,t} + \left(1-\delta_j\right) P_{j,t} \right) K_{j,t} + w_t L_t + B_{t-1}$$

$$X_t = D_t + \left(1-\delta_D\right) X_{t-1}.$$

  - L_t is the number of (effective) workers and inelastically supplied.

- The Euler equation w.r.t. B_t is

$$\lambda_t = \beta \lambda_{t+1} \underbrace{R_t / \Pi_{C,t+1}}_{= r^*_{t+1}} \quad \text{with } \lambda_t = \frac{\left(C_t^{\gamma} X_t^{1-\gamma} \right)^{1-\sigma}}{C_t}.$$

  - i^* is the index for the non-durable consumption good.

Representative Firm in Sector $n \in \mathcal{C} \cup \mathcal{I}$

- The representative firm in non-durable good producer i^* solves

$$\max_{(K_{j,t}),L_t} A_t \left(\prod_{j\in\mathcal{I}} K_{j,t}^{\alpha\theta_j} \right) L_t^{1-\alpha} - \sum_{j\in\mathcal{I}} r_{j,t} K_{j,t} - w_t L_t.$$

- The other firms for $n \neq i^*$ solve

$$\max_{M_{n,t}} \quad P_{n,t} A_{n,t} M_{n,t} - P_{i^*,t} M_{n,t} \underbrace{\rightarrow}_{\text{FONC}} p_{n,t} \equiv P_{n,t}/P_{i^*,t} = 1/A_{n,t}.$$

- The change in growth rate of relative price of good n reflects the directed tech progress.

$$\mathbf{d}g_{p_{n,t}} = -\mathbf{d}g_{A_{n,t}}.$$

Our Objects of Interest : Long-Run Implications

- Consider negative permanent shocks on the **growth** rates of TFP (Fact 2), denoted by $(\mathbf{d}g_{A_n})_{n \in \mathcal{N}}$.
- We are interested in the **permanent** changes in macro variables induced by the shocks.
- By focusing on the steady-state changes, we can obtain their closed-form expressions.
  - Useful when we want to decompose the changes into various factors.
  - For an analysis of transition, see the Appendix of our paper.

Quick Review : Long-Run Implication for Growth

- The standard growth model with $Y = AK^{\alpha}L^{1-\alpha}$ implies

$$\mathbf{d}g_{GDP/L} = \underbrace{\mathbf{d}g_A}_{\text{Direct Effect}} + \underbrace{\alpha \mathbf{d}g_A + \alpha^2 \mathbf{d}g_A + \cdots}_{\text{Indirect Effect}} = \frac{1}{1-\alpha}\mathbf{d}g_A.$$

- Our model is a generalization of the standard growth model, $Y = A\prod_{j\in\mathcal{I}} K_j^{\theta_j \alpha} L^{1-\alpha}$.

$$\mathbf{d}g_{GDP/L} = \frac{\mathbf{d}g_A}{1-\alpha} + \underbrace{\sum_{j\in\mathcal{I}} \frac{\alpha\theta_j}{1-\alpha} \times \mathbf{d}g_{A_j}}_{\text{Investment Specific TFP Progress}}.$$

Implication for Aggregate Inflation : Start with Accounting Identity

- Start with the accounting identity:

$$\pi \equiv (1 - s_D)\,\pi_C + s_D \pi_D = \pi_C + s_D \times \underbrace{(\pi_D - \pi_C)}_{= -g_{A_D}} = \pi_C - s_D g_{A_D}.$$

- Note that the benchmark inflation rate π_C is an endogenous variable.

Object of Interest

- The object of interest is how much aggregate inflation **permanently** increases due to the technology shocks to the durable and ICT good holding the nominal interest rate constant.

$$\mathbf{d}\pi^{\text{Tech}} = -s_D \mathbf{d}g_{A_D} + \sum_{i \in \mathcal{T}} \frac{\partial \pi_C}{\partial g_{A_i}} \times \mathbf{d}g_{A_i} \quad \mathbf{d}g_{A_i} \leq 0.$$

  - $\mathcal{T} = \{D, \text{ICT}\}$.

- The BOJ's policy rate has been at the effective lower bound.
- We are interested in the pure effects from technology shocks, not the compounded effects.

Implication for π_C

- Recall the Euler equation:

$$\lambda_t = \beta \lambda_{t+1} \underbrace{R_t / \Pi_{C,t+1}}_{=R^*_{t+1}} \quad \lambda_t = \frac{\left(C_t^{\gamma} X_t^{1-\gamma}\right)^{1-\sigma}}{C_t}$$

$$\to \ln R^* = r^* = \ln \beta^{-1} + g_C + (\sigma - 1)\left(\gamma g_C + (1-\gamma) g_D\right).$$

- Since the interest rate is pegged, $r = \bar{r}$, the following holds (Fisher effect).

$$\frac{\partial r^*}{\partial g_{A_i}} = -\frac{\partial \pi_C}{\partial g_{A_i}}.$$

- So, $\mathbf{d}\pi^{\text{Tech}}$ is decomposed to two pieces:

$$\mathbf{d}\pi^{\text{Tech}} = -s_D \mathbf{d} g_{A_D} - \sum_{i \in \mathcal{T}} \frac{\partial r^*}{\partial g_{A_i}} \times \mathbf{d} g_{A_i}$$

Implication for Aggregate Inflation : Sign Restriction Approach

- Mechanically speaking, $\partial\pi_C/\partial g_{A_i}$ is determined by the Fisher effect in our model.

$$\text{Negative Tech Shock } \partial g_{A_i} < 0 \underbrace{\rightarrow}_{\text{Euler + BGP}} \text{Lower natural rate } \partial r^* < 0 \underbrace{\rightarrow}_{\partial r = 0} \text{Rise in inflation } \partial\pi_C > 0.$$

  - The model gives the exact mappings.

- There are valid concerns for relying on this method to obtain $\partial\pi_C/\partial g_{A_i}$.
  - The Euler equation and BGP assumption might not characterize the economy well.
  - The strong form of the Fisher effect is empirically questionable.

- To overcome these critiques, we develop a sign restriction approach. Assume:
  1. when a negative TFP shock happens, the natural rate increases, $\partial r^*/\partial g_{A_i} \geq 0$;
  2. when the natural rate increases, the inflation rate declines $\partial\pi_C/\partial r^* \leq 0$.

Implication for Aggregate Inflation : Informative Lower Bound

- Under the sign restrictions, we obtain the lower bound for $\mathbf{d}\pi^{\text{Tech}}$.

$$\mathbf{d}\pi^{\text{Tech}} = -s_D \mathbf{d}g_{A_D} + \sum_{i \in \mathcal{T}} \underbrace{\frac{\partial g_{P_{i^*}}}{\partial r^*}}_{\leq 0} \times \underbrace{\left(\frac{\partial r^*}{-\partial g_{A_i}} \right)}_{\leq 0} \times \underbrace{(-\mathbf{d}g_{A_i})}_{\geq 0} \geq -s_D \mathbf{d}g_{A_D} > 0.$$

- This lower bound for $\mathbf{d}\pi^{\text{Tech}}$ is actually obtained when (a) the utility function is log, $\sigma = 1$ and; (b) there is a shock only to the durable good, $\mathbf{d}g_{A_D}$.
  - If we work with NK model in non-stationary environment, we get the same result as a steady state analysis, i.e., BGP analysis. (Aoki (2001))

- The lower bound is informative only if we have many goods.
  - If the economy has one good as standard macro models, the lower bound is zero.

Implication for Aggregate Inflation : More Structure Leads Tighter Bound

- By imposing more model structures, we can obtain a tighter bound.

1. When TFP shocks happen, the natural rate increases by more than:

$$\frac{\partial r^*}{\partial g_{A_i}} = \frac{\partial}{\partial g_{A_i}} g_C + \underbrace{(\sigma - 1)\left(s_C \frac{\partial}{\partial g_{A_i}} g_C + s_D \frac{\partial}{\partial g_{A_i}} g_D \right)}_{\geq 0} \to \sum_{i \in \mathcal{T}} \frac{\partial r^*}{\partial g_{A_i}} \mathbf{d} g_{A_i} \geq \underbrace{\sum_{i \in \mathcal{T}} \frac{\alpha \theta_i}{1-\alpha} \mathbf{d} g_{A_i}}_{= \mathbf{d} g_C} .$$

2. Assume the Fisher effect:

$$\begin{aligned} \mathbf{d}\pi^{\text{Tech}} &= -s_D \mathbf{d} g_{A_D} - \sum_{i \in \mathcal{T}} \frac{\partial r^*}{\partial g_{A_i}} \times \mathbf{d} g_{A_i} \\ &\geq -s_D \mathbf{d} g_{A_D} + \underbrace{\sum_{i \in \mathcal{T}} \frac{\alpha \theta_i}{1-\alpha} \left(-\mathbf{d} g_{A_i} \right)}_{\text{Additioanl Effect Coming from BGP}} . \end{aligned}$$

Summary of Our Results, $\mathbf{d}\pi^{\text{Tech}}$

- Recall the natural rate:

$$r^* = \ln \beta^{-1} + g_C + (\sigma - 1)\left(\gamma g_C + (1-\gamma)\, g_D\right).$$

- We have various lower bounds.

$$\text{[Loose Bound (No Fisher Effect)]} \quad : \quad \mathbf{d}\pi^{\text{Tech}} \geq -s_D \mathbf{d}g_{A_D}$$

$$\text{[Tight Bound]} \quad : \quad \mathbf{d}\pi^{\text{Tech}} \geq -s_D \mathbf{d}g_{A_D} + \underbrace{\frac{\alpha\theta_{\text{ICT}}}{1-\alpha}\left(-\mathbf{d}g_{A_{\text{ICT}}}\right)}_{g_{A_{\text{ICT}}} \to g_C \to r^*}$$

$$\text{[Exact Expression]} \quad : \quad \mathbf{d}\pi^{\text{Tech}} = -s_D \mathbf{d}g_{A_D} + \frac{-\mathbf{d}g_{A_{i^*}}}{1-\alpha} + \sum_{j \in \mathcal{I}} \frac{\alpha\theta_j}{1-\alpha}\left(-\mathbf{d}g_{A_j}\right)$$

$$+ \underbrace{(\sigma-1)\frac{\alpha\theta_{\text{ICT}}}{1-\alpha}\left(-\mathbf{d}g_{A_{\text{ICT}}}\right)}_{\mathbf{d}g_{A_{\text{ICT}}} \to g_C, g_D \to r^*} + \underbrace{(\sigma-1)\,\gamma\left(-\mathbf{d}g_{A_D}\right)}_{\mathbf{d}g_{A_D} \to g_D \to r^*}$$

Implication for Nominal Consumption and GDP

- Using the tight bound, we can bound the growth rate of nominal consumption.

$$\mathbf{d}g_{NC}^{\text{Tech}} = \mathbf{d}\pi^{\text{Tech}} + \mathbf{d}g_{C}^{\text{Tech}} \geq 0.$$

- The same argument is applied for the nominal GDP, $\mathbf{d}g_{NGDP}^{\text{Tech}} \geq 0$.
- The implications are consistent with the fact that:
  - growth of real consumption and GDP has stagnated but;
  - growth of nominal consumption and GDP hasn't.

Implication When the Monetary Policy is Unconstrained

- Consider the Taylor rule with the Taylor principle with fixed intercept:

$$r_t = \phi \pi_t.$$

- The real interest rate along the BGP is

$$r - \pi = (\phi - 1)\,\pi.$$

- To deliver the lower real interest rate, long-run inflation *declines*.

- So the technology stagnation does not necessarily induce higher inflation.
  - It is critically important that the monetary policy is constrained or not.
  - Moreover, short-run implications also differ.

Mapping The Model To Data

Parameter Specification

- In order to to estimate $(\theta_j)_{j\in\mathcal{I}}$, we use the method by Gourio and Rognlie (2020). ▸ Detail
- KLEMS estimates the time-series of α (excluding housing) so we use the average. ▸ Time-Series
- Unlike $(\theta_j)_{j\in\mathcal{I}}$, it is hard to estimate $(\gamma_i)_{i\in\mathcal{C}}$. But along the BGP,

$$0 < \gamma_i \leq s_i.$$

Estimated Parameters $\left(\alpha, (\theta_j)_{j\in\mathcal{I}}\right)$ and Consumption Shares $(s_i)_{i\in\mathcal{C}}$

	Capital Share α	Rental Cost Share θ_j	Consumption Share s_i
	32%	$*$	$*$
Services	$*$	$*$	50.2%
Non Durable	$*$	$*$	22.4%
Food	$*$	$*$	17.3%
Durable	$*$	$*$	**10.1%**
Structure	$*$	34.2%	$*$
Other Equipment	$*$	26.2%	$*$
R&D	$*$	15.6%	$*$
Software	$*$	8.6%	$*$
ICT equipment	$*$	**8.1%**	$*$
Transportation Equipment	$*$	6.4%	$*$
Weapons, Cultivated Assets, Other IPP	$*$	$< 0.6\%$	$*$

Estimation of Sectoral TFP and Shock

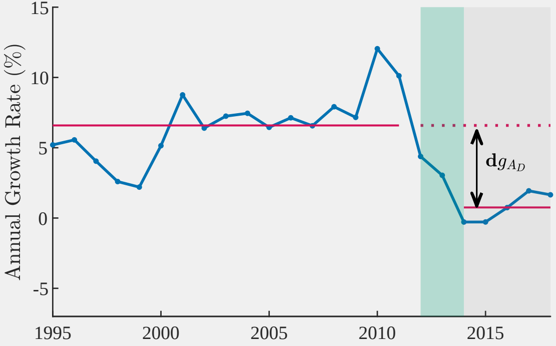
- The Solow residual corresponds to the aggregate TFP A_t.

$$\underbrace{g_{GDP_t}}_{\text{JSNA}} - \alpha \sum_{j \in \mathcal{I}} \theta_j \underbrace{g_{K_{j,t}}}_{\text{JSNA}} - (1-\alpha) \underbrace{g_{L_t}}_{\text{JIP}} = g_{A_t}$$

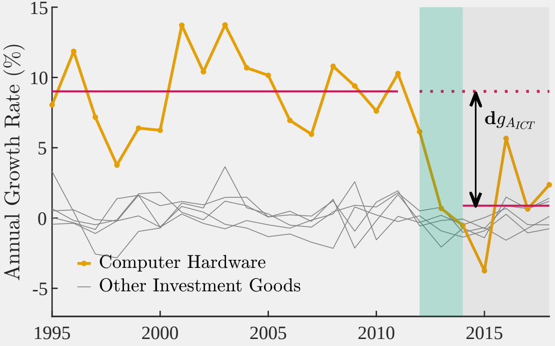
$$\underbrace{g_{p_{n,t}}}_{\text{JSNA}} = -g_{A_{n,t}} \quad \forall \boldsymbol{n} \in \boldsymbol{n} \in \mathcal{C} \cup \mathcal{I}.$$

- We use JSNA, JIP, and the estimated parameters.

Negative Technology Shocks to Durable and ICT Goods



Consumption Goods



Investment Goods

- We interpret that only $\mathbf{d}g_{A_D}$ and $\mathbf{d}g_{A_{\text{ICT}}}$ reflect a supply shock.

Quantitative Implication for Long-Run Inflation

- Use the sufficient statistics to quantify the effect from the tech slowdown of durable and ICT goods.

$$\begin{aligned} \text{[Loose Bound]} \quad &: \quad \mathbf{d}\pi^{\text{Tech}} \geq s_D \mathbf{d}g_{p_D} \\ \text{[Tight Bound]} \quad &: \quad \mathbf{d}\pi^{\text{Tech}} \geq s_D \mathbf{d}g_{p_D} + \frac{\alpha\theta_{\text{ICT}}}{1-\alpha}\mathbf{d}g_{p_{\text{ICT}}} \end{aligned}$$

  - $\mathbf{d}g_{p_D} = -\mathbf{d}g_{A_D}$ and $\mathbf{d}g_{p_{\text{ICT}}} = -\mathbf{d}g_{A_{\text{ICT}}}$.

- We can also obtain bounds based on the full model.

$$\text{[Full Model]}: \quad s_{c_{\text{Durable}}}\mathbf{d}g_{p_{\text{Durable}}} + \sigma\frac{\alpha\theta_{\text{ICT}}}{1-\alpha}\mathbf{d}g_{p_{\text{ICT}}} \leq \mathbf{d}\pi^{\text{Tech}} \leq \sigma\left(s_{c_{\text{Durable}}}\mathbf{d}g_{p_{\text{Durable}}} + \frac{\alpha\theta_{\text{ICT}}}{1-\alpha}\mathbf{d}g_{p_{\text{ICT}}}\right).$$

  - Inequality follows since we do not have an estimate for γ_i, $0 \leq \gamma_i \leq s_i$.
  - When $\sigma < 1$, then the upper and lower bounds are reversed.

Quantitative Effect of the Technology Stagnation on Aggregate Inflation

Data	Type of Bounds for $\hat{\pi}$	Lower Bound	Upper Bound
1.18%	Loose Bound	0.59%	∞
	Tight Bound	0.88%	∞
	Bounds Based on Full Model ($\sigma = 2$)	1.17%	1.76%
	Bounds Based on Full Model ($\sigma = 2/3$)	0.59%	0.78%

- Using the loose bound, the model can account for around 50% of the observed rise of inflation.
  - The only channel is that the relative price of durable goods has stagnated.
- Using the tight bound, the model can account for around 80% of the observed rise of inflation.
- Even $\sigma = 2/3 < 1$, half of the observed increase in inflation is explained by the model.

Quantitative Effect of TFP Slowdown on Other Macro Variables

	Quantification			Decomposition			
				Durable Goods		ICT Goods	
Variable	Data	Model	(Fraction)	(Weight)	$(\hat{g}_{A_D})$	(Weight)	$(\mathbf{d}g_{A^{\text{ICT}}})$
$\hat{g}_{C/L}$	-1.33%	-0.88%	(66%)	-0.59%		-0.29%	
				(0.10)	(6.4%)	(0.03)	(8.6%)
$\hat{g}_{GDP/L}$	-0.48%	-0.29%	(60%)	0%		-0.29%	
				0%	0%	(0.03)	(7.2%(8.6%)

$$\text{[Consumption per } L\text{]} \quad : \quad \hat{g}_{C/L} = s_D \mathbf{d}g_{A_D} + \frac{\alpha\theta_{\text{ICT}}}{1-\alpha}\hat{g}_{A_{\text{ICT}}}$$

$$\text{[GDP per } L\text{]} \quad : \quad \hat{g}_{GDP/L} = \frac{\alpha\theta_{\text{ICT}}}{1-\alpha}\hat{g}_{A_{\text{ICT}}}$$

Validation Exercise

- If the technology stagnation is common across the countries, should we see the rise in inflation everywhere?

- No because of the monetary policy.

- We explore the implication for countries in the Euro ares.

Implication For Countries in the Euro Area

- Our model predicts that for each country c in the Euro area,

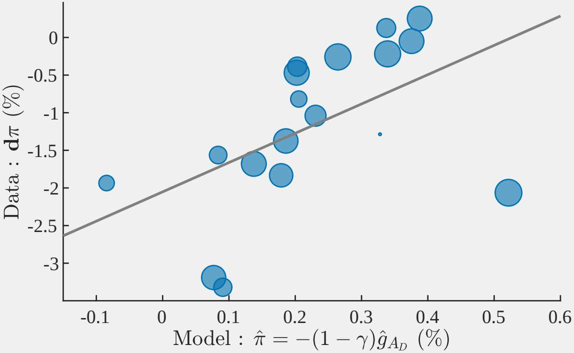
$$\hat{\pi}_c = \underbrace{\hat{\pi}_C(\hat{r})}_{\text{Common Across Countries } c} + (1 - \gamma_c)\,\hat{g}_{c,A_D}.$$

- The change $\hat{g}_{c,A_D}$ of country c can be measured by the relative price of the durable good.

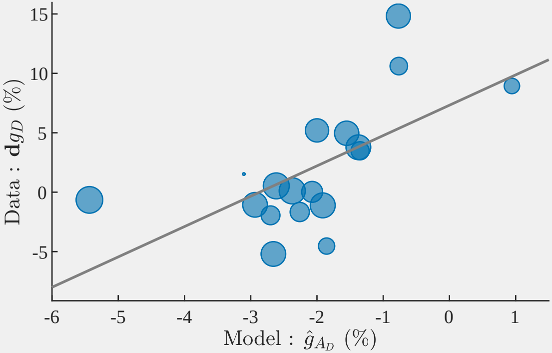
$$\hat{g}_{c,A_D} = \text{average}_{t \geq 2014}\left(\pi_{c,C,t} - \pi_{c,D,t}\right) - \text{average}_{t \leq 2011}\left(\pi_{c,C,t} - \pi_{c,D,t}\right).$$

- Both terms, γ_c, $\pi_{c,C,t}$, and $\pi_{c,D,t}$ are observable and we download them via OECD Stat.

Hidden Stagflation in European Countries as Well



Aggregate Inflation



Durable Consumption

Extension
Two Goods NK Model

Objective

- The previous model does not have any nominal rigidity.
- Extend the three equation NK by adding one more consumption good.
    - There are two goods: non-durable and durable goods.
- The model is similar to the NK model with investment-specific technology progress.
    - Here there is no investment, but are two consumption goods (Aoki (2001)).
    - There is non-stationary technology progress specific to the durable good.
    - The durable good producer converts the non-durable good to the durable good by a linear technology.

Graphical Overview of the Model

Main Players : Households and Firms

Households

$$\max_{(C_t,D_t,N_t,B_t)\geq 0} \sum_{t=0}^{\infty} \beta^t u\left(C_t, D_t, N_t\right)$$

$$s.t. \quad P_{C,t}C_t + P_{D,t}D_t + \frac{B_t}{R_t} \leq w_t N_t + B_{t-1}$$

Non Durable Producer

$$Y_t = \left(\int_0^1 Y_t\left(i\right)^{\frac{\varepsilon-1}{\varepsilon}} di\right)^{\frac{\varepsilon}{\varepsilon-1}}$$

Intermediate Good Producer

$$Y_t\left(i\right) = A_{C,t}N_t\left(i\right)$$

$$\max_{P_t^*} \sum_{s=0}^{\infty} \theta^s M_{t+s}^t \left(P_t^* - \frac{W_t}{A_{C,t}}\right) Y_t\left(i\right)$$

$$s.t. \quad Y_t\left(i\right) = \left(P_t^*/P_{C,t}\right)^{-\varepsilon} Y_t$$

Durable Producer

$$D_t = A_{D,t}M_{D,t}$$

Non-Durable Good is Consumed and Used for Intermediate Inputs

Households

$$\max_{(C_t,D_t,N_t,B_t)\geq 0} \sum_{t=0}^{\infty} \beta^t u\left(C_t, D_t, N_t\right)$$

$$s.t. \quad P_{C,t}C_t + P_{D,t}D_t + \frac{B_t}{R_t} \leq w_t N_t + B_{t-1}$$

Durable Good Market

$$Y_t = \underbrace{C_t}_{\text{Final Good Demand}} + \underbrace{M_t}_{\text{Used As Intermediate Input}}$$

Labor Market

$$N_t = \int_0^1 N_t\left(i\right) di$$

Non Durable Producer

$$Y_t = \left(\int_0^1 Y_t\left(i\right)^{\frac{\varepsilon-1}{\varepsilon}} di\right)^{\frac{\varepsilon}{\varepsilon-1}}$$

Intermediate Good Producer

$$Y_t\left(i\right) = A_{C,t}N_t\left(i\right)$$

$$\max_{P_t^*} \sum_{s=0}^{\infty} \theta^s M_{t+s}^t \left(P_t^* - \frac{W_t}{A_{C,t}}\right) Y_t\left(i\right)$$

$$s.t. \quad Y_t\left(i\right) = \left(P_t^*/P_{C,t}\right)^{-\varepsilon} Y_t$$

Durable Producer

$$D_t = A_{D,t}M_{D,t}$$

Linearized Equilibrium System

- The linearized economy is characterized by familiar equations:

$$
\begin{aligned}
\text{[Euler Eq]} \quad & \hat{x}_{C,t} = E_t \hat{x}_{C,t+1} - \left(\hat{r}_t - E_{t+1}\hat{\pi}_{C,t+1}\right) \\
\text{[Philips Curve]} \quad & \hat{\pi}_{C,t} = \kappa \hat{x}_{C,t} + \beta E_t \hat{\pi}_{C,t+1} \\
\text{[Monetary Policy]} \quad & \hat{r}_t = \begin{cases} \phi\left(\gamma\hat{\pi}_{C,t} + (1-\gamma)\,\hat{\pi}_{D,t}\right) & \text{normal rule} \\ 0 & \text{pegged rule} \end{cases} \\
\text{[Relative Price]} \quad & \hat{\pi}_{D,t} = \hat{\pi}_{C,t} - \hat{g}_{A_{D,t}}.
\end{aligned}
$$

- Notation:
  - $\hat{x}_{C,t}$ is the output gap, the log-deviation of C_t from its efficient allocation $C_t^* = \gamma A_{C,t}$.
  - $\hat{\pi}_{C,t}$ is the deviation from the steady state inflation rate for the non-durable good.

- We begin by analyzing the steady state, and proceed to study the dynamics.

Impulse Response Functions When the Government Pegs the Interest Rate

$$
\begin{aligned}
\text{[Euler Eq]} \quad & \hat{x}_{C,t} = E_t \hat{x}_{C,t+1} - \left(\hat{r}_t - E_{t+1} \hat{\pi}_{C,t+1}\right) \\
\text{[Philips Curve]} \quad & \hat{\pi}_{C,t} = \kappa \hat{x}_{C,t} + \beta E_t \hat{\pi}_{C,t+1} \\
\text{[Monetary Policy]} \quad & \hat{r}_t = 0 \\
\text{[Relative Price]} \quad & \hat{\pi}_{D,t} = \hat{\pi}_{C,t} - \hat{g}_{A_{D,t}}.
\end{aligned}
$$

- There may be possible sunspot fluctuations.
- But the IRF (relative to the sunspot equilibrium) is the same:

$$
\begin{aligned}
\hat{x}_{C,t} &= \hat{\pi}_{C,t} = 0, \hat{\pi}_{D,t} = -\hat{g}_{A_{D,t}} \\
\hat{\pi}_t &= \gamma \hat{\pi}_{C,t} + (1-\gamma)\, \hat{\pi}_{D,t} = -(1-\gamma)\, \hat{g}_{A_{D,t}} \\
\hat{g}_{C_t^{agg}} &= (1-\gamma)\, \hat{g}_{A_{D,t}}.
\end{aligned}
$$

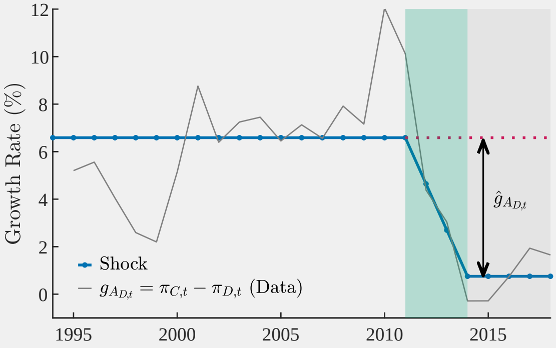
- Note that the nominal consumption does not stagnate, but the real consumption does.

Dynamic Response

- Use the following equation to back out $g_{A_{D,t}}$.

$$g_{A_{D,t}} = \pi_{C,t} - \pi_{D,t}.$$

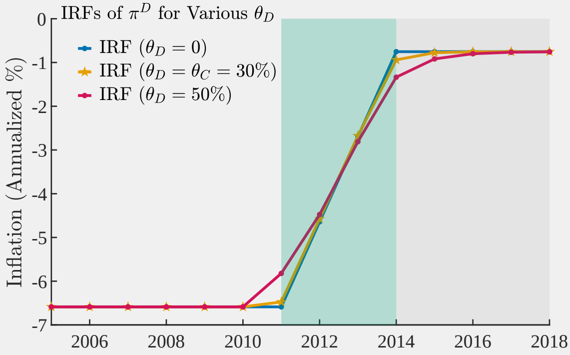
- We take the shift of the average growth rate as a permanent shock, $\hat{g}_{A_D}$.
- At $t = 2011$, the TFP growth rate for the durable good suddenly declines.
  - The economy reaches the new steady state in three years.
- We solve for the perfect foresight equilibrium.



Impulse Response Function for Various Calvo Parameter θ_D

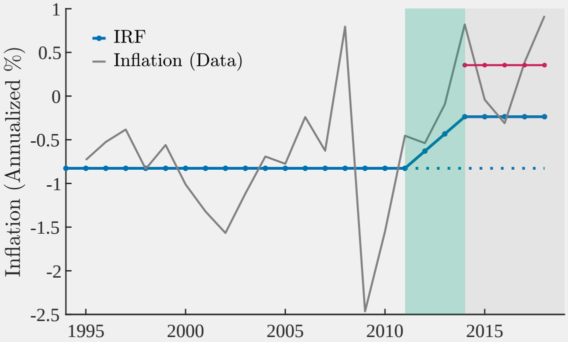
- The economy make a smooth transition to the new steady state for any θ_D. Go

- The inflation rate with higher θ_D responds more at the beginning of the shock.
  - NB : permanent shock not transitory shock.
  - If a firm has a chance, it changes its price a lot.



Impulse Response Function for Inflation

- In the data, the average inflation rate increased by 1.18%.
- The model predicts that the technology shock increases the inflation by around 0.59% at the steady state.
- The model can account for around 50% of the observed increase.
- Without having TFP stagnation, Japan inflation rate would stay negative (-0.23%).



Robustness

The Rise in Price Might Come from Rise in Markup

- The rise of the relative prices might reflect the rise of markup of durable goods producers.
  - There are many papers which show the rise of markup (at least in the US.)

- We can extend the model so that the firms have markup power. Then:

$$\hat{g}_{p_n} = \underbrace{\hat{g}_{\mu_n}}_{\text{Change in Markup}} - \hat{g}_{A_n} \rightarrow \hat{g}_{p_n} \geq -\hat{g}_{A_n}.$$

  - So the change in the growth rate of the relative price might overestimate the technology stagnation.

- Here we provide an sectoral evidence of the markup for the durable goods sector.

Sectoral Markup and Aggregating Markup

- Using the KLEMS dataset, we can measure the sectoral markup for each sector n:

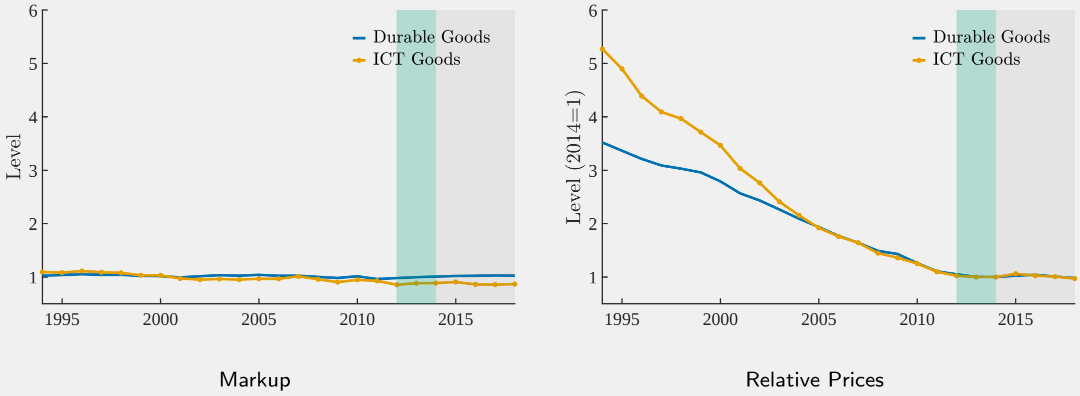
$$\mu_{n,t} = \frac{P_{n,t}}{MC_{n,t}} = \frac{P_{n,t}Y_{n,t}}{MC_{n,t}Y_{n,t}} = \frac{P_{n,t}Y_{n,t}}{\sum_j r_{j,t}K_{j,t} + w_{n,t}L_{n,t} + p_t^M M_{n,t}}.$$

- Compute the aggregate markups for durable and ICT goods:

$$\mu_t^{\mathrm{D}} = \sum_{n\in\tilde{\mathcal{C}}} \tilde{s}_{n,t}^{\mathrm{D}}\mu_{n,t}, \quad \mu_t^{\mathrm{ICT}} = \sum_{n\in\tilde{\mathcal{I}}} \tilde{s}_{n,t}^{\mathrm{ICT}}\mu_{n,t}.$$

  - $\tilde{\mathcal{C}}$ consists of: household electric appliances; misc electronic equipment; image and audio equipment; communication equipment; computer; and motor vehicles.
  - $\tilde{\mathcal{I}}$ consists of: image and audio equipment; communication equipment and; electronic data processing machines, digital and analog computer equipment and accessories.
  - $\tilde{s}_{n,t}^{\mathrm{D}}$ is the share of consumption good n between the sectors in $\tilde{\mathcal{C}}$.
  - $\tilde{s}_{n,t}^{\mathrm{ICT}}$ is the share of investment good n between the sectors in $\tilde{\mathcal{I}}$.

Markup of the Durable Goods Sector Has Barely Moved



- Nakamura and Ohashi (2019) estimate firm-level markup, and confirm the same pattern that the markup has not increased in Japan.

What if Prices Are Mismeasured by the Statistical Agency?

- It is difficult to measure the prices of durable goods since quality keeps changing.
  - Conceptually the prices $P_{i,t}$ in the model should be quality-adjusted prices.

- To analyze this mismeasurement issue, consider the following extreme case.
  - the TFP growth rates have not changed at all, $\hat{g}_{A_i} = 0$ for all goods i.
  - the true growth rates of prices have not changed at all, $\hat{g}_{P_i} = 0$ for all goods i.

- Information set and (mis)measurement.
  - All the agents in the model correctly see the prices, but not the statistical agency.
  - Let $\tilde{P}_{i,t}$ denote the measured price of good i.
  - The statistical agency mis-measures prices, and wrongly concludes that,

$$\hat{g}_{\tilde{P}_D} > \hat{g}_{P_D} = 0, \quad \hat{g}_{\tilde{P}_i} = \hat{g}_{P_i} = 0 \quad i \neq D$$

  - The statistical agency correctly measures the values V_i and shares s_i.

What if Prices Are Mismeasured by the Statistical Agency?

- Call $\hat{g}_{\tilde{p}_D}$ $\left(= \hat{g}_{\tilde{P}_D/\tilde{P}_{\text{Non-Durable}}}\right)$ the mismeasurement shock.
- Since $\hat{g}_{A_i} = \hat{g}_{P_i} = 0$ for all goods i, the economy is along the BGP all the time.
  - So, the true consumption growth rates and inflation rate don't change, $\hat{g}_{C_n} = \hat{\pi} = 0$.
- What happen to the measured consumption $g_{\tilde{C}}$ and inflation $\tilde{\pi}$?

$$g_{\tilde{C}} = \sum_{i \in \mathcal{C}} s_i g_{\tilde{C}_i} \quad \tilde{\pi} = \sum_{i \in \mathcal{C}} s_i g_{\tilde{P}_i},$$

where

$$g_{\tilde{C}_i} \equiv g_{V_i} - g_{\tilde{P}_i} \neq g_{C_i}.$$

The Measured Consumption Growth and Inflation

- We find:

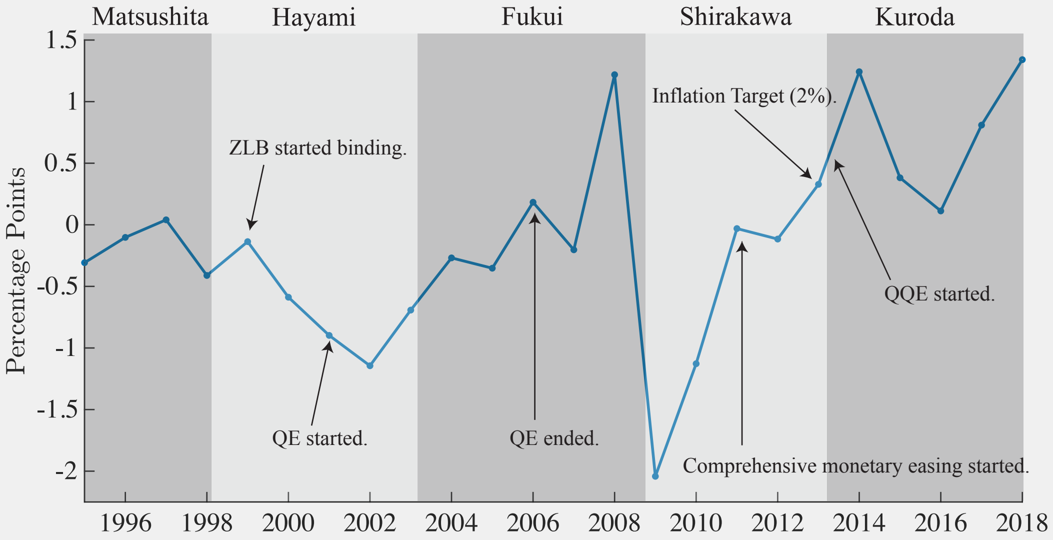
$$\underbrace{\hat{g}_{\tilde{C}}}_{\text{Measured Consumption Growth Change}} = - \underbrace{s_D}_{\text{Durable Share}} \times \underbrace{\hat{g}_{\tilde{p}_D}}_{\text{Mismeasurement Shock}} < 0$$

$$\underbrace{\hat{\tilde{\pi}}}_{\text{Measured Inflation Rate Change}} = \underbrace{s_D}_{\text{Durable Share}} \times \underbrace{\hat{g}_{\tilde{p}_D}}_{\text{Mismeasurement Shock}} > 0.$$

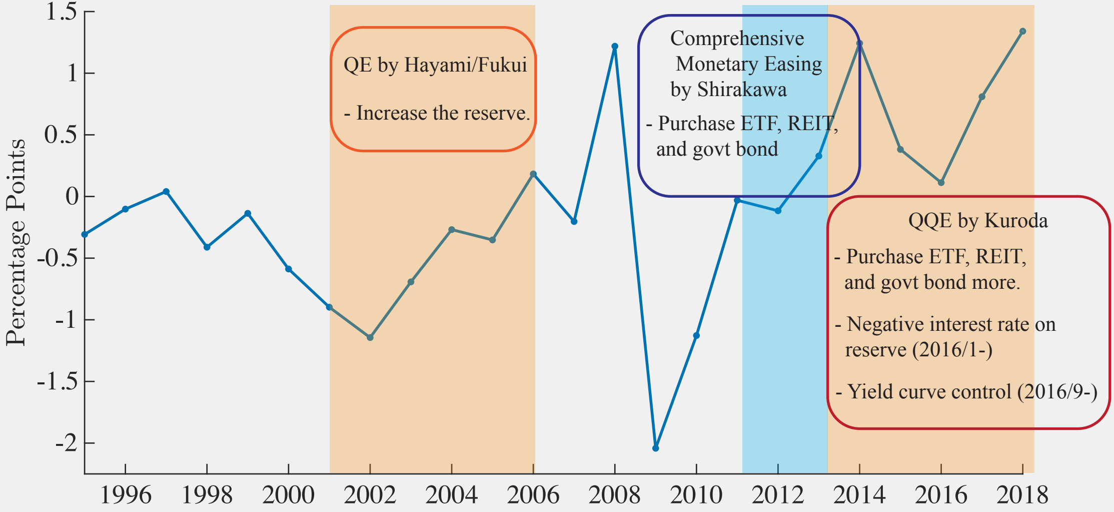
- The mismeasurement shock $\hat{g}_{\tilde{p}_D}$ behaves as if the economy experiences a negative shock.
  - The effects of $\hat{g}_{\tilde{p}_D}$ are the same ones of $\hat{g}_{A_D}$ under the loose bound in our model.
- So our conclusion still holds, but the interpretation differs.

Implications

Various Monetary Policies Have Been Implemented



Various Monetary Policies Have Been Implemented



The Rise in Inflation Is Often Attributed to QQE

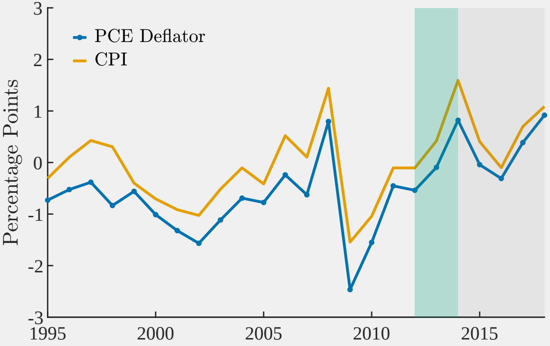
- In its assessment of QQE (Bank of Japan (2016)), BOJ says that:
  - "QQE has lowered real interest rates by raising inflation expectations and pushing down nominal interest rates.... As a result, economic activity and price developments improved, and Japan's economy is no longer in deflation, which is commonly defined as a sustained decline in prices."
- Bernanke expresses a similar view by saying that:
  - "Kuroda's program of "qualitative and quantitative easing" has had important benefits, including higher inflation and nominal GDP growth and tighter labor markets."
- Hausman and Wieland (2014, 2015), Caldara et al. (2020), and Ito (2021) reach a similar conclusion.
- We challenge this interpretation by providing a different interpretation.

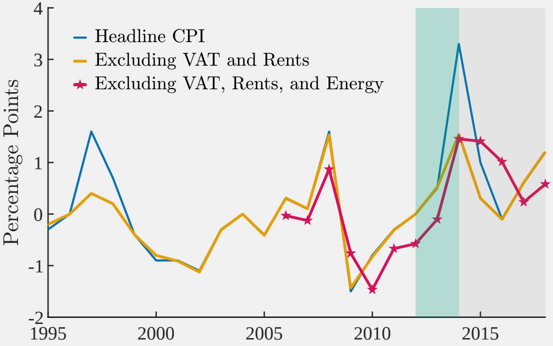
Conclusion

- Exploiting the sufficient statistics results, our counter-factual analysis finds:
  - the depressed TFP growth can explain **more than half** of the observed rise of inflation since 2014.
  - the aggregate inflation rate would be **around 0%** since 2014 without the technology stagnation.
- The depressed TFP growth induced lower consumption and GDP growth, consistent with the data.
- In sum, we argue that the recent rise of inflation is largely attributed to **hidden stagflation**.
- Central banks in developed countries would face a similar situation to Japan in the future.

Additional Slides

Comparison of Various Measures of (Chain-Linked) Inflation





- Although the level of inflation rate differs, the movements of all series are almost the same.
  - The average difference between the CPI and PCE is $0,53\%$.
  - The changes in inflation are $\mathbf{d}\pi^{\text{CPI}} = 0.95\%$ and $\mathbf{d}\pi^{\text{PCE}} = 1.18\%$. Go Back

Consumption Tax Adjustment

▸ Go Back

	CPI Excluding Imputed Rent Fixed Weight			CPI Excluding Imputed Rent Chain-Linked		Consumption Deflator Excluding Imputed Rent Chain-Linked	
Year	YoY	VAT-Adjusted	Diff	YoY	VAT-Adjusted	YoY	VAT-Adjusted
⋮	⋮	⋮	⋮				
2013	0.5%	0.5%	0.0%	0.4%	0.4%-0.0%	-0.1%	-0.1%-0.0%
2014	**3.3%**	**1.5%**	**1.8%**	3.4%	3.4%-**1.8%**	2.6%	2.6%-**1.8%**
2015	1.0%	0.3%	0.7%	1.1%	1.1%-0.7%	0.7%	0.7%-0.7%
2016	-0.1%	-0.1%	0.0%	-0.1%	-0.1%-0.0%	-0.3%	-0.3%-0.0%
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

- Consumption tax was raised in 1997, 2014 (5% $\rightarrow$ 8%), and 2019.

Estimation of Rental Rates $\{\theta_i\}_{i\in\mathcal{I}}$ by Gourio and Rognlie (2020) ▸ Go Back

- Connect the rental rates with easily measured objects by using the model.

- Assume there are no growth (for simplicity). Arbitrage implies the user cost formula:

$$r_i = \left(r + \delta_i^K\right) p_i \quad r = \beta^{-1} - 1.$$

- Nominal depreciation is related with the new investment:

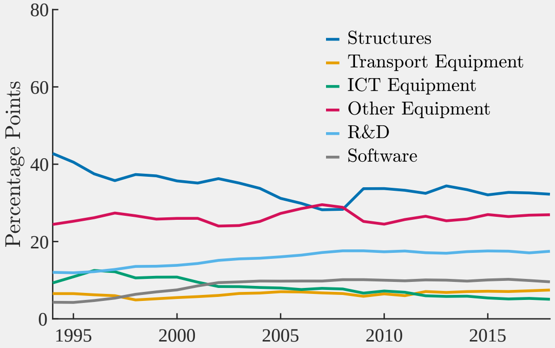
$$r_i K_i = \left(r + \delta^K\right) p_i K_i \Longrightarrow r_i K_i = r p_i K_i + \underbrace{\delta_i^K p_i K_i}_{\text{Investment}} = r p_i K_i + p_i I_i.$$

- The rental rate for a is expressed in terms of observables.

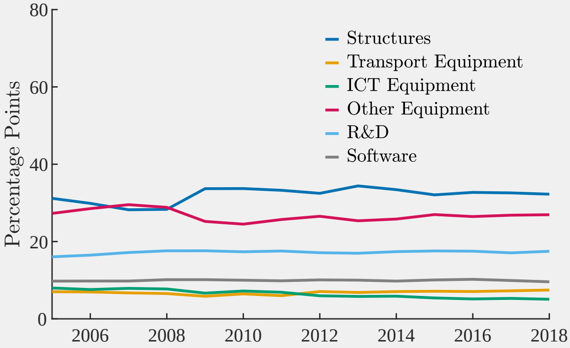
$$\theta_i = \frac{r_i K_i}{\sum_{a\in\mathcal{I}} r_a K_a} = \underbrace{s_I}_{\text{Total Investment Share}} /\alpha \underbrace{\frac{p_i I_i}{\sum_{a\in\mathcal{I}} p_a I_a}}_{\text{Investment Share of } i} + (1 - s_I/\alpha) \underbrace{\frac{p_i K_i}{\sum_{a\in\mathcal{I}} p_a K_a}}_{\text{Capital Share of } i} .$$

Time-Series Estimates of $\left(\alpha, (\theta_i)_{i \in \mathcal{I}}\right)$

▸ Go Back

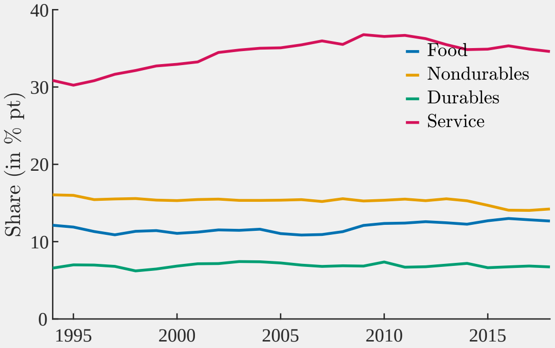


From 1994 to 2018

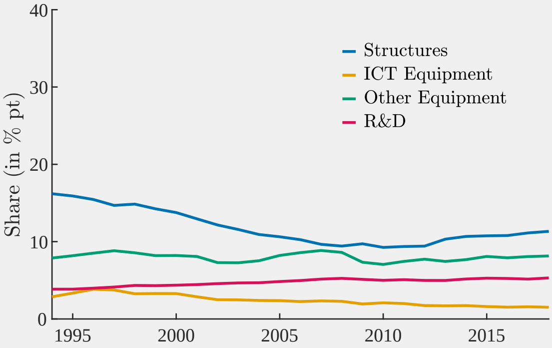


From 2005 to 2018

Time-Series of Shares in GDP $(s_{n,t})_{n \in \mathcal{N}, t}$ ▸ Go Back

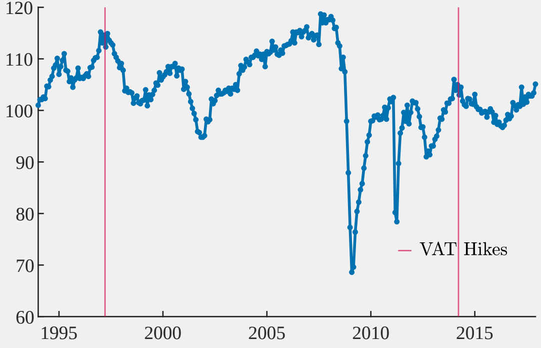


Consumption Goods

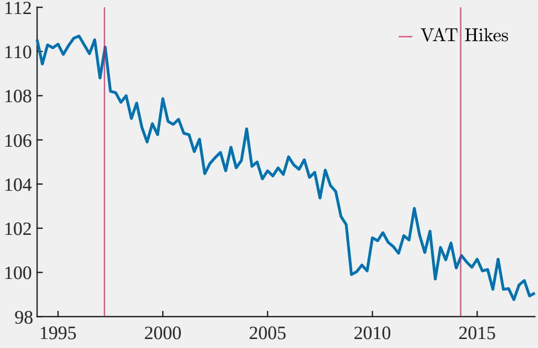


Investment Goods

Utilization of Manufacturing Around VAT Hike



Utilization Index (Manufacturing)

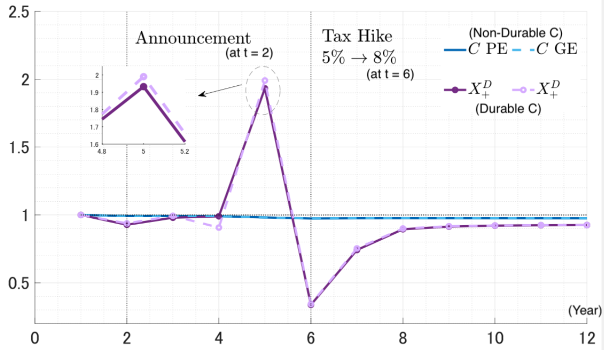


Hours Index

- Both figures show that the production side might not be affected.

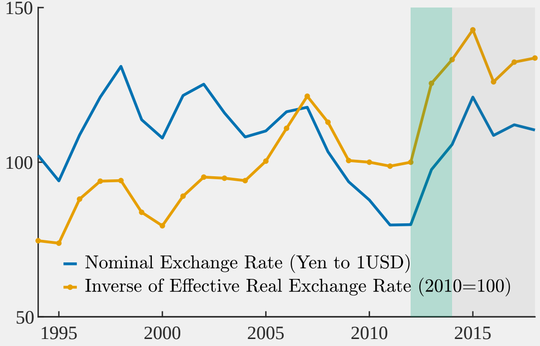
Estimated Consumption Response by Hino (2021)

- Hino (2021) calibrates his model for Japan to study the effects of the rise of VAT in 2014.

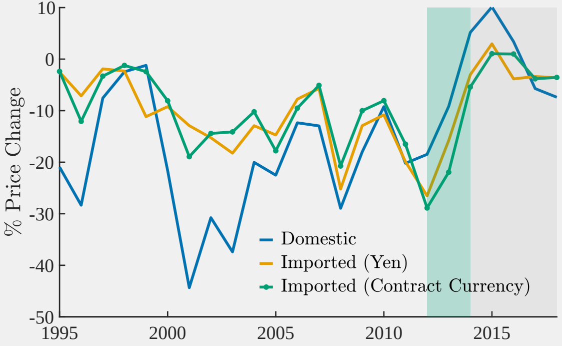


- The consumption level is high right before the implementation, and low when implemented.
  - The negative effect from the VAT hike on the consumption growth is concentrated in the period when the hike is implemented, $t = 6$. ▸ Go Back

Robustness : Effect From Nominal Exchange Rate



Exchange Rates



Relative Prices of Desktop Computers in PPI

- The depreciation from 2012 is temporal, so that it can affect the *level* of the relative prices.
- Since 2014, the yen has not depreciated, but the relative prices stopped declining.
  - The depreciation cannot explain the *growth* stagnation. Go Back

Fact 4 : Cobb-Douglass Demand

- Consider the minimization problem with a CES function.

$$\min_{X_i} \quad \sum_{i=1}^{N} p_i X_i$$

$$s.t. \quad \left(\sum_{i=1}^{N} \theta_i^{\frac{1}{\varepsilon}} X_i^{\frac{\varepsilon-1}{\varepsilon}} \right)^{\frac{\varepsilon}{\varepsilon-1}} \geq \bar{Y}.$$

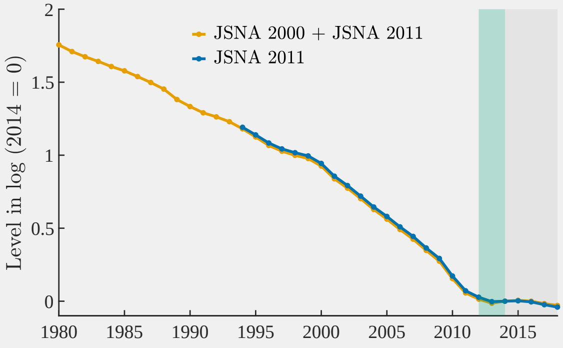
- Then:

$$\ln \frac{p_i X_i}{p_j X_j} = \ln \theta_i / \theta_j + (1-\varepsilon) \ln \frac{p_i}{p_j}.$$

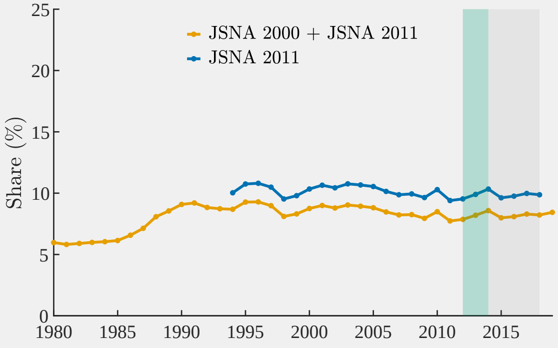
- The Cobb-Douglass production function ($\varepsilon = 1$) implies

$$\ln \frac{p_i X_i}{p_j X_j} : \text{constant}.$$

Fact 4 From 1980 : Unit Elasticity of Demand



Relative Durable Deflator from 1980



Nominal Durable Consumption Share from 1980

- The relative price of durable goods had declined consistently (at least since 1980).
- The small difference reflects the imputed rents. Go Back

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