

Hidden Stagflation

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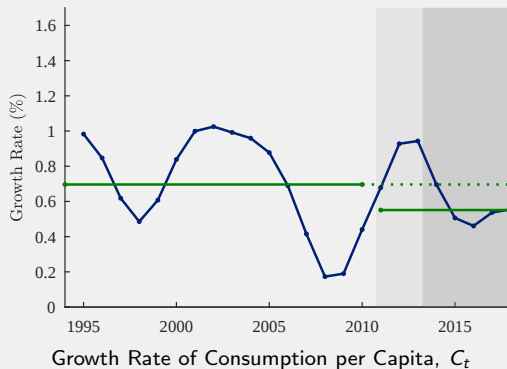
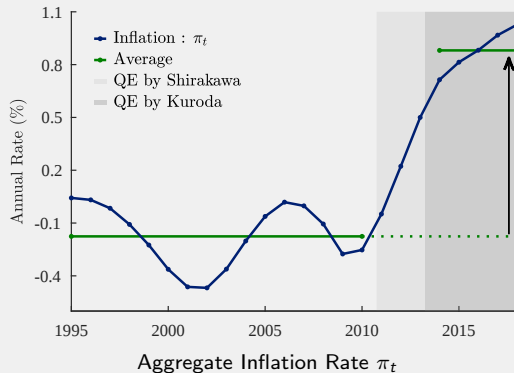
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Motivation

- There is a widespread perception that Japanese growth has been disappointing due to deflation.
 - This perception has motivated the Bank of Japan to adopt various unconventional monetary policies.
- After then-governor Kuroda implemented his QE (QQE), Japan has finally emerged from deflation.

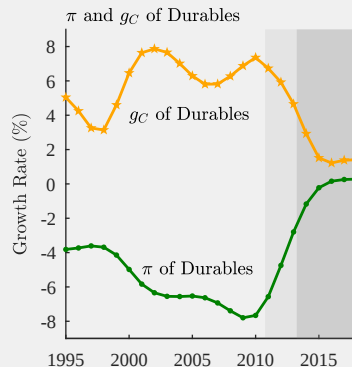
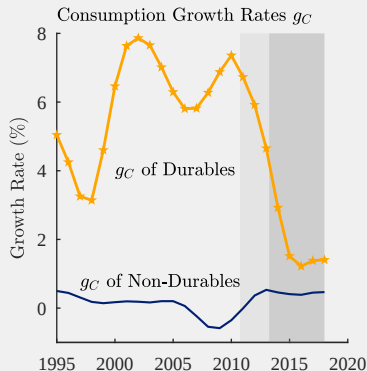
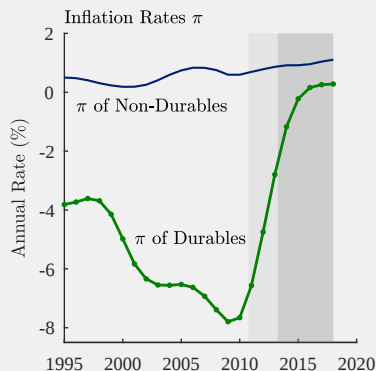
Kuroda's program of "qualitative and quantitative easing" has had important benefits, including higher inflation and nominal GDP growth and tighter labor markets. Bernanke (2017a)
- From this perspective, it is puzzling that consumption growth began to stagnate *further* precisely when the economy emerged from deflation.

Puzzle: Rise in Prices $\pi_t \uparrow \dots$ but Slowdown in Quantities $g_{C_t} \downarrow$



- “There is little evidence that expansionary monetary policy had large effects on consumption.” (Hausman et al. (2021))

Disaggregated Inflation and Consumption Suggest an Overlooked Aspect



- Inflation and consumption growth of durables have changed greatly.
- The changes are statistically significant while other changes of non-durables are insignificant.

We Propose a Structural Interpretation of the Puzzling Phenomena

- We argue that TFP growth rate of durables declined permanently.
 - The productivity slowdowns increases the relative price of durables.
 - Lower output growth of durables.
 - Lower growth of aggregate consumption $g_{C_t} \downarrow$.
- Use the New Keynesian model and connect the change in the relative price to aggregate π_t .
- With the effectively pegged interest rate and extra conditions, the model implies that:
 - The productivity slowdown primarily affects durables, not others.
 - Higher inflation of durables is directly transmitted to the rise in inflation $\pi_t \uparrow$.
- The puzzle reflects the *stagflation* resulting from the durables specific technology stagnation.

Overview of the Presentation

- Provide a theoretical framework.
 - Standard New-Keynesian (NK) model with multiple consumption goods.
- Examine the facts about the Japanese economy.
 - Provide evidence of the productivity slowdown of the manufacturing good.
 - Quantify the impacts of the technology stagnation on inflation and growth.
- Discuss the implications of our analysis for unprecedented monetary policies in Japan.

Theoretical Framework

Overview of Our Model

- Our theoretical framework follows the recent New Keynesian model by Guerrieri et al. (2021).
- It is an extension of the standard NK model by introducing multiple consumption goods.
- The consumption goods are composites of intermediate inputs.
- Intermediate-firms are subject to the nominal pricing friction with different degrees.
- **NB:** We can generalize our model to incorporate durability explicitly in the Appendix.

Representative Household

- The economy is populated by a representative household.
- There is a continuum of workers distributed over $[0, 1]$ who belong to this household.
- They are ex-ante heterogeneous and there are two types, a and b , indexed by j .
 - Workers are immobile in a sense that workers of type j can work in sector j .
 - The fraction of type j workers is ω_j and $\omega_a + \omega_b = 1$.
- The total hours worked for each type of workers are denoted by $L_{a,t}$ and $L_{b,t}$.

The Maximization Problem for the Representative Household

- The utility of the representative household is

$$U = E_0 \sum_{t=0}^{\infty} \beta^t (u(C_{a,t}, C_{b,t}) - \omega_a v(L_{a,t}) - \omega_b v(L_{b,t})).$$

- $C_{j,t}$ is the consumption of good $j \in \{a, b\}$
 - The function $v(\cdot)$ represents the disutility from labor
-
- The flow budget constraint in period t is given by

$$\sum_{j \in \{a, b\}} P_{j,t} C_{j,t} + B_t = \sum_{j \in \{a, b\}} W_{j,t} L_{j,t} + R_{t-1} B_{t-1} + T_t.$$

- All quantity variables are articulated on a per-capita basis.
- The representative household maximizes U subject to the flow budget constraint.

Final-Goods Firms

- The final goods in this economy ($Y_{a,t}$ and $Y_{b,t}$) are produced by competitive representative firms.
- The final-goods firm in sector j combines intermediate inputs $(Y_{j,t}(k))_k$ by CES functions.
- As usual, the demand for intermediate good k :

$$Y_{j,t}(k) = (P_{j,t}(k) / P_{j,t})^{-\varepsilon_j} Y_{j,t}$$

- $P_{j,t}(k)$ is the price charged by the intermediate-good firm k in sector j .
- $\varepsilon_j > 1$ is the substitution parameter of CES production function.
- $P_{j,t}$ is the relevant price index for sector j , $P_{j,t} = \left(\int_{k \in [0,1]} P_{j,t}(k)^{1-\varepsilon_j} dk \right)^{1/(1-\varepsilon_j)}$.

Intermediate-Goods Firms

- The intermediate-goods firms in sector j provide goods to the final-goods firm in sector j .
- The intermediate-good firm k in sector j has a linear technology, $Y_{j,t}(k) = A_{j,t}L_{j,t}(k)$.
- The firm k in sector j has monopoly power, but is subject to the Calvo pricing friction.
 - The intermediate-goods firms in sector j can reset their prices with probability Θ_j .
- A firm k in sector j allowed to reset its price in period t selects its price $\tilde{P}_{j,t}$ to maximize

$$\max_{\tilde{P}_{j,t}} E_t \sum_{T=0}^{\infty} v_{t+T}^t \Theta_j^T \left(\tilde{P}_{j,t} Y_{j,t+T}(k) - W_{j,t+T} L_{j,t+T}(k) \right).$$

- v_{t+T}^t is the nominal stochastic discount factor between t and $t+T$.

Other Specifications

- Aggregate consumption growth (real GDP growth) is a weighted average of growth rates of $C_{j,t}$.

$$g_{C_t} = \sum_{j \in \{a,b\}} \underbrace{\gamma_{j,t-1}}_{\text{Expenditure share of good } j} \times \underbrace{g_{C_{j,t}}}_{\text{Growth rate of } C_{j,t}}.$$

- Aggregate inflation is a weighted average of inflation rates $\pi_{j,t}$.

$$\pi_t = \sum_{j \in \{a,b\}} \gamma_{j,t-1} \underbrace{\pi_{j,t}}_{\text{Inflation rate of good } j}.$$

- Monetary policy follows the interest rate rule:

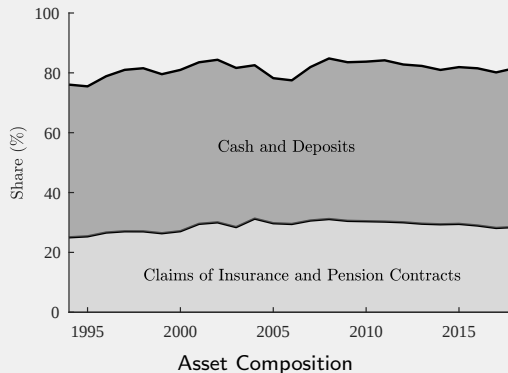
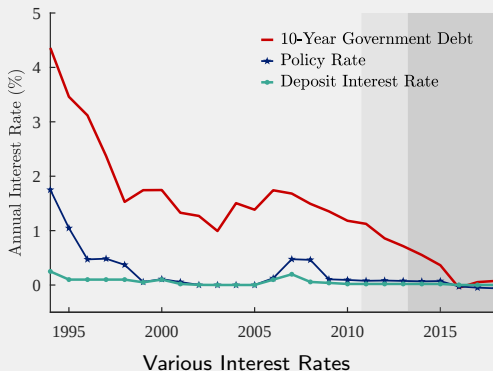
$$\ln R_t = \max \left\{ r^* + \phi (\pi_t - \pi^*), \underbrace{\bar{r}}_{\text{Effective Lower Bound}} \right\}.$$

Model Specification and Calibration

Model Specification and Calibration

- Establish several key facts about Japanese economy for model specification and calibration.

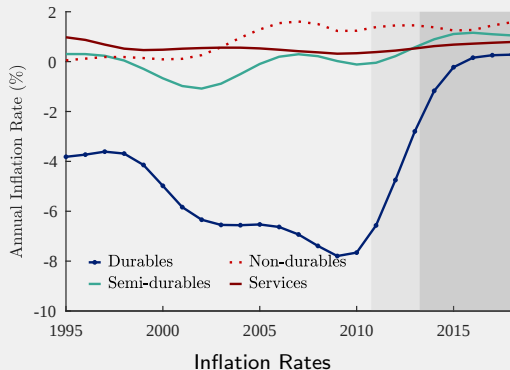
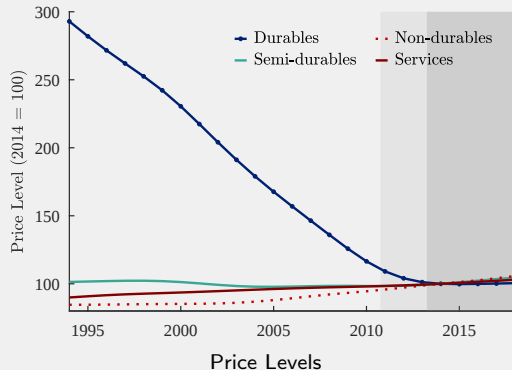
Monetary Policy in Japan: Effective Lower Bound



- Moreover $\geq 70\%$ of the households have zero equity.
- The relevant interest rate is the deposit rate, which is at the effective lower bound (ELB).

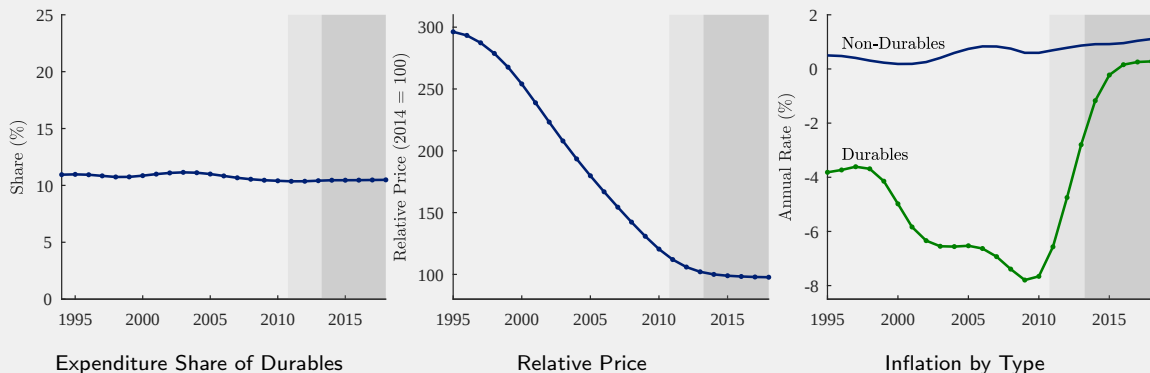
→ The interest rate is pegged throughout our sample, $R_t = \bar{r}$.

Aggregation of Goods



- There is smaller heterogeneity among non-durables, semi-durables, and services.
- We aggregate them using the weighed average to construct non-durable inflation rate.

Two Types of Consumption: Durables and Non-Durables



- The share of durables has been constant while the relative price had declined sharply (200% ↓).
- These figures suggest the unit elasticity of demand.

Utility Specification: Unit Elasticities

- We assume the unit elasticity of substitution and unit elasticity demand.

$$u(C_a, C_b) = \sum_{j \in \{a, b\}} \gamma_j \ln C_j.$$

- a = durables and b = non-durables.

- The Euler equation (along the BGP) is

$$g_{C_j} = \ln \beta + \ln R - \pi_j \quad \text{for } j \in \{a, b\}.$$

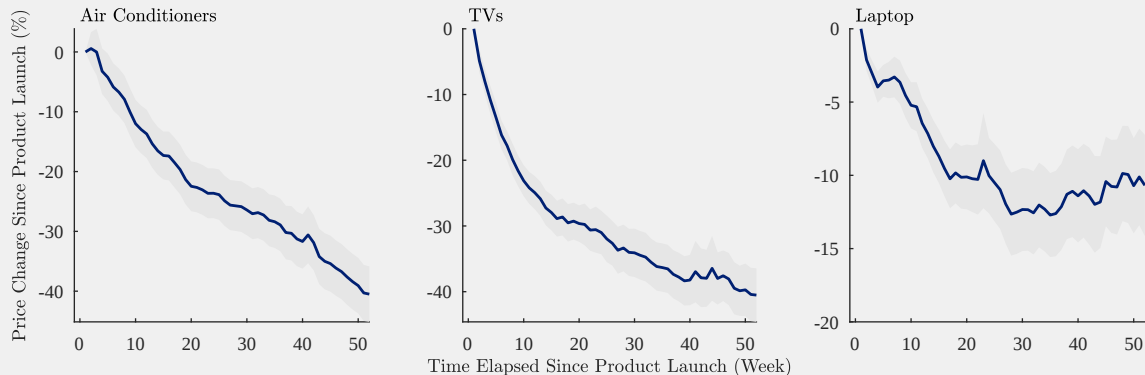
- This specification has strong implication for the change in g_{C_j} and that in π_j .
- One percent decrease in g_{C_j} should be associated with the one percent increase in π_j .

Check the Strong Implication

	Until 2010	Since 2014	Change
π of Durables	−6.3%	−0.7%	5.6 %pts
g_C of Durables	6.6%	0.6%	−6.0 %pts

- For durables, the changes in π and g_C are statistically significant, and
- the strong implication based on the Euler equation is satisfied.
- For non-durables, the changes in π and g_C are not statistically significant from zeros, and
- the strong implication is hard to check, while it is not rejected.
- In the paper, we also verify a similar cross-sectional implication for durables.

On Price Adjustment of Durable Goods: Micro Data



- The prices continuously decline after the introduction of specific products.
- We assume that the durable-good firms can fully change prices (in a year) so that $\Theta_a = 0$.

Theoretical Results

How the Economy Responds to the TFP Stagnation of Durables at the ELB

- The pieces of empirical evidence suggest that
 - the nominal interest rate is at the effective lower bound, $R_t = \bar{r}$,
 - the durable-good firms are not subject to pricing frictions, and
 - the (long-run change in) relative price reflects the technology stagnation.
- The model boils down to Aoki (2001) and Wolman (2011) from Guerrieri et al. (2021).
- Explore the implication of this particular shock on aggregate inflation and consumption using the calibrated models.

A Closer Look at the Consumer's Problem

- The representative consumer's optimality conditions are

$$\underbrace{\frac{P_{a,t}C_{a,t}}{P_{b,t}C_{b,t}} = \frac{\gamma_a}{\gamma_b}}_{\text{Cobb-Douglas}}, \quad \underbrace{\frac{C_{j,t}}{\gamma_j} v'(L_{j,t}) = \frac{w_{j,t}}{P_{j,t}}}_{\text{Intra-temporal optimality}}$$
$$\underbrace{1 = E_t \frac{C_{j,t+1}}{C_{j,t}} \frac{\bar{R}P_{j,t}}{P_{j,t+1}}}_{\text{Euler equation}}, \quad \underbrace{0 = \lim_{t \rightarrow \infty} E_0 \beta^t \frac{B_t}{P_{j,t}C_{j,t}}}_{\text{TVC}}.$$

- Let $(C_{a,t}, C_{b,t}, L_{a,t}, L_{b,t}, B_t)$ be the optimal allocation for the representative consumer.
- Suppose that $P_{a,t}$ increases to $P'_{a,t}$ (due to the decline in $A_{a,t}$.)

Optimal Response of the Consumer to the Price Changes

- The representative consumer's optimality conditions are

$$\underbrace{\frac{P_{a,t} C'_{a,t}}{P_{b,t} C_{b,t}} = \frac{\gamma_a}{\gamma_b}}_{\text{Cobb-Douglas}}, \quad \underbrace{\frac{C'_{a,t}}{\gamma_j} v'(L_{j,t}) = \frac{w_{j,t}}{P'_{a,t}}}_{\text{Intra-temporal optimality}}$$

$$\underbrace{1 = E_t \frac{C'_{a,t+1}}{C'_{a,t}} \frac{\bar{R} P'_{a,t}}{P'_{a,t+1}}}_{\text{Euler equation}}, \quad \underbrace{0 = \lim_{t \rightarrow \infty} E_0 \beta^t \frac{B_t}{P'_{a,t} C'_{a,t}}}_{\text{TVC}}.$$

- $(C'_{a,t}, C_{b,t}, L_{a,t}, L_{b,t}, B_t)$ is optimal under $(P'_{a,t}, P_{b,t}, w_t, R)$ where $C'_{a,t} \equiv P_{a,t}/P'_{a,t} C_{a,t}$.
- The labor supply, saving, and consumption of non-durables are unaffected.
 - The substitution effects and the associated income effects cancel each other out.
- NB:** the unit elasticities play crucial roles for these results.

How the Macro Economy Responds to the Shock

- The demand for durables remains unchanged as well.
 - Lower demand for durables is perfectly offset by the decline in the technology, $A_{a,t}$.
- The shock specific to durables only affects consumption of durables.
- This observation allows us to sharply characterize how the economy responds to the shock.

The Impulse Response Functions in Closed-Form

- The TFP growth rate of durables unexpectedly shifts from $g_{A_{a,t}}$ to $g_{A_{a,t}} + \hat{g}_{A_{a,t}}$.

$$\hat{g}_{A_{a,t}} = (1 - \rho^{t-t_0+1}) \hat{g}_{A_a}.$$

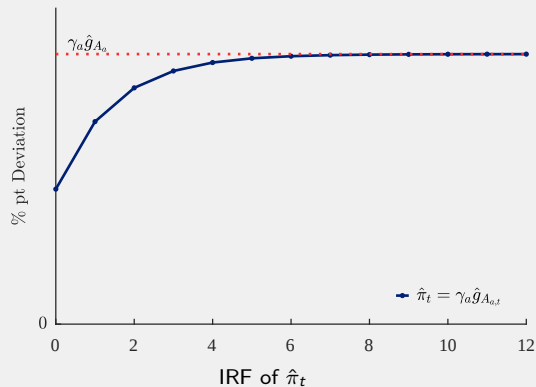
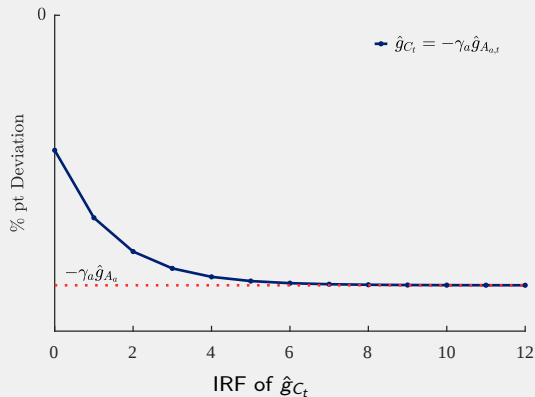
- $\hat{g}_{A_a}$ is the long-run change in growth of $g_{A_{a,t}}$.

- The responses to shocks $\hat{g}_{A_{a,t}}$ is characterized in a clean closed-form

$$\hat{g}_{C_t} \equiv \gamma_a \underbrace{\hat{g}_{C_{a,t}}}_{=\hat{g}_{A_{a,t}}} + \gamma_b \underbrace{\hat{g}_{C_{b,t}}}_{=0} = \gamma_a \hat{g}_{A_{a,t}}, \quad \hat{\pi}_t \equiv \gamma_a \underbrace{\hat{\pi}_{a,t}}_{=-\hat{g}_{A_{a,t}}} + \gamma_b \underbrace{\hat{\pi}_{b,t}}_{=0} = -\gamma_a \hat{g}_{A_{a,t}}.$$

- NB: we focus our analysis on the minimum state variable solution.
 - g_{C_t} and π_t can fluctuate due to sunspot shocks.

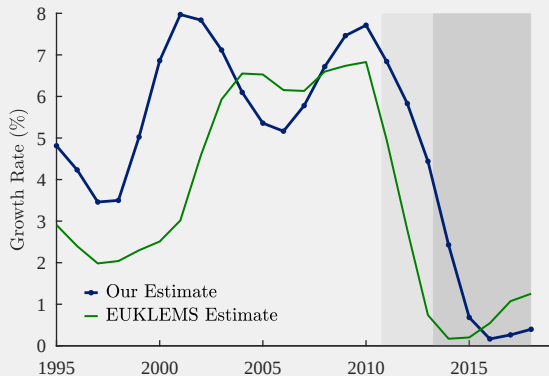
Smooth Transition to the New Steady-State Value



- From this slide onward, we will focus on the steady-state implications.

TFP Estimates

- We measure the TFP growth rate of durables by $g_{C_{a,t}}/g_{L_t}$.
- This is the model-consistent way, but many other potential factors can affect $g_{C_{a,t}}$ (e.g., capital.)
- Comparing to the EUKLEMS-type estimates confirms that we accurately measures the change in growth rate.
 - This result align with the literature (e.g., Basu et al. (2013).)



Quantification at the Steady State

	Durable TFP Stagnation	Data Counterpart
$\hat{\pi}_{\infty}$	0.43 %pts	1.06 %pts
$\hat{g}_{C_{\infty}}$	-0.43 %pts	-0.15 %pts
$\hat{g}_{C_{\infty}/L_{\infty}}$	-0.43 %pts	-1.03 %pts
$\hat{\pi}_{\infty} + \hat{g}_{C_{\infty}/L_{\infty}}$	0 %pt	-0.02 %pts

- The data-counterpart of $\hat{\pi}_{\infty}$ is the difference between average inflation $t \leq 2010$ and $t \geq 2014$.
- This TFP stagnation can explain a sizable fraction of the observed rise in π_t and decline in $g_{C/L}$.
- The puzzle is largely driven by this specific technology stagnation.
 - “Hidden” in our title has the connotation that this stagflation has been largely ignored.

Discussions of Our Modeling Assumptions

- Our analysis does not rule out the possibility that Japan has been in a liquidity trap.
 - Along the balanced growth path,

$$Y_t^{\text{BGP}} = \underbrace{\Gamma}_{\text{Output gap}} \times \underbrace{A_t}_{\text{Technology}} \times \underbrace{L^*}_{\text{Efficient level of } L_t}.$$

- Output gap only affects the *level* of output so that our argument goes through for *any* level of Γ .
- Our results go through under non-horizontal asset supply curves (Appendix).
 - The key is that the TFP shock to durables does not affect the saving behavior.
- The responses of g_{C_t} and π_t to transitory TFP shocks are the same unlike the simple NK model.
 - In such a NK model, temporal positive TFP shock is deflationary while persistent shock is inflationary.

Relation to the Optimal Policy Literature

- It turns out that efficiency requires that only durables respond to the shock $g_{A_a,t}$ (Aoki (2001)).
 - ↪ It is optimal for the BOJ not to respond to this shock.
 - The pegged interest rate rule is the optimal response to this shock.
 - Of course, the pegged interest rate rule is suboptimal to other shocks.
- The same argument implies that the optimal policy at the steady state calls for price stabilization of non-durables, $\pi_b = 0$. (Wolman (2011))
 - ↪ The optimal aggregate inflation rate can be negative if $g_{A_a} > 0$.

Extension

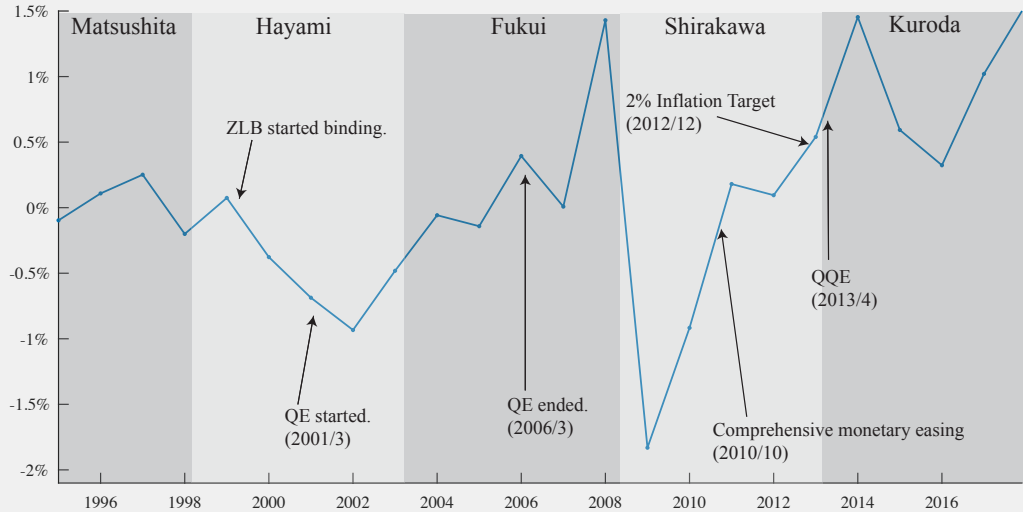
Extension

- Productivity slowdown in ICT investment goods are also observed.
 - We explore the implications of the shock to the ICT goods sector.
- To accommodate these, we extend the model as follows.
 - Introduce multiple capital goods.
 - Allow the representative household to have non-unitary EIS.
- For simplicity, we conduct the steady-state analysis, not dynamics.

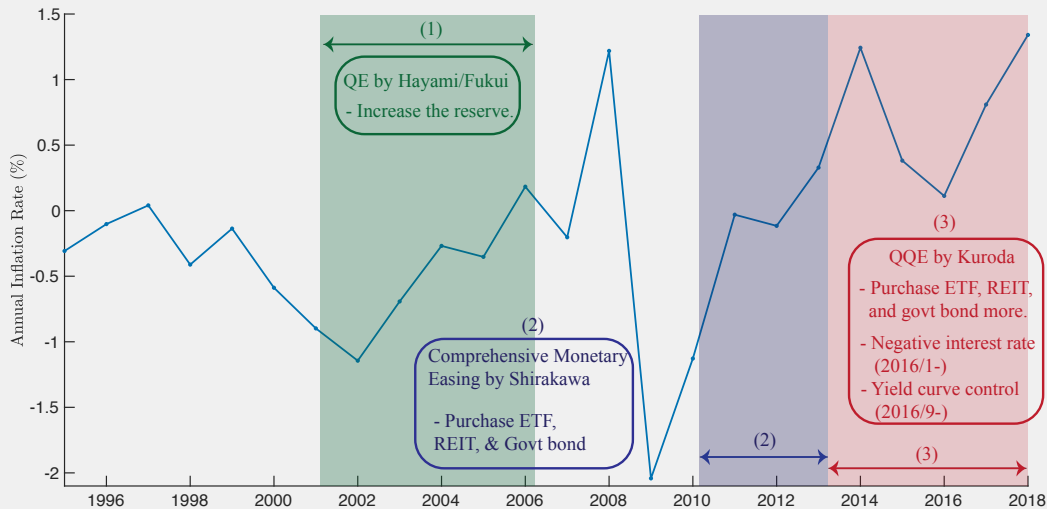
► [Go to Extension](#)

Policy Implication

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 (BOJ (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.”
- Ito (2021) says that:
 - “All inflation indicators were in the negative territory (i.e. deflation) before Abe II started, but rose into positive territory during the Abe II period.... It is clear ... that the first arrow of Abenomics [aggressive monetary policy] was successful in lifting the economy out of deflation.”
- Other works reach a similar conclusion.
 - E.g. Hausman and Wieland (2015), Bernanke (2017b), and Caldara et al. (2020).

Our Findings Call for Challenge to this Conventional Interpretation

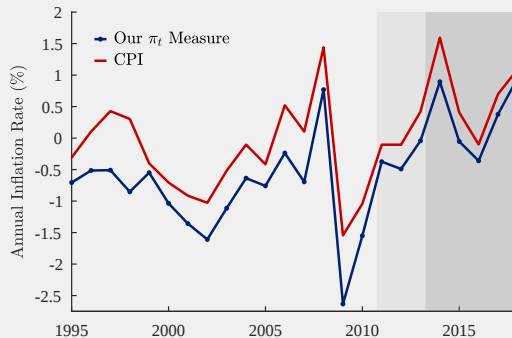
- Their arguments hold true if there are no other contemporaneous inflationary shocks.
- Our study reveals that the technology shock increased inflation and reduced consumption growth, consistent with the data.
- Consequently, we raise a concern about the conventional interpretation relying on the time-series identification strategy.
 - NB: We do *not* challenge the effectiveness of QQE itself.

Conclusion

- We propose a resolution to the puzzle of the Japanese economy, $\pi_t \uparrow$ and $g_{C_t} \downarrow$.
- The technology stagnation can explain **half** of the observed rise of inflation since 2014.
 - Aggregate inflation would be **barely above 0%** since 2014 without the this technology stagnation.
- This stagnation has induced lower consumption and GDP growth, consistent with the data.
- In sum, the recent rise of inflation could be largely attributed to **hidden stagflation**.

Appendix

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 our π_t is 0.53% pt.
 - The changes in inflation are $\hat{\pi}^{\text{CPI}} = 0.95\% \text{pt}$ and our $\hat{\pi} = 1.18\% \text{pt}$.

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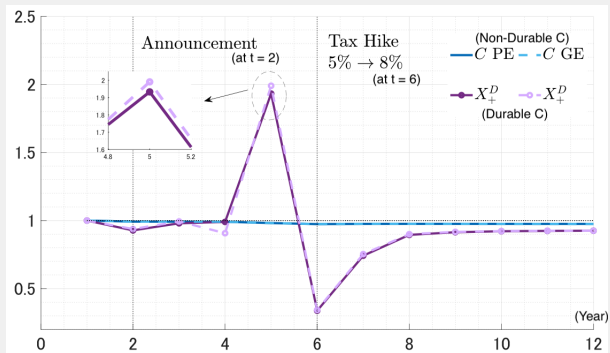
Consumption Tax Adjustment

Year	CPI Excluding Imputed Rent Fixed Weight			CPI Excluding Imputed Rent Chain-Linked		Consumption Deflator Excluding Imputed Rent Chain-Linked	
	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 (3% → 5%), 2014 (5% → 8%) for our sample period.

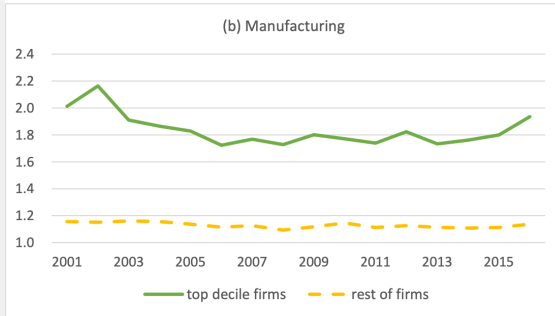
Estimated Consumption Response by Hino (2021)

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

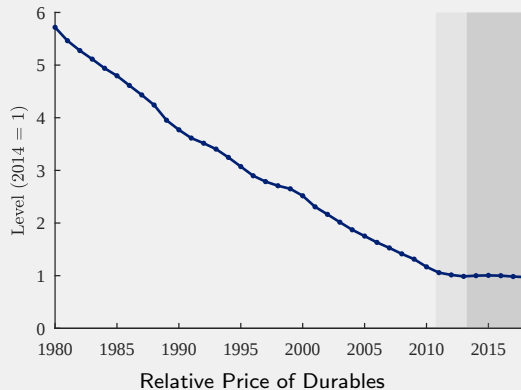
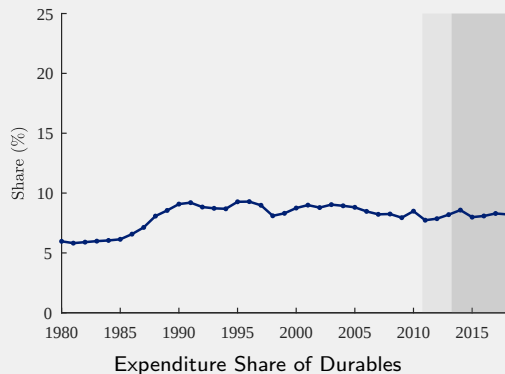


- The consumption level is high right before the implementation, and low when implemented.
 - The negative effect from the VAT hike on the consumption growth is concentrated in the period when the hike is implemented, $t = 6$.

Markup Estimate by Nakamura and Ohashi (2019, Figure A2)

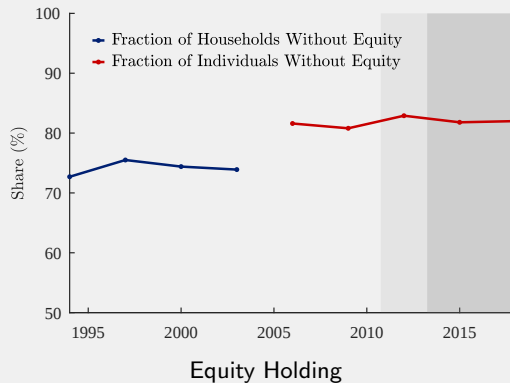


Nominal Consumption Shares from 1980



- The relative price of the manufacturing good had declined by about 80%.
- The share of manufacturing consumption has been constant.

Asset Composition of Japanese Households

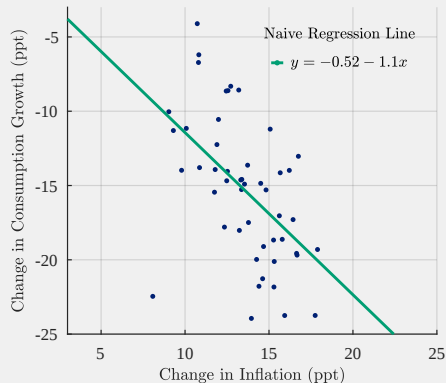


Cross-Sectional Implication

- The time-series evidence is clear at least for us, but it provided us only a single data point.
 - This concern motivates us to explore the cross-sectional evidence.
- Extend the Euler equations geographically: $g_{C_a^i} = \ln \beta + r - \pi_a^i$.
 - $g_{C_a^i}$: consumption growth rate of the durables in city i .
 - π_a^i : inflation of the durables in city i .
- The changes satisfy: $\hat{g}_{C_a^i} = -\hat{\pi}_a^i$.
- The model has the tight cross-sectional prediction too that **1% pt relative rise in π_a^i** is associated with **1% pt relative decline in $g_{C_a^i}$** .

Cross-Sectional Implication

- Most observations are on the -45 degree line.
 - The naive regression shows the coefficient is significant and estimated to around -1 .
- The cross-sectional prediction is, at least, consistent with our cross-sectional data.



EUKLEMS-type TFP Sequences for Durables and ICT

- Using EUKLEMS-type dataset, we can measure the sectoral TFP for each sector j , denoted by $g_{A_j,t}^{\text{KLEMS}}$.
- Measure the aggregate TFP sequences for durables and ICT goods as follows:

$$g_{A_a,t}^{\text{KLEMS}} = \sum_{n \in \tilde{\mathcal{C}}} \tilde{s}_{n,t}^a g_{A_n,t}^{\text{KLEMS}}, \quad g_{A_{\text{ICT}},t}^{\text{KLEMS}} = \sum_{n \in \tilde{\mathcal{I}}} \tilde{s}_{n,t}^{\text{ICT}} g_{A_n,t}^{\text{KLEMS}}.$$

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

Model with Capital

- There are multiple investment good producers $n \in \mathcal{I}$ in addition to consumption-goods producers.
- The households own multiple types of capital stocks, $K_{n,t}$ and rent them to the firms.
- The output is now produced by $Y_{j,t} = A_{j,t} \left(\prod_{n \in \mathcal{I}} K_{n,j,t}^{\theta_n} \right)^{\alpha} L_{j,t}^{1-\alpha}$.
- The Euler equation becomes

$$\bar{r} - \pi_j = \ln \beta^{-1} + g_{C_j}.$$

Classic Results: BGP Growth Rate

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

$$\hat{g}_Y = \underbrace{\hat{g}_A}_{\text{Direct Effect}} + \underbrace{\alpha \hat{g}_A + \alpha^2 \hat{g}_A + \cdots}_{\text{Indirect Effect}} = \frac{1}{1-\alpha} \hat{g}_A.$$

- Our model is a generalization of the standard growth model, $Y_{j,t} = A_{j,t} \left(\prod_{n \in \mathcal{I}} K_{n,j,t}^{\theta_n} \right)^\alpha L_{j,t}^{1-\alpha}$.

$$\hat{g}_{Y_j} = \hat{g}_{A_j} + \sum_{n \in \mathcal{I}} \frac{\alpha \theta_n}{1-\alpha} \times \hat{g}_{A_n}.$$

- The effect of the ICT productivity slowdown on the GDP is

$$\hat{g}_Y = s_{\text{ICT}} \hat{g}_{A_{\text{ICT}}} + \frac{\alpha \theta_{\text{ICT}}}{1-\alpha} \times \hat{g}_{A_{\text{ICT}}}.$$

Summary of Our Results, $\hat{\pi}$

- Keep in mind the Euler equation:

$$\bar{r} - \pi_j = \ln \beta^{-1} + g_{C_j}.$$

- Let now $\hat{\pi}$ denote the change in inflation induced by $\hat{g}_{A_a}$ and $\hat{g}_{A_{ICT}}$.

- We extend the previous result:

$$\hat{\pi} = \underbrace{-\gamma_a \hat{g}_{A_a}}_{(A)} - \underbrace{\frac{\alpha \theta_{ICT}}{1 - \alpha} \hat{g}_{A_{ICT}}}_{(B)}$$

(A) The direct effect from DST shock

(B) The indirect effect from ICT-ST shock

Map the Formulas to Data

- Decomposition formula:

$$\hat{\pi} = \gamma_a (-\hat{g}_{A_a}) + \frac{\alpha \theta_{\text{ICT}}}{1 - \alpha} (-\hat{g}_{A_{\text{ICT}}})$$

$$\hat{g}_{C_{\infty}/L_{\infty}} = \gamma_a \hat{g}_{A_a} + \frac{\alpha \theta_{\text{ICT}}}{1 - \alpha} \hat{g}_{A_{\text{ICT}}}$$

$$\hat{g}_{Y_{\infty}/L_{\infty}} = s_a \hat{g}_{A_a} + s_{\text{ICT}} \hat{g}_{A_{\text{ICT}}} + \frac{\alpha \theta_{\text{ICT}}}{1 - \alpha} \hat{g}_{A_{\text{ICT}}}$$

- We can directly observe, (γ_a, γ_b) , nominal shares, and $(g_{p_n})_n$, relative prices.

- Let $\hat{g}_{p_n} = \text{average}_{t \geq 2014} g_{p_n} - \text{average}_{t \leq 2011} g_{p_n}$.
- Recall that $\hat{g}_{A_n} = -\hat{g}_{p_n}$.

- Additional parameters are $(\alpha, (\theta_i)_{i \in \mathcal{I}})$.

- EUKLEMS estimates the time-series of α (excluding housing) so we use the average. [▶ Time-Series](#)
- In order to estimate $(\theta_i)_{i \in \mathcal{I}}$, we use the method by Gourio and Rognlie (2020b). [▶ Detail](#)

Quantification with Capital

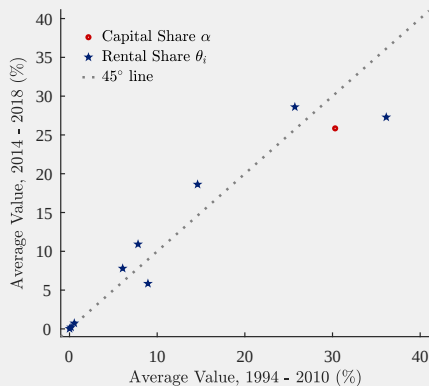
$\hat{\pi}_{\infty}$		$\hat{g}_{C_{\infty}/L_{\infty}}$		$\hat{g}_{Y_{\infty}/L_{\infty}}$	
$-(A)$	0.55 %pt	(A)	-0.55 %pt	(C)	-0.28 %pt
$-((A) + (B))$	0.70 %pt	$(A) + (B)$	-0.70 %pt	$(C) + (D)$	-0.55 %pt
				$(C) + (D) + (B)$	-0.70 %pt
Data	1.06 %pt	Data	-1.03 %pt	Data	-0.37 %pt

$$\hat{\pi} = \underbrace{\gamma_a(-\hat{g}_{A_a})}_{-(A)} + \underbrace{\frac{\alpha\theta_{\text{ICT}}}{1-\alpha}(-\hat{g}_{A_{\text{ICT}}})}_{-(B)}$$

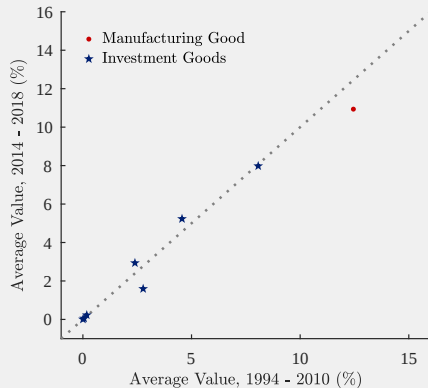
$$\hat{g}_{C_{\infty}/L_{\infty}} = \underbrace{\gamma_a\hat{g}_{A_a}}_{(A)} + \underbrace{\frac{\alpha\theta_{\text{ICT}}}{1-\alpha}\hat{g}_{A_{\text{ICT}}}}_{(B)}$$

$$\hat{g}_{Y_{\infty}/L_{\infty}} = \underbrace{s_a\hat{g}_{A_a}}_{(C)} + \underbrace{s_{\text{ICT}}\hat{g}_{A_{\text{ICT}}}}_{(D)} + \underbrace{\frac{\alpha\theta_{\text{ICT}}}{1-\alpha}\hat{g}_{A_{\text{ICT}}}}_{(B)}$$

Stability of Parameters $(\alpha, (\theta_i)_{i \in \mathcal{I}})$ and GDP Share s_n



Parameters



GDP Share

- The labor share weakly has increased in the last decade.

Rental Costs Estimation by Gourio and Rognlie (2020a) [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:

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

- Nominal depreciation is related with the new investment:

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

- The share in rental costs for asset i is expressed in terms of observables.

$$\theta_i = \frac{r_i K_i}{\sum_{j \in \mathcal{I}} r_j K_j} = \underbrace{s_I}_{\text{Total Investment Share}} / \alpha \underbrace{\frac{P_i I_i}{\sum_{j \in \mathcal{I}} P_j I_j}}_{\text{Investment Share of } i} + (1 - s_I / \alpha) \underbrace{\frac{P_i K_i}{\sum_{j \in \mathcal{I}} P_j K_j}}_{\text{Capital Share of } i}.$$

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