Hidden Stagflation*

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Abstract

There is a widespread perception that the Japanese economy has been underperforming due to chronic deflation. From this perspective, it is puzzling that consumption growth began to further stagnate precisely when the economy emerged from deflation around 2014. We attribute this puzzling phenomenon to technology stagnation specific to manufacturing goods and the zero lower bound constraint on nominal interest rates. Our extended New Keynesian model reveals that this technology stagnation alone can account for approximately half of the observed rise in inflation and more than 40% of the decline in consumption growth.

JEL Classification: E31, E43, E52, E58

1 Introduction

The Japanese economy has faced low growth and low inflation since the stock market crash of 1990. Initially termed "the lost decade," this prolonged period of poor economic performance eventually came to be known as "the two lost decades" and, more recently, it has been referred to as secular stagnation. To combat this stagnation, the Japanese government implemented a variety of fiscal, monetary, and deregulation policies. A pivotal change occurred in December

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2012, when Prime Minister Abe assumed office. Advocating drastic expansionary policies, he openly pressured the Bank of Japan (BOJ) to adopt more aggressive monetary policies.[1]

To achieve this goal, his cabinet appointed Kuroda as the governor of the BOJ. Upon his appointment in April 2013, Governor Kuroda introduced a new package of unconventional monetary policies termed *quantitative and qualitative easing* (QQE).[2] Shortly after the introduction of QQE, the economy finally began to emerge from deflation (see Figure 1a). Given this sequence of events, both policy authorities (such as BOJ (2016) and Caldara et al. (2020)) and academia (including Bernanke (2017a) and Hausman and Wieland (2015) and Ito (2021)) credit QQE for this uptick in inflation. For example, Bernanke offered the following assessment of QQE:

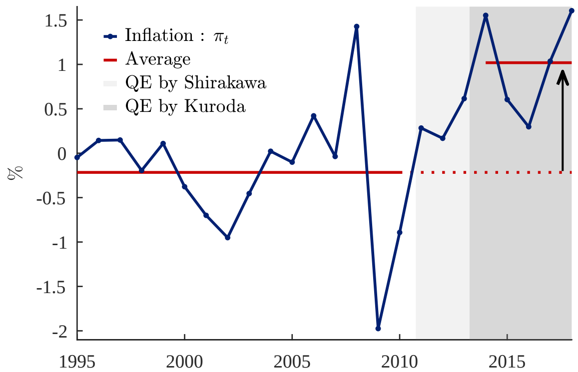
> *Kuroda's program of "qualitative and quantitative easing" has had important benefits, including higher inflation and nominal GDP growth and tighter labor markets.* Bernanke (2017b)

However, the uptick in inflation did not translate into a discernible improvement in the real economy, as illustrated in Figure 1b. Real consumption per capita has remained stagnant since the introduction of QQE, although it had been increasing until around 2010. In line with this observation, Hausman and Wieland (2015) analyze Japan's cross-sectional consumption data and find little evidence that Kuroda's expansionary monetary policy significantly affected consumption. These findings are puzzling, particularly given the widespread belief that Japan's economic underperformance stems from deflation.

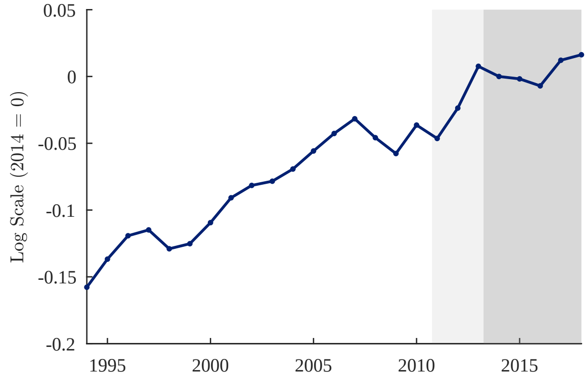
In this paper, we offer a resolution to this puzzling phenomenon. The key to our resolution lies in the observation that a specific subcategory of goods has been pivotal in driving both the inflation uptick and the dip in consumption growth. In Figure 2, we disaggregate inflation and consumption data into manufacturing and non-manufacturing goods. The left panel of Figure 2 highlights how the inflation rate for the manufacturing good, which was previously negative, turned positive around the time QQE was introduced. Concurrently, the consumption growth of the manufactured good—which had greatly outpaced that of the non-manufacturing good—began to level off, as depicted in the right panel of Figure 2. These trend shifts indicate a potential stagflation scenario—a combination of stagnant

[1]The Abe administration continued until September 2020. Prime Minister Abe introduced a policy package widely known as "Abenomics." Broadly speaking, the core of the package was characterized by three components: (i) aggressive monetary policy, (ii) flexible fiscal policy, and (iii) growth strategies by stimulating private investment.

[2]Kuroda was the governor until April 2023. During him term in office, the BOJ strengthened its monetary policy in various ways. The BOJ introduced a negative interest rate on reserves and yield curve control. Consequently, not only short-term interest rates but also long-term interest rates have been pushed down to near-zero. Moreover, the BOJ's asset purchase program to acquire various financial assets, including ETFs and REITs, has also been expanded on an unprecedented scale.



(a) Aggregate Inflation Rate π_t



(b) Real Consumption per Capita, C_t

Figure 1: Japanese Macroeconomy

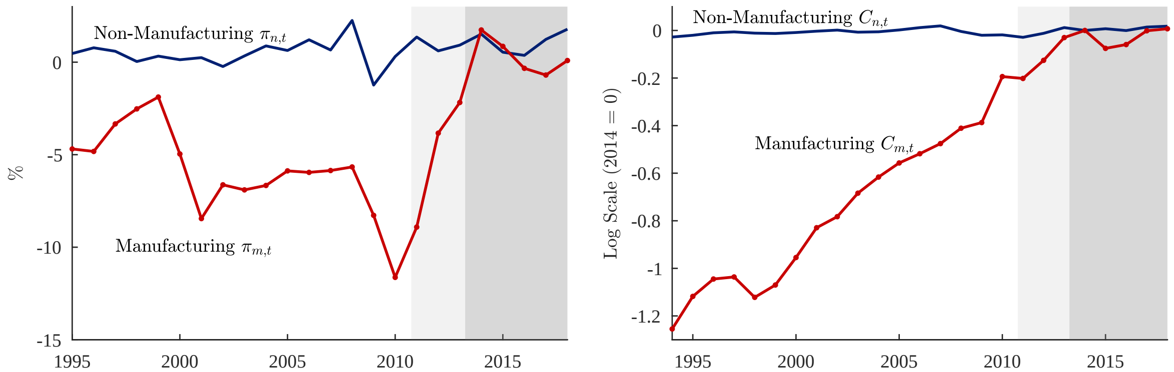
Notes: See Section 3.1 and Appendix A for details on the variables used in these graphs. The blue-colored areas represent periods of QE by Governor Shirakawa and the red-colored areas represent periods of QQE by Governor Kuroda. The average growth rate of real consumption per capita before QE is around 0.8%. After QQE, the average growth declined to around 0.2%.

consumption and higher inflation. More specifically, the data suggests that a supply shock to the manufacturing goods sector has reduced its consumption growth and pushed inflation upward.

To formally explore the possibility of stagflation, we introduce a theoretical framework that builds upon New Keynesian models. Contrary to the canonical New Keynesian model, our model delineates three distinct goods: generic outputs, manufacturing goods, and non-manufacturing goods. Drawing upon the modeling assumptions used in New Keynesian models with investment-specific technology shocks (for example, Justiniano et al. (2011) and Christiano et al. (2014)), producers of the consumption goods employ linear, yet distinct, technologies to transform generic output into each category of consumption goods. This linear technology assumption implies that the relative price of the manufacturing good reflects the technology specific to the manufacturing good, which is an important aspect for our analysis.[3] The generic output is produced by combining intermediate goods supplied by monopolistic intermediate-good firms. These firms choose their prices to maximize their profit subject to the pricing friction given by Calvo (1983).

We employ this framework to investigate the Japanese economy from 1994 to 2018. As emphasized earlier, the foundation of our discussion is the fact that the prices of manufactured goods steadily declined until around 2010 and have remained relatively stable since then. Based on our theoretical model, this persistent decline mirrors the technological progress specific to the manufacturing good. On the flip side, the cessation of the relative

[3] According to Greenwood et al. (1997), it is common in the macroeconomic analysis to infer this type of directed technology progress from relative prices.



(a) Inflation Rates

(b) Real Consumption per Capita

Figure 2: Manufacturing and Non-Manufacturing Goods

Notes: The average growth of consumption of the manufacturing good before the introduction of quantitative easing by Shirakawa was 7%. After the introduction of QQE, it was merely 0.7%.

price decrease for the manufacturing good suggests that manufacturing-specific technology has reached an impasse. Thus, according to our model, the data suggests that the Japanese economy has been experiencing a negative and permanent technology shock since around 2010. We refer to this technological stagnation as the *manufacturing-specific technology stagnation* (MST stagnation).

Now, we proceed to derive the theoretical implications of the MST stagnation for aggregate inflation and consumption. The MST stagnation reduces the efficiency of production of the manufacturing good, thereby leading to a decline in its relative price. When the elasticity of substitution between consumption goods is one, a value strongly supported by our data, the MST stagnation leaves labor supply, saving, and consumption of the non-manufacturing good unaffected. This property, combined with the fact that the nominal interest rate is effectively pegged in Japan, implies that only inflation and consumption of the manufacturing good are responsive to the MST stagnation. Consequently, these effects ripple through aggregate inflation and consumption.

Having established the theoretical implications, we quantify the impact of the MST stagnation on inflation and consumption growth. We find that the MST stagnation alone accounts for approximately 50% of the observed increase in inflation and 40% of the observed decline in consumption growth since 2014. In other words, in the absence of the MST stagnation, the aggregate inflation rate would have barely risen above 0%. Thus, our resolution to the puzzle is encapsulated in the title of this paper: the increase in inflation and weak consumption can be attributed to stagflation. However, since this resolution has largely gone unnoticed, we termed it "hidden stagflation."

Our quantification depends heavily on the structure of the model, which prompts us to validate the theoretical model. Specifically, we extensively utilize the intertemporal Euler equation. As widely recognized in the literature, the Euler equation has a range of sharp predictions that are often met with skepticism. For example, a one percentage point *permanent* increase in inflation should be associated with a one percentage point *permanent* decline in consumption growth in the long run. Furthermore, our theoretical model has a similar sharp cross-sectional implication. If a city experiences a one percentage point higher inflation than other cities, that city should exhibit a one percentage point greater decline in the growth of consumption compared to the other cities. Remarkably, we find that our data supports these sharp predictions.

Before concluding this paper, we undertake two sets of additional exercises to prove the robustness of our analysis. First, we verify that the MST stagnation is observed in many other datasets and other developed countries, including Germany and the United States. These robustness exercises are particularly important because the premise of our analysis is that the MST stagnation has occurred in Japan. Second, we explore two extensions of the model. We allow the representative consumer to have a more general utility function and introduce multiple investment goods. By introducing capital, we can also examine the effects of technology stagnation specific to information and communication technology (ICT) investment goods, which is also substantiated in our data. Our quantification results are either only slightly changed or even reinforced by these extensions.

In addition to the papers already mentioned, our study belongs to several lines of research. First, our study is related to the literature that analyzes the Japanese economy. A seminal work in this area is that of Hayashi and Prescott (2002), who examine the slowdown of economic growth by using a real business cycle model. They argue that the lost decade was largely driven by the permanent decline in the growth of total factor productivity (TFP). A follow-up study by Kawamoto (2005) scrutinizes the premise in Hayashi and Prescott (2002) that TFP growth has declined. Additionally, there are papers that examine sources of the TFP stagnation (Sekine et al. (2003), Nakakuki et al. (2004), Fukao and Kwon (2006), Caballero et al. (2008), and Muto et al. (2023)). From a theoretical perspective, Aoki et al. (2017) and Illing et al. (2018) propose alternative models for the stagnant growth in Japan. These papers typically focus on the slowdown from 1990, but our study focuses on slower economic growth and higher inflation since around 2011.

Another more specific strand of related studies is the recent literature that analyzes Japan's unconventional monetary policies or Abenomics. Hausman and Wieland (2014), Hausman and Wieland (2015), and Ito (2021) provide an initial assessment of Abenomics, and Michelis and Iacoviello (2016) study the effect of the explicit inflation target rule adopted by the BOJ in December 2012. Other related studies include that of Fukui and Yagasaki

(2023), which identifies the effect of the ETF purchase of the BOJ on stock and bond prices. We propose a new channel that explains the rise in inflation and consumption stagnation and provide a quantitative analysis.

In a broader context, our research aligns with the growing body of literature on secular stagnation, often delineated by low output, low inflation, and low nominal interest rates (Summers (2016)). Studies such as Michau (2018), Caballero and Farhi (2018), Eggertsson et al. (2019b), Eggertsson et al. (2019a), and Asriyan et al. (2021), propose a theory for secular stagnation. These papers often focus on low output level and low inflation, but not on the growth rate of output. A notable exception is Benigno and Fornaro (2018). Their model has multiple steady states, one of which has low growth and low inflation. Our paper proposes a different mechanism that explains the *rise* in inflation and *lower* consumption growth in Japan from a supply shock specific to a certain sector. Consequently, our paper resonates with studies that advocate that secular stagnation results from issues in the supply side of the economy (Gordon (2015), Barro (2016), and Ramey (2020)).

The remainder of this paper is organized in the following manner. In Section 2, we introduce our theoretical framework. Section 3 empirically analyzes the Japanese macroeconomy through the lens of the model and provides the quantification results. Section 4 confirms the robustness of our empirical findings regarding the MST stagnation. Section 5 reveals that the results of the quantification are not overturned by extending the theoretical framework. Section 6 concludes by discussing the implications of our study for the monetary policy.

2 Theoretical Framework

Our theoretical framework is a modified version of New Keynesian models that incorporate investment-specific technology shocks (e.g., Justiniano et al. (2011) and Christiano et al. (2014)). In these existing models, a final good is either consumed by a representative consumer or linearly transformed into an investment good. Unlike these models, we introduce a generic output that is linearly converted, with different efficiency, into two types of consumption goods: manufacturing and non-manufacturing goods. In our baseline model, we do not include capital accumulation, but subsequently extend the model to incorporate it in Section 5. A key assumption shared by our model and the existing models is that the government can control aggregate inflation, but not relative prices. Apart from this assumption, our model closely aligns with the canonical New Keynesian model. In fact, when the relative price of the manufacturing good is equal to one, our model boils down to the canonical New Keynesian model.

Generic-output producer. At date t, a generic output, Y_t, is produced by a perfectly competitive representative firm. The representative firm produces the generic output by combining intermediate goods $(Y_t(k))_{k\in[0,1]}$ with technology, $Y_t = \left(\int_{k\in[0,1]} Y_t(k)^{(\varepsilon-1)/\varepsilon} dk\right)^{\varepsilon/(\varepsilon-1)}$, where $\varepsilon > 1$. The representative firm maximizes its profit given the price of the generic output, P_t, and the prices of the intermediate goods, $(P_t(k))_{k\in[0,1]}$. The demand for intermediate good k is given by

$$Y_t(k) = (P_t(k)/P_t)^{-\varepsilon} Y_t. \tag{1}$$

The constant returns-to-scale production function implies that in equilibrium, the price of the generic output satisfies $P_t = \left(\int_{k\in[0,1]} P_t(k)^{1-\varepsilon} dk\right)^{1/(1-\varepsilon)}$.

Intermediate-goods firms. Intermediate good k is monopolistically supplied by intermediate-good firm k. Labor is the only input, and the production function is identical across all intermediate-goods firms:

$$Y_t(k) = A_t L_t(k), \tag{2}$$

where $L_t(k)$ is the labor demand of firm k and A_t represents the economy-wide technology. The process of A_t can be non-stationary. As in other New Keynesian models, we assume that the intermediate-goods firms are subject to pricing frictions, which are spelled out in Calvo (1983): the firms can reset their prices only with probability Θ at each date t. A firm able to reset its price at date t selects its price $\tilde{P}_t$ to maximize

$$\max_{\widetilde{P}_t} \quad E_t \sum_{k=0}^{\infty} \upsilon_{t+k}^t \Theta^k \left(\widetilde{P}_t Y_t(k) - W_t L_t(k)\right),$$

subject to (1) and (2). Variable υ_{t+k}^t is the nominal stochastic discount factor between date t and $t+k$.

Consumption-goods firms. There are two consumption goods indexed by $i \in \{m, n\}$ in this economy: the manufacturing good m and the non-manufacturing good n. There is a representative firm that produces good i. Each firm has a linear technology function, which converts the generic output to the consumption good i. The non-manufacturing-good firm has technology $Y_{n,t} = M_{n,t}$ and the manufacturing-good firm has technology $Y_{m,t} = A_{m,t} M_{m,t}$. Here, $Y_{i,t}$ stands for the amount of production by firm i and $M_{i,t}$ represents the amount of generic outputs used as intermediate goods for production. Variable $A_{m,t}$ represents *manufacturing-specific technology* (MST), which increases the quantity or quality of the manufacturing good produced, given the same amount of generic outputs used. We allow $A_{m,t}$ to be non-stationary. When $A_{m,t} = 1$ for all t, then the model boils down to the canonical New Keynesian model.

Similar to the evolution of the relative price of the investment good revealed by Greenwood et al. (1997), the relative price of the manufacturing good has been declining substantially over a long period of time (See Section 3). Because of this similarity, we assume that these representative consumption-goods firms can set their prices freely, following Justiniano et al. (2011) and Christiano et al. (2014). Then, in an equilibrium, the relative price of the manufacturing good is given by[4]

$$p_{m,t} \equiv P_{m,t}/P_{n,t} = A_{m,t}^{-1}. \tag{3}$$

This characteristic implies that the relative price is always efficient and can be used for recovering $A_{m,t}$.

Representative consumer. There is a representative consumer in this economy, whose lifetime utility function is given by

$$U = E_0 \sum_{t=0}^{\infty} \beta^t \left(\gamma_n \ln C_{n,t} + \gamma_m \ln C_{m,t} - v\left(L_t\right)\right) \quad \text{with } \gamma_n + \gamma_m = 1, \tag{4}$$

where $C_{n,t}$ is the consumption of the non-manufacturing good, $C_{m,t}$ is the consumption of the manufacturing good, L_t is labor supply, the function $v(\cdot)$ is disutility from labor, and β is the discount factor. All quantity variables are articulated on a per-capita basis.

There are two aspects worth mentioning regarding the specification of the utility function. First, we assume that the elasticity of intertemporal substitution parameter (EIS parameter for short) is one. This assumption guarantees the existence of a *balanced growth path* (BGP) of the economy, which is frequently made in medium-scale macroeconomic models.[5] Second, the instantaneous utility function implies that the shares of nominal consumption expenditure are constant. While the assumption may appear restrictive, it is supported strongly in our data (see Section 3.2).

The flow budget constraint at date t is given by

$$P_{m,t}C_{m,t} + P_{s,t}C_{s,t} + B_t = W_t L_t + R_{t-1}B_{t-1}, \tag{5}$$

where B_t is the government bond, R_t is the nominal interest rate, and W_t is the wage rate. Additionally, we assume that the representative consumer cannot short-sell the bond, $B_t \geq 0$.

[4]While relative prices are often used to estimate this type of directed technology progress in the literature (Greenwood et al. (1997)), this method may provide inaccurate estimates of technology progress. To assure credibility, we provide various robustness exercises in Section 4.

[5]In Section 5, we consider the cases in which the EIS parameter is not unity.

The representative consumer maximizes her utility U subject to the flow budget constraints and the short-selling constraints.

Government. As shown in Section 3.2, the effective lower bound on the nominal interest rate has been binding since the mid 1990s. In light of this observation, we simply assume that the nominal interest rate is pegged, $R_t = \bar{R} \geq 1$. This assumption can be also interpreted in the following manner: The government implements a Taylor rule with a large coefficient on the inflation rate. Then, as shown by Benhabib et al. (2001), there are two steady states: target inflation equilibrium and deflationary equilibrium. Given this monetary policy rule, it can be considered that the Japanese economy remains stuck at the deflationary equilibrium and the nominal interest rate is at the effective lower bound. Since these two policies are observationally equivalent, we adopt the former interpretation for simplicity. Moreover, as in the standard New Keynesian model, the net bond supply is zero.

Market Clearing Conditions and Equilibrium. The market clearing conditions for generic output and consumption goods are

$$\begin{aligned} M_{n,t} + M_{m,t} &= Y_t, \\ C_{i,t} &= Y_{i,t}, \end{aligned}$$

and the labor market clearing condition is

$$L_t = \int_{k \in [0,1]} L_t(k)\, dk.$$

We adopt the standard competitive equilibrium concept for our analysis. Moreover, because technology processes $(A_t, A_{m,t})$ are non-stationary, our analysis focus on a BGP of the economy and the fluctuations around it. A BGP is a particular type of competitive equilibrium in which all the endogenous variables grow at constant, but not necessarily the same, rates. Let g_X denote the growth rate of variable X along the BGP. By allowing a slight abuse of notation, let g_{X_t} denote the growth rate of variable X at date t.

Macroeconomic Variables. Because there are multiple goods in this economy, we must specify how they are aggregated to define inflation and consumption. We define these variables as mimicking the national accounts. The growth rate of aggregate consumption is calculated as the weighted average of consumption growth rates, using the relevant nominal consumption shares as done in the official national accounts:[6]

$$g_{C_t} \equiv \gamma_n g_{C_{n,t}} + \gamma_m g_{C_{m,t}}.$$

Lastly, we define the inflation rate as the weighted average of the individual inflation rates using the same weights:

$$\pi_t \equiv \gamma_n \pi_{n,t} + \gamma_m \pi_{m,t}, \tag{6}$$

where $\pi_{i,t}$ is the inflation rate of good i, $\pi_{i,t} \equiv \ln P_{i,t}/P_{i,-1}$.

3 Empirical Analysis

In this section, we analyze the uptick in inflation through the lens of the theoretical model developed in Section 2. Our analysis begins with an overview of the data, followed by a detailed quantification. Finally, we conduct validation exercises to assess the robustness of our model.

3.1 Data

We mainly rely on the National Accounts of Japan (JSNA) with the benchmark year of 2011, which covers the period from 1994 to 2018.[7] Throughout our paper, we use the JSNA price indexes and real sequences. We categorize consumption expenditure into two groups: manufacturing and non-manufacturing. The former category includes expenditure on durables produced by the manufacturing sector and the latter includes all other consumption expenditures.[8] We choose this categorization based on the evidence presented in Figure 3. It

[6]In this economy, aggregate consumption corresponds to real GDP, not Y_t.

[7]Those familiar with the Japanese economy may question the extent of the impact of the hike in value added tax (VAT), which was implemented in April 2014. We eliminate the mechanical components of price increases due to the hike (see Appendix A.1.2 for the details), but cannot eliminate the impacts on prices and quantities resulting from endogenous reactions by households. However, the impacts of the VAT hikes on the annual growth rate of consumption are expected to be small. For example, Cashin and Unayama (2016) study the VAT hike in April 1997 and find that the consumption level of durables rose right before the implementation of the VAT hike (March), but declined when the VAT hike was implemented (April). Thus, if we take the annual average growth rate, the impact of the VAT hike on consumption growth is minute.

[8]In this paper, we ignore the durability of the manufacturing good. This simplifying assumption is frequently used in macroeconomic analysis (e.g., Nakamura and Steinsson (2010), Wolman (2011), and Herrendorf et al. (2021)). Moreover, if we incorporate the durability of the manufacturing good, as done by Erceg and Levin (2006), our New Keynesian model has an unrealistic implication. Specifically, if the nominal interest rate is pegged, a persistent shock to the TFP growth rate has unrealistically huge effects on the economy. A similar phenomenon occurs in the three-equation New Keynesian model. There are many ways to fix this unrealistic implication of the model due to the durability of the manufacturing good. See Section 3 of the Online Appendix, which explains this unrealistic implication and how to fix it by introducing cognitive discounting (Gabaix (2020)). We could, in principle, combine these models and analyze permanent

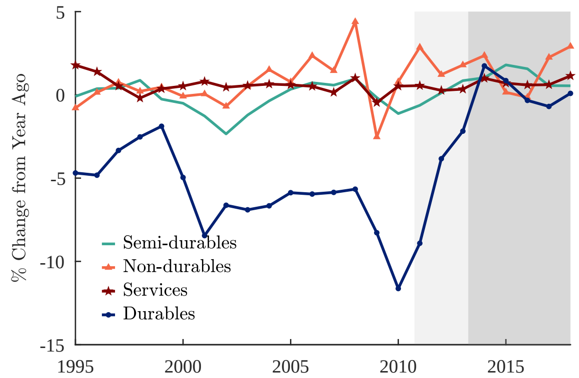


Figure 3: Inflation by Subcategory

illustrates that the average inflation levels for non-durable goods, semi-durable goods, and services are approximately equal. This allows us to group them together as a composite good, thereby simplifying our analysis.[9] For the sake of brevity, we call the category non-manufacturing "good" although it includes services and some of the manufacturing goods.[10] Appendix A provides additional details regarding the the data construction.

A quick look at Japanese data yields three findings. First, the data substantiate the use of the Cobb-Douglass preference in our model. Although the price of the manufacturing good decreased by 64% from 1994 to 2011 compared to the price of the non-manufacturing good, the share of the manufacturing good has remained virtually unchanged during this period (see Figures 4a and 4b). This empirical pattern suggests that the elasticity of substitution between the consumption goods is approximately one.[11] We set γ_m to the average value of the share of the manufacturing good in total expenditure—$\gamma_m = 10.1\%$.

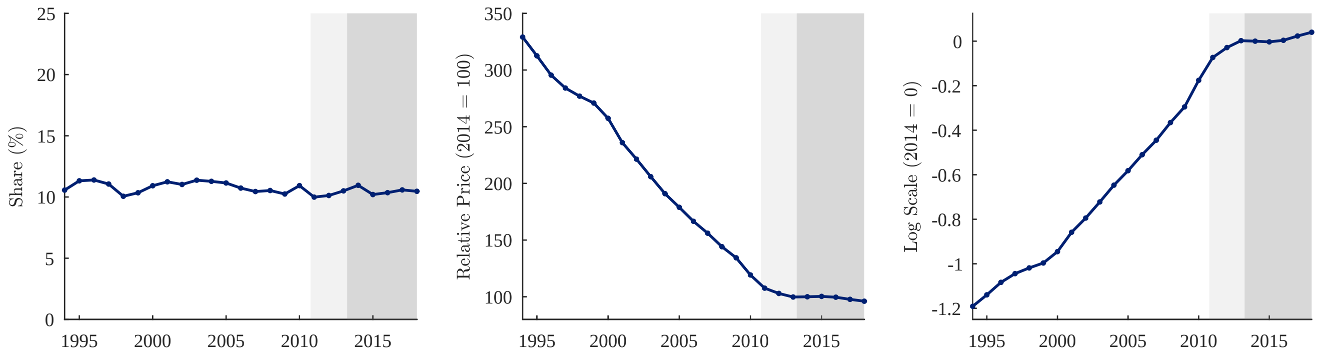
Second, as mentioned in the introduction, the inflation rate of the manufacturing good $\pi_{m,t}$ increased sharply compared to that of the non-manufacturing good $\pi_{n,t}$ since around 2010. Equation (3) implies that this sharp rise in the relative price reflects the technology stagnation of the manufacturing-good firm. To visualize the stagnation at a glance, we depict the MST in Figure 4c. As evident from Figure 4c, the growth rate of $A_{m,t}$ declined permanently in the last decade. The growth rate from 2014 onward decreased by 5.9 percentage points compared to that up until 2010. In the next subsection, we explore the implications

technology shocks, which requires a global, not local to a steady state, analysis. Such analysis is left for future research.

[9]The same analysis is undertaken without constructing this composite good. The quantitative results are largely unchanged. To simplify the notation and our analysis, we group them together.

[10]One may wonder whether calling the composite good as a non-manufacturing good is suitable. One justification is that its sizable component is food and services, which are often not considered to be manufacturing goods. See, for example, Herrendorf et al. (2014).

[11]The same observations hold true for the United States, which led Wolman (2011) to adopt the Cobb-Douglas preference.



(a) Share of Manufacturing (b) Relative Price $P_{m,t}/P_{n,t}$ (c) Logarithm of MST

Figure 4: The Prices and the Share of the Consumption of the Manufacturing Good

of this dramatic and permanent change in MST.

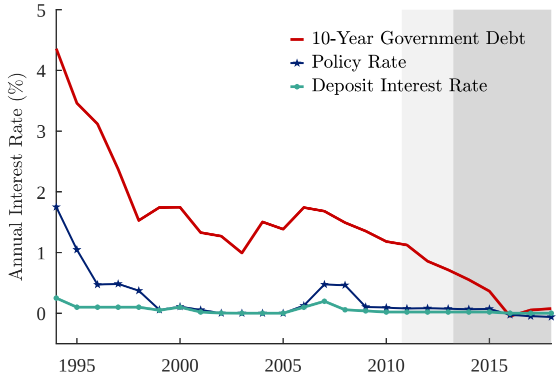
The final observation is that Japanese consumers have faced nominal interest rates at their effective lower bound. Figure 5a displays the policy interest rate, the 10-year government bond interest rate, and the average deposit interest rate faced by Japanese households. In the late 1990s, in response to the banking crisis, the BOJ drove its policy rate to near-zero range and has been effectively trapped in the range.[12] However, the zero interest rate alone was not sufficient to revive the economy. To stimulate the economy, the BOJ has introduced various unconventional monetary policies. In recent years, the BOJ has focused on measures to lower longer-term interest rates to deal with the ongoing economic downturn and deflation.

While the 10-year government bond interest has been positive most of the time, the deposit interest rate has hovered near-zero since the early 1990s. Thus, from the consumers' viewpoint, the nominal interest rate has been at the effective lower bound. Furthermore, there is another factor preventing the BOJ from changing its nominal interest rate. The Abe administration pressured the BOJ to adopt an explicit 2% inflation targeting rule. As long as the aggregate inflation rate remains below the target level, the BOJ has been politically unable to raise nominal interest rates. These considerations support one of our modeling assumptions that the BOJ effectively pegs its nominal interest rate at the the lower bound.[13]

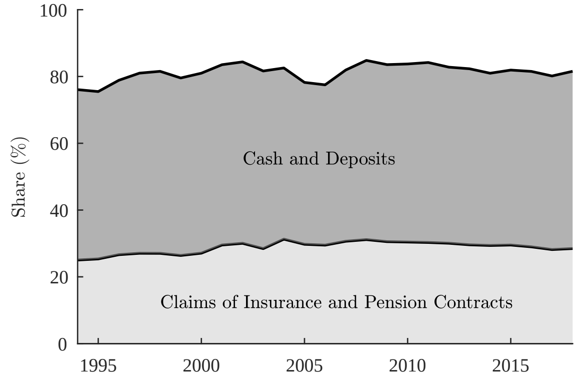
One might question whether the deposit interest rate accurately reflects the marginal

[12] In 2006-2007, the BOJ attempted to move away from the near-zero policy rate that had been in place. Unfortunately, the onset of the global financial crisis necessitated a halt in the attempt.

[13] Since 2022, Japan's inflation rate has exceeded the 2% target. However, as of August 28, 2023, the BOJ has not raised the policy rate, while other central banks have significantly tightened monetary policies. On August 2, 2023, Deputy Governor Uchida explained the BOJ's policy, stating, "...sustainable and stable achievement of the price stability target of 2 percent has not yet come in sight." This situation highlights the difficulty the BOJ faces in raising the nominal interest rate. The transcript can be downloaded from this URL.



(a) Various Interest Rates



(b) Asset Composition of Households

Figure 5: Monetary Policy and Asset Composition of Japanese Households

Notes. The deposit interest rate and the policy rate are downloaded from the website of the BOJ. The ID for the deposit interest rates is IR02'DLDR120. The policy rate is taken from the official discount rate (ID: IR01'MADR1Z@D) until September 1995 and the call rate (uncollateralized overnight, ID: FM02'STRACLUCON and FM01'STRDCLUCON) since October 1995. The interest rate for the 10-year government bonds are downloaded from the website of the Ministry of Finance, Japan. The Annual Report on National Accounts for 2018, Part of Stock II Accounts classified by Institutional Sectors in JSNA, provides the data for Figure 5b.

interest rate that Japanese households face. Figure 5b displays the asset composition of Japanese households, revealing that their assets primarily comprise deposits and cash, followed by illiquid claims of insurance and pension contracts. Deposits and cash account for approximately 50% of the total financial assets of Japanese households and claims of insurance and pension constitute roughly 30%. This portfolio pattern is in stark contrast to that of the United States where deposits and cash accounts for merely around 10% and claims of insurance and pension constitute a similar share of nearly 35%.[14] Furthermore, data from a survey conducted by the Japan Securities Dealers Association indicates that over 70% of households did not possess any equity during this sample period.[15] These facts suggest that the marginal interest rate most relevant to households is likely the deposit interest rate, which has been at its effective lower bound: $\ln R_t = \bar{r}$.[16]

[14]This claim is based on Table B.101.h of Financial Accounts of the United States from the webpage of the Board of Governors of the Federal Reserve System.

[15]The survey data can be retrieved from Figure 6 (page 149) in the PDF file, `https://www.jsda.or.jp/shiryoshitsu/toukei/2021jikeiretuhyou.pdf`.

[16]In our analysis, the term "consumption" does not include rent. However, it is important to note that these factors might indirectly influence overall consumption patterns. Specifically, a decrease in the interest rates on long-term government bonds could potentially lead to reduced mortgage rates for existing homeowners, generating income effects and thereby leading higher consumption. However, according to the findings of Hausman et al. (2019), such transmission to mortgage rates for existing homeowners has been rather limited. Consequently, although this transmission channel is theoretically plausible, its quantitative impact in the context of Japan appears to be limited.

3.2 Quantification

Building upon our model, we are now ready to derive the theoretical implications of a *permanent* decline in the growth rate of $A_{m,t}$ (the MST shock for short) for aggregate inflation and consumption. Our analysis hinges on the following insight: when an MST shock occurs, it impacts the efficiency of the manufacturing-good firm, which is evident from the change in its relative price. Since the manufacturing-good firm is not subject to any pricing frictions, this movement of the relative price is, in fact, efficient. Moreover, the unit elasticity of substitution between goods and the pegged interest rate implies that income effects on labor supply, savings, and consumption of the non-manufacturing good offset the corresponding substitution effects. Thus, only consumption and the price of the manufacturing good are influenced by the MST shock. Consequently, this relative price change directly influences aggregate inflation and consumption. Below, we formalize this insight.

Recall the optimality conditions for the representative consumer are

$$\frac{P_{m,t}C_{m,t}}{\gamma_m} = \frac{P_{n,t}C_{n,t}}{\gamma_n}, \quad v'\left(L_t\right)\frac{C_{n,t}}{\gamma_n} = \frac{w_t}{P_{n,t}} \tag{7}$$

$$E_t\frac{C_{n,t+1}}{C_{n,t}}\frac{\bar{R}P_{n,t}}{P_{n,t+1}} = 1, \quad \lim_{t\to\infty} E_0\beta^t\frac{B_t}{P_{n,t}C_{n,t}} = 0, \tag{8}$$

and the flow budget constraints (5). Let $(C_{n,t}, C_{m,t}, L_t, B_t)$ denote an optimal (state-contingent) allocation given some equilibrium price system, $\left(P_{n,t}, P_{m,t}, w_t, \bar{R}\right)$. Suppose that the price of the manufacturing good $P_{m,t}$ increases to $P'_{m,t}$ due to the decline in $A_{m,t}$. Then, an allocation $\left(C_{n,t}, C'_{m,t}, L_t\right)$, where $C'_{m,t} = P_{m,t}/P'_{m,t}C_{m,t}$, satisfies all the above conditions and the budget constraints given $\left(P_{n,t}, P'_{m,t}, w_t, , \bar{R}\right)$. Thus, labor supply, saving, and consumption of non-manufacturing goods do not react to a shock on $P_{m,t}$. Moreover, the demand for generic output remains unaffected:

$$M_t = \frac{1}{A'_{m,t}}C'_{m,t} = \frac{P'_{m,t}C'_{m,t}}{P_{n,t}} = \frac{P_{m,t}C_{m,t}}{P_{n,t}}.$$

We take advantage of this property to fully characterize the dynamic responses of the minimum-state-variable solution to the MST shock.[17] Suppose that an unexpected shock occurs at date t_0 and the growth rate of $A_{m,t}$ shifts from $g_{A_{m,t}}$ to $g_{A_{m,t}} + \hat{g}_{A_{m,t}}$, where

$$\hat{g}_{A_{m,t}} = \left(1 - \rho^{t-t_0+1}\right)\hat{g}_{A_m}. \tag{9}$$

[17] Here, we focus our analysis on minimum-state-variable (MSV) solutions since we are primarily interested in the permanent change in aggregate inflation. Although accommodating sunspot shocks could potentially cause fluctuations in the inflation rate of the non-manufacturing good, the long-run implications remain consistent. Additionally, Angeletos and Lian (2023) reveal a certain fragility of non-MSV solutions that provides a justification for focusing on the MSV solutions.

Parameter $\rho \in (0, 1)$ governs how quickly $\hat{g}_{A_{m,t}}$ converges to $\hat{g}_{A_m}$. Since only consumption and inflation of the manufacturing good are affected by the changes in $A_{m,t}$, equilibrium consumption and inflation under the MST shock are simply given by

$$\hat{g}_{C_{m,t}} = \hat{g}_{A_{m,t}} \quad \hat{g}_{C^*_{n,t}} = 0 \tag{10}$$

$$\hat{\pi}^*_{m,t} = -\hat{g}_{A_{m,t}} \quad \hat{\pi}^*_{n,t} = 0, \tag{11}$$

where $\hat{g}_{C_{m,t}}$ represents the impulse response of consumption growth of the manufacturing good to the MST shock relative to the initial equilibrium consumption growth. Similarly, the other variables with the "hat" notation $(\hat{})$ stand for the corresponding impulse responses. Using equations (10) and (11), we can obtain the impulse responses to aggregate inflation and consumption growth:

Proposition 1. *Consider MST shock (9). Then, the impulse responses of aggregate inflation and consumption growth to the MST shock are given by*

$$\hat{\pi}_t = -\gamma_m \hat{g}_{A_{m,t}} \tag{12}$$

$$\hat{g}_{C_t} = \gamma_m \hat{g}_{A_{m,t}}. \tag{13}$$

Figure (6) illustrates the MST shock (9) and the impulse response of aggregate inflation (12). Aggregate inflation depends solely on the MST shock and gradually converges to a new steady-state level. As indicated by equation (13), the impulse response of aggregate consumption mirrors that of the inflation rate. [18]

Having established the theoretical implications, we quantify the impact of the MST shock using Proposition 1. We assume that the MST shock occurs in year 2011 ($t_0 = 2011$) and almost converges to its steady-state value, $\hat{g}_{A_m}$, by the year 2014, as suggested by Figure 3. Let $\hat{g}_{C_\infty}$ and $\hat{\pi}_\infty$ denote the associated new steady-state values:

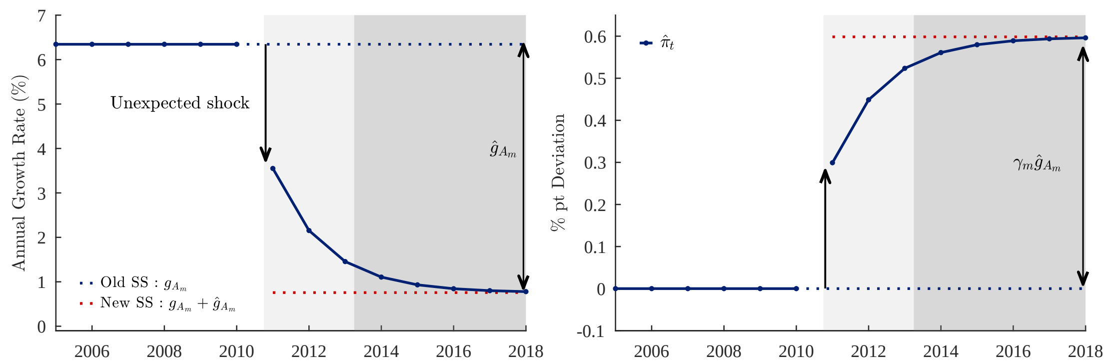
$$\hat{g}_{C_\infty} = \gamma_m \hat{g}_{A_m} \tag{14}$$

$$\hat{\pi}_\infty = -\gamma_m \hat{g}_{A_m}. \tag{15}$$

We measure the size of the MST shock, $\hat{g}_{A_m}$, as the difference in average growth rate of the MST until 2010 and since 2014: $\hat{g}_{A_m} = -5.9\%$.

Table 1 encapsulates the findings of our steady-state analysis. According to the data,

[18] One might be wondering how this paper is related to the Neo-Fisherian debate (Uribe (2022)). The debate is regarding how the permanent changes in policy nominal rates affect other interest rates and inflation in the short run. In our context, the nominal interest rate is pegged so that our paper is not directly related to the debate. In terms of the dynamics, our model implies that the permanent shock on the growth rate of MST increases the inflation in both the short and long run, which is largely consistent with the data.



(a) Shock (b) Aggregate Inflation Rate, $\hat{\pi}_t$

Figure 6: Impulse Responses

Notes: we set ρ to 0.5.

there was a rise in the aggregate inflation rate by 1.24 percentage points. Notably, roughly half of this increase can be attributed to the MST shock alone. To delve deeper into this impact, we explore a counterfactual scenario in which the MST did not experience stagnation since 2011. Our analysis suggests that in such a scenario, the aggregate inflation rate would have lingered around 0.4%, a rate considerably closer to zero than the actual, although still positive. Therefore, we conclude that the MST shock has been a pivotal factor in driving the inflation observed in Japan since 2014.[19]

However, the rise in inflation caused by the MST shock is by no means a signal that the economy is performing well. In fact, according to our model, the MST shock reduces aggregate consumption growth by -0.59 percentage points. It might be tempting to compare this number with the change in the growth rate of aggregate consumption per capita. However, such a comparison could lead to an overestimation, since during the Abenomics period, labor market participation for older people and women increased more rapidly than earlier. The observed increase might partially be a result of the government effectively increasing the retirement age to 65 years from April 2013 onward, a factor that our current model does not account for. [20] Therefore, it would be prudent to compare $\hat{g}_{C_\infty/L_\infty}$ with its data counterpart, which more accurately captures the effect of the MST shock.[21] According to our analysis, 40% of the observed decline in consumption growth is explained by the MST

[19]While we assume that the manufacturing good is perishable, durability of the manufacturing good does not affect our steady-state analysis. This is because along the BGP, the growth rates of purchase of durable good and its stock are equal.

[20]There seem to be other factors such as delayed exit from labor market of Japanese baby boomers who are rather concentrated cohort born in 1947-49. This baby boomer generation has remained in the labor market well beyond the retirement age.

[21]When we conduct validation exercises in the next subsection, we examine the change in the growth rate of manufacturing consumption per capita. This is the correct counter-part because we use the Euler equation of the representative consumer.

	MST-Induced Change in Model	Data Counterpart
$\hat{\pi}_\infty$	0.59% pt	1.24% pt
$\hat{g}_{C_\infty}$	−0.59% pt	−0.59% pt
$\hat{g}_{C_\infty/L_\infty}$	−0.59% pt	−1.41% pt
$\hat{\pi}_\infty + \hat{g}_{C_\infty/L_\infty}$	0% pt	−0.17% pt

Table 1: Steady-State Result for Macro Variables

Notes. The data-counterpart of $\hat{\pi}_\infty$is the difference between the average inflation before 2011 and since 2014. The data counterparts of the other variables are similarly computed.

shock. Thus, the model can simultaneously account for the rise in inflation and the weak real consumption, thereby providing a resolution to the puzzle. The puzzling weak consumption accompanied with the rising inflation can be interpreted as a manifestation of stagflation that results from the MST shock.

Discussions There are five aspects worth mentioning with regard to Proposition 1 and our baseline results. First, within our framework, the impulse responses are not sensitively affected by the representative consumer's expectations of the evolution of the MST shock. To help understand this aspect, consider the canonical three-equation New Keynesian model under a Taylor rule that satisfies the Taylor principle. Imagine the following two cases: TFP temporarily rises only today, or TFP has permanently risen from today onward. The inflation rate declines today in the first case, whereas it rises in the second case. Note that in both cases, the TFP level increases today. The response of inflation depends delicately on whether the representative consumer perceives that the TFP shock is temporary or permanent.[22] In contrast, our model does not have this sensitivity issue. A negative MST shock increases the relative price of the manufactured good.Consequently the inflation rate today always increases, irrespective of whether the MST shock is perceived as a temporary or permanent shock. In this dimension, our impulse response analysis is robust.

Second, our analysis does not eliminate the possibility that the Japanese economy is in a liquidity trap with a permanently negative output gap. To elaborate on this aspect, note that along the BGP, Y_t is expressed in the following manner: $Y_t = \Gamma \times A_t \times L^*$, where L^* is the efficient level of employment along the BGP and Γ represents the distortion stemming

[22] These results are well-known in the literature, but for completeness, we derive them in Section 3.1 of the Online Appendix.

from the nominal pricing friction.[23] If Γ is less than one, the real GDP is lower than the efficient level. In other words, the economy has a permanently negative output gap. Because our argument holds for any level of Γ, our quantification results remain valid even if the economy is in a liquidity trap with a permanently negative output gap.

Third, Proposition 1 holds even if the saving function of the representative consumer is not horizontal. The key property underpinning Proposition 1 is that the MST shock affects only the consumption of the manufacturing good, not saving, labor supply, or the consumption of the non-manufacturing good. In Appendix B, we introduce an overlapping generations model in which the asset supply curve is upward-sloping and demonstrate that Proposition 1 still holds.

Fourth, our argument relies on the premise that the BOJ is constrained at its effective lower bound, $R_t = \bar{R}$. Interestingly, even if the BOJ is not constrained and is free to choose any interest rate rule, it is optimal for the BOJ not to respond to the MST shock. This is because the MST shock impacts efficiency without causing any distortions. Consequently, the BOJ should disregard the relative price movements triggered by the MST shock. This result follows from Aoki (2001). Furthermore, Wolman (2011) shows that in our context, the optimal trend inflation rate is negative as long as there is the MST progress. Conversely, when the MST slows down, the optimal trend inflation rate rises. Both studies indicate that the BOJ should aim to minimize efficiency losses due to price distortions and ignore efficient price fluctuations.

Finally, our baseline results have policy implications for Japan. A conventional interpretation of the recent increase in inflation attributes this increase to the unconventional monetary policies by Governor Kuroda. However, our baseline results suggest an alternative explanation: the BOJ's monetary policy is effectively constrained, thereby leading Japan to experience a rise in inflation driven by the MST shock. Consequently, Japan has concurrently faced an inflation and a stagnation in real consumption. As such, Governor Kuroda's triumphant declaration that "Japan's economy is finally no longer in deflation" appears premature and potentially misleading. Our findings serve as a cautionary note against drawing simplistic conclusions regarding the Japanese economy based solely on the analysis of the headline aggregate inflation rate.[24]

[23] When $A_{m,t} = 1$, then Γ corresponds to the GDP gap.

[24] This quote is from Governor Kuroda's speech at the 2019 Michel Camdessus Central Banking Lecture, International Monetary Fund. The transcript can be downloaded from https://www.boj.or.jp/en/about/press/koen_2019/data/ko190723a1.pdf.

3.3 Validation of the Key Mechanism

Thus far, we have used our model to explore the implications of the MST stagnation when the interest rate is effectively pegged. To derive Proposition 1, we rely heavily on the Euler equations of the representative consumer. Unfortunately, the Euler equations have sharp implications for the change in inflation and consumption growth rate. Since these implications have not yet been empirically established in the existing literature, readers may question the reliability of our findings. To ensure our study's credibility, we conduct two validation exercises in this subsection. In the first exercise, we examine the model's time-series implications. In the second exercise, we study the cross-sectional implications of the model.

We begin by deriving the implications for the steady-state changes. The steady-state version of the intertemporal Euler equation is

$$g_{C_i} = \ln\beta + r - \pi_i. \tag{16}$$

Let operator $\mathbf{d}$ stand for the change from an initial steady-state value to a final steady-state value. It should be noted that this $\mathbf{d}$ operator conceptually differs from the "ˆ" operator, which extracts steady-state changes solely induced by the MST shock. Applying the $\mathbf{d}$ operator to equation (16), we obtain

$$\mathbf{d}g_{C_i} = \mathbf{d}\ln\beta - \mathbf{d}\pi_i. \tag{17}$$

Here, we assume that the nominal interest rate is pegged, $\mathbf{d}r = 0$, and allow the possibility that the discount factor β changes.[25] According to equation (17), an increase in the long-run inflation by one percentage point leads to a corresponding decline in consumption growth by one percentage point. This sharp theoretical prediction closely resembles the classic Fisher effect, where nominal interest rates and inflation move together in the long run.[26] In our model, when the nominal interest rate is instead pegged, inflation and consumption growth move exactly in opposite directions in the long run, a prediction we refer to as the *Fisher-like effect*.

The presence of $\mathbf{d}\beta$ prevents us from directly applying equation (17) to the data. We eliminate this unobserved term by using equation (17). Equation (17) holds for $i = n, m$, so that

$$\mathbf{d}g_{C_m} - \mathbf{d}g_{C_n} = -\left(\mathbf{d}\pi_m - \mathbf{d}\pi_n\right). \tag{18}$$

[25] For example, Braun and Nakajima (2012) and Werning (2015) propose heterogeneous-agent models in which the discount factor of "the representative agent" in their models is endogenously determined.

[26] See Uribe (2022) for empirical evidence supporting this classic Fisher effect.

	Until 2010	Since 2014	Change
$\pi_m - \pi_n$	-6.3%	-0.7%	5.6% pts
$g_{C_m} - g_{C_n}$	6.6%	0.6%	-6.0% pts

Table 2: Time-Series Evidence

We examine whether this modified version of the Fisher-like effect is supported by our data. Table 2 presents the data counterpart of $\mathbf{d}\pi_m - \mathbf{d}\pi_n$ and $\mathbf{d}g_{C_m} - \mathbf{d}g_{C_n}$. As evident from Table 2, equation (18) holds true: the relative inflation rate increases by 6.2 percentage points, and this relative increase is accompanied by an almost equal decline in the associated relative consumption growth by 6.0 percentage points. In the long run, the relative consumption growth rate and the relative inflation rate move precisely in opposite directions, thereby confirming the Fisher-like effect in our time-series data.[27]

While the time-series evidence is clear at first glance, it essentially provides us with a single data point. Therefore its reliability must be carefully scrutinized. To gain more credibility, we present additional cross-sectional evidence. We begin by extending the model geographically, assuming that there is a representative consumer for each city indexed by a. Then, the Euler equation (16) holds for all city a:

$$g_{C_m^a} = \ln\beta + r - \pi_m^a, \tag{19}$$

where $g_{C_m^a}$ is the growth rate of manufacturing consumption in city a and π_m^a is the corresponding inflation rate. Note that the nominal interest rate is common across cities.[28] Again, applying the $\mathbf{d}$ operator to equation (19), we obtain the following equation:

$$\mathbf{d}g_{C_m^a} = \mathbf{d}\ln\beta - \mathbf{d}\pi_m^a. \tag{20}$$

If city a experiences inflation that is higher by one percentage point than that in the other cities, its corresponding consumption growth rate will be lower by one percentage point than that of the the others. Consequently, our model also has a sharp prediction for cross-sectional patterns of inflation and consumption growth. Assuming that the changes in the discount factor are common across a, we examine whether equation (20) is supported by the data.

The exact same inflation measure of the manufacturing good by each city, as the national counterpart, is unfortunately unavailable. Thus, we aggregate the city-level inflation rates of

[27] When the discount factor is truly exogenous, we can directly take equation (17) to the data. The inflation rate of the manufacturing good increased by 6.2 percentage points and the corresponding consumption growth rate declined by 5.9 percentage points. Thus, we confirm the Fisher-like effect for the case in which β is exogenous as well.

[28] Indeed, deposit interest rates differ only slightly among cities in Japan.

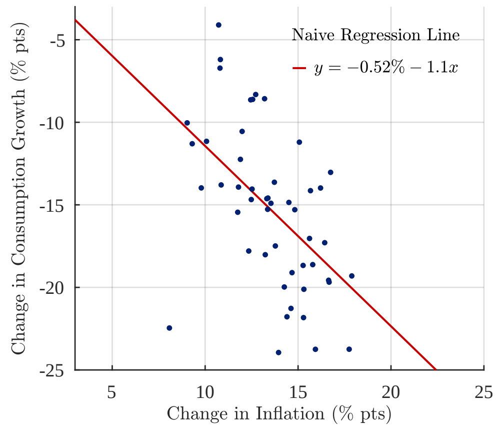


Figure 7: Cross-Sectional Fisher-Like Effect

home appliances and furniture, computer hardware, and audio-visual equipment to construct the empirical counterpart of $\mathbf{d}\pi_m^a$. Similarly, we apply the same aggregation method to construct the empirical counterpart of $\mathbf{d}g_{C_m^a}$. See Appendix A.4 for a detailed explanation of our construction of these variables.

In Figure 20, we plot the change in inflation, $\mathbf{d}\pi_m^a$, on the horizontal axis, and the corresponding change in real consumption, $\mathbf{d}g_{C_m^a}$, on the vertical axis for each major city a. Most observations lie on the -45 degree line. Indeed, the naive regression indicates that the slope is approximately -1, as predicted by the cross-sectional version of Fisher-like effect, (20). While the confidence interval of the coefficient of the naive regression is not tight, $[-1.6, -0.6]$, we find evidence that the implication of the cross-sectional Fisher-like effect (20) is at least consistent with our data.

4 Robustness of the MST Stagnation

In line with previous literature, we assume that the relative output price of the manufacturing good reflects the MST, $A_{m,t}$. However, there are several factors that could lead to inaccuracies in this method of recovering the MST. For example, trade and market power have a direct impact on output prices. The observed increase in the relative price of the manufacturing good may result from factors unrelated to technology. This raises legitimate concerns regarding our finding that the MST has stagnated. To ensure the credibility of our findings, we conduct four robustness exercises in this section.

First, we compare the MST obtained through our method with the TFP of manufacturing sectors published by the Japan Industrial Productivity Database 2021, which is a KLEMS-type data. We refer to the database simply as KLEMS. Second, we scrutinize the impact of both international and domestic sectoral trade on relative prices, utilizing data from the World Input Output Database (WIOD) and Japan's import price index.[29] Third, we explore the effect of markups on relative prices, motivated by the recent research (Loecker and Eeckhout (2021); Loecker et al. (2020)) that reveals that markups in the U.S. have increased significantly. It is natural to imagine that a similar phenomenon may have occurred in Japan. If this is the case, our relative price would reflect relative market power, not technology. We examine whether it is a legitimate concern. Finally, we demonstrate that the MST stagnation is a common phenomenon observed across developed countries. Based on these additional analyses, we affirm that our finding of the MST stagnation is indeed robust.

4.1 TFP Estimate by KLEMS

KLEMS directly measures sectoral output and various inputs, and subsequently deduces sectoral TFP in domestic production through growth accounting decomposition. This approach is advantageous as it is less susceptible to issues arising from the use of relative prices of final goods. For example, if the relative price of the manufacturing good decreases due to a decline in the prices of imported final goods, this movement is not considered a technological improvement in the sectoral TFP by KLEMS.[30] Furthermore, this approach only requires that sectoral production functions exhibit constant-returns-to-scale. Because of these favorable properties, TFP sequences by KLEMS-type data are frequently used in the literature (e.g., Carvalho and Gabaix (2013).)

Figure 8 displays our estimated MST and the manufacturing TFP obtained from KLEMS.[31] Until 2010, both increased steadily and significantly, even though their average growth rates differed. However, since around 2011, they began stagnating, and since 2014, they have almost stopped improving. Thus, we confirm that the TFP by KLEMS has also stagnated as our estimated MST. In fact, this finding is consistent with the previous studies by Basu et al. (2013) and Fernald (2015) who argue that the low-frequency movement of relative prices reflect technological progress.

[29] See Timmer et al. (2015) for a detailed description of the dataset.

[30] Sectoral linkage might affect both the relative prices and sectoral TFP. This issue is scrutinized in the next subsection.

[31] We calculate the KLEMS counterpart of the productivity of manufacturing good by taking a weighted average of the sectoral TFP from KLEMS, which aligns with our definition of the manufacturing good. We use weights that are proportional to consumer purchases from the manufacturing sectors. See Appendix A.3 for a more detailed explanation.

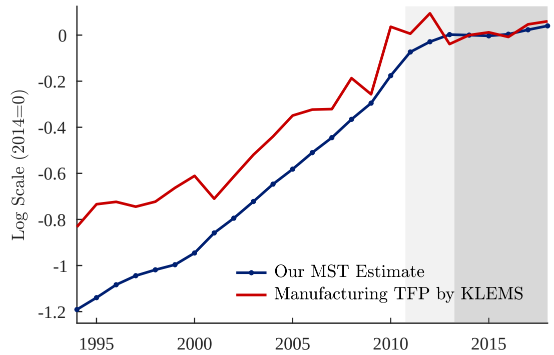


Figure 8: Comparison of the Estimates of Technology

4.2 Evidence from WIOD and Import Price

In the first exercise above, we do not directly account for the effects of international and domestic sectoral trade and/or exchange rates. In this subsection, we aim to do so by employing the methodology developed by Auer et al. (2019).[32]

Auer et al. (2019) delineate a model that explicitly captures international and domestic sectoral linkages of production networks. In their model, the unit nominal cost function for a given sector s in country i is given by $W_{i,s,t} = F_{i,s}\left(\chi_{i,s,t}, \mathbf{P}_{i,s,t}\right)$, where $\chi_{i,s,t}$ denotes the effective cost of non-material inputs (e.g., labor, capital, and technology) and $\mathbf{P}_{i,s,t}$ is a vector of intermediate input prices, $\mathbf{P}_{i,s,t} = \left(P_{ji,ks,t}\right)_{j,k}$. This price vector encapsulates the global input-output linkages. Under certain conditions, they show that the inflation of sector s in country i can be decomposed as a weighted average of the growth rate of $\chi_{i,s,t}$ and the inflation rates:

$$\pi_{i,s,t} = \underbrace{\gamma^C_{i,s,t-1}\Delta\ln\chi_{i,s,t}}_{\text{Own Contribution}} + \underbrace{\sum_{j,k}\gamma_{ji,ks,t-1}\pi_{j,k,t}}_{\text{Linkage Contributions}} \quad \text{with } \gamma^C_{i,s,t-1} + \sum_{j,k}\gamma_{ji,ks,t-1} = 1, \tag{21}$$

where $\gamma^C_{i,s,t-1}$ is the share of the non-material inputs in the gross output, and $\gamma_{ji,ks,t-1}$ is the share of the material input from sector k in country j in the gross output. Notably, all the variables, except $\Delta\ln\chi_{i,s,t}$ in equation (21) are observable in the WIOD. Therefore, we are able to infer $\Delta\ln\chi_{i,s,t}$ by solving equation (21). Equation (21) enables us to determine whether inflation in a sector is driven by the cost of its own non-material inputs, $\gamma^C_{i,s,t-1}\Delta\ln\chi_{i,s,t}$, or by the factors originating from international and domestic sectoral trade linkages, $\sum_{j,k}\gamma_{ji,ks,t-1}\pi_{j,k,t}$.

Our analysis focuses on the decomposition of the inflation rate of the sector in the WIOD industry classification that most closely aligns with our narrow definition of the manufac-

[32] For the sake of completeness, we provide a detailed explanation in Section 1 of the Online Appendix.

turing sector (i.e., durable goods sector). Specifically, we examine sector C26, "Manufacture of computer, electronic, and optical products" in Japan. Additionally, to facilitate easier comparison, we subtract the inflation rate of the non-manufacturing good $\pi_{n,t}$ from both sides of equation (21).

In Figure 9a, the relative price, the level of the own contribution, and the level of the linkage contributions are depicted. Due to the coverage of the latest edition of the WIOD, we can only plot them from the year 2000 until the year 2014. Nevertheless, Figure 9a provides useful information. First, the relative price of sector C26 exhibits a similar pattern to the relative price of the manufacturing good: it declined consistently until around 2011, and then ceased to do so. According to decomposition (21), own contribution has increased sharply since 2012, thereby causing the relative price to stop declining.

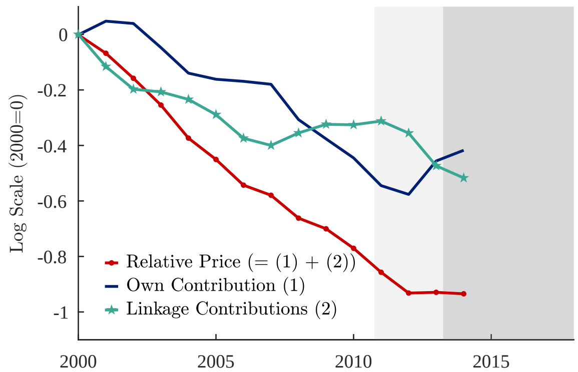
Unfortunately, current data limitations prevent us from ascertaining whether the observed trends have persisted after 2014. In an effort to supplement our analysis from a different perspective, we turn our attention to the import price index. In Figure 9b, we depict the import price of "Computers and Peripheral Equipment" relative to the import price of "Electric and Electronic Equipment," excluding "Computers and Peripheral Equipment." It is important to note that this relative price tends to be less influenced by international and domestic sectoral linkages, given that both categories of goods are imported and produced similarly. Intriguingly, Figure 9b echoes the same empirical pattern as that highlighted in Figure 2a. The relative import price declined substantially until around 2014, but remained stable thereafter. Note that the price of imported computers had declined sharply relative to other electric and electronic equipment. Thus, Figure 9b implies that computer-specific technological progress had been fast but began stagnating, which confirms the MST stagnation. Moreover, the same empirical pattern is observed even if the relative price is constructed based on the contract currency. We conclude that the MST stagnation is not entirely driven by international and domestic sectoral linkages and currency depreciation.

4.3 Markup

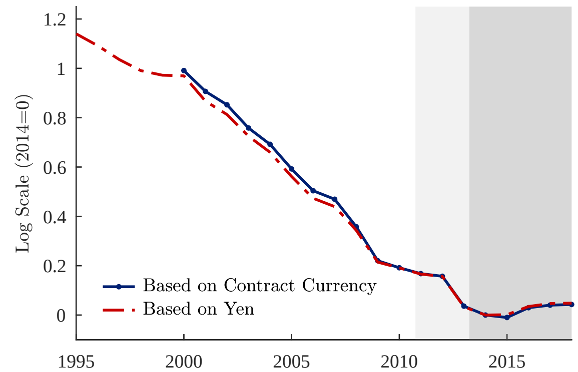
Now we turn to focus on the concern regarding market power in domestic markets. We adapt our model by incorporating the exogenous markup $\mu_{i,t}$ of good i. Consequently, the relative inflation rate of the manufacturing good becomes

$$\pi_{m,t} - \pi_{n,t} = g_{\mu_{m,t}} - g_{\mu_{n,t}} - g_{A_{m,t}}. \tag{22}$$

The relative price increases due to either the relative increase of the markup of the manufacturing good producer, $g_{\mu_{m,t}} - g_{\mu_{n,t}}$, or the relative technology stagnation, $g_{A_{m,t}}$. As such, our



(a) Decomposition Exercise



(b) The Relative Import Prices

Figure 9: Effects from Trade

Notes. To draw the level of the relative price, the own contribution and the linkage contributions, we first compute $\pi_{i,t} - \pi_{n,t}$, $\gamma^C_{i,s,t-1}\left(\hat{\chi}_{i,s,t} - \pi_{n,t}\right)$ and $\sum_{j,k}\gamma_{ji,ks,t-1}\left(\pi_{j,k,t} - \pi_{n,t}\right)$, where $\pi_{n,t}$ is the manufacturing inflation rate in Japan, i is Japan, and s corresponds to sector C26. Then, we compute the cumulative sums of the relative inflation rate and these contributions to recover the levels. The import price index is available from the website of the BOJ.

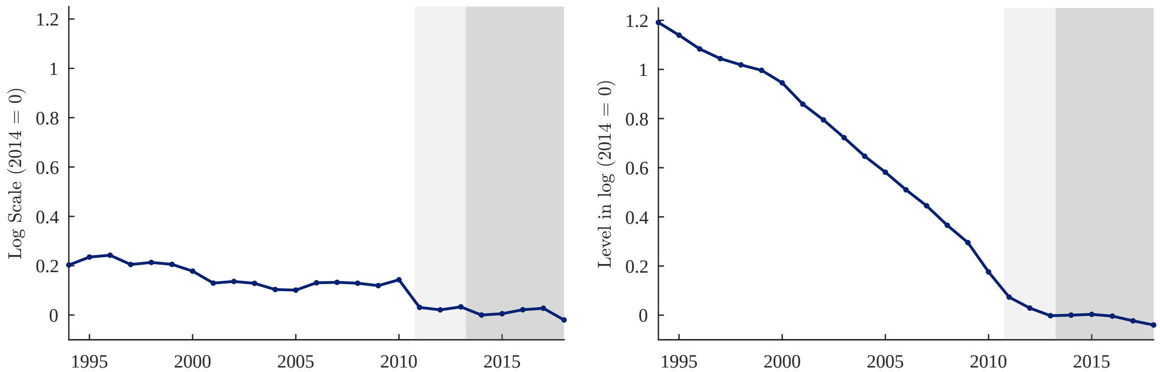
measure of MST might be distorted due to the presence of the relative change in markup.

To examine this potential bias, we use the sectoral markups $\mu_{n,t}$ estimated by KLEMS. KLEMS measures the sectoral markup i as

$$\mu_{i,t} = \frac{\text{Gross Operating Surplus}_{i,t} + \text{Labor Cost}_{i,t} + \text{Intermediate Input Cost}_{i,t}}{\text{Capital Cost}_{i,t} + \text{Labor Cost}_{i,t} + \text{Intermediate Input Cost}_{i,t}}.$$

We aggregate these sectoral markups as we did in Section 4.1 to construct the markup for both the manufacturing and the non-manufacturing goods. We plot the time-series of the relative markup and the relative price of the manufacturing good in Figures 10a and 10b. The growth rate of the relative markup of the manufacturing sector, $g_{\mu_{m,t}} - g_{\mu_{n,t}}$, has remained essentially constant, contrasting with the noticeable movement in the relative price.

Our finding aligns with the results presented in Nakamura and Ohashi (2019), which estimate the firm-level markups of Japanese companies, adopting the approach by Loecker and Warzynski (2012) and Loecker et al. (2020). They find that there has been no significant increase in various types of aggregate markups, including the overall manufacturing markup and the aggregate markup among the top 10% of firms, over the specified period in Japan. When these findings are considered collectively, it supports our conclusion that markups have had a minimal influence on the observed stagnation in the MST.



(a) Relative Markup of Manufacturing Good (b) Relative Price of Manufacturing Good

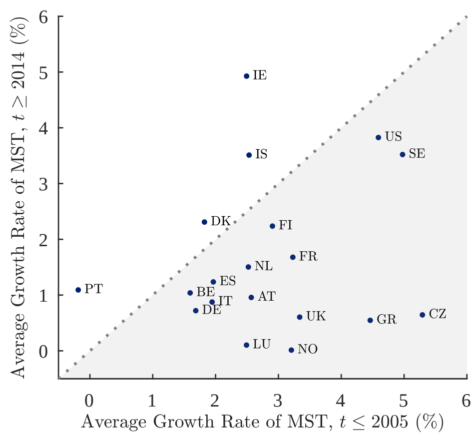


Figure 10: Cross-Country Evidence

4.4 Cross-Country Evidence

Finally, we present cross-country evidence to support our argument. If technological progress has stagnated in Japan, a similar trend should be observed in other developed countries. This is because they are likely to share the same level of technology on the frontier. We find that this is indeed the case.[33]

Figure 10 illustrates the growth rates of the MST for numerous developed countries. The vertical axis represents the average growth rates of the MST up until 2005, while the horizontal axis displays those since 2014. As evident from Figure 10, although the extent of MST stagnation varies among countries, most developed countries have experienced MST stagnation.

Considering the evidence provided in this section, we argue that our observation of MST

[33] In Takahashi and Takayama (2023), we examine the implications of the technology stagnation of the durable consumption good and the ICT investment good on the slowdown of growth across developed countries.

stagnation in Japan is a robust finding.

5 Extension

In the baseline model in Section 2, we abstract from capital accumulation and assume that the EIS is one. In this section, we relax these to see if the results from the baseline model survive under more general settings. These extensions are significant because (1) technological progress specific to ICT equipment has also stagnated, potentially causing additional inflationary pressure, and (2) numerous studies have found the EIS to be estimated at less than one.[34]

To maintain tractability in our analysis, we impose the following restrictions. The generic-output producer is assumed to have a Cobb-Douglas production function that combines capital and labor inputs. Moreover, we only conduct the steady-state analysis on the impact of the MST shock and additional technology stagnation specific to ICT equipment on aggregate inflation and consumption. We demonstrate that these extensions either strengthen or do not substantially alter our baseline results.

5.1 Introduction of the Extended Model

In this economy, multiple investment goods exist, such as ICT equipment, transportation equipment, research and development (R&D) , and more. Let $\mathcal{I}$ denote the set of these investment goods. The representative producer of the generic output combines these capital stocks and labor. The technology is given by

$$Y_t = A_t \prod_{j \in \mathcal{I}} K_{j,t}^{\alpha\theta_j} L_t^{1-\alpha}, \quad \text{with} \sum_{j \in \mathcal{I}} \theta_j = 1, \tag{23}$$

where $K_{j,t}$ is capital stock $j \in \mathcal{I}$ installed at date t. The consumption-goods producers have the same linear technology functions as in the baseline model. Similarly, the representative investment-good firms utilize linear technology functions to convert generic output to investment goods with $I_{j,t} = A_{j,t} M_{j,t}$. Thus, the relative price of investment good j is

$$p_{j,t} \equiv \frac{P_{j,t}}{P_t} = A_{j,t}^{-1},$$

where $P_{j,t}$ is the price of investment good j at year t. The technology progress $A_{j,t}$ is referred to as j-investment-good specific technology progress, or$j$-IST for short.

[34]See Havranek (2015) for a meta-analysis.

Extending the results by Greenwood et al. (1997), we obtain the formula for the impact of the technology shocks, $\hat{g}_A$, $\left(\hat{g}_{A_j}\right)_{j\in\mathcal{I}}$, on the growth rate of the output, $\hat{g}_Y$:[35]

$$\hat{g}_Y = \frac{1}{1-\alpha}\hat{g}_A + \sum_{j\in\mathcal{I}} \frac{\alpha\theta_j}{1-\alpha}\hat{g}_{A_j}. \tag{24}$$

The term $\alpha\theta_j$ represents the output elasticity of capital stock j, and the term, $1/(1-\alpha)$ corresponds to the capital deepening effect. Since there are multiple sources of technology progress, output growth is a linear combination of these technology progress.

The instantaneous utility function of the representative consumer is generalized in the following manner:

$$u\left(C_{n,t}, C_{m,t}\right) = \begin{cases} \frac{\left(C_{n,t}^{\gamma_n} C_{m,t}^{\gamma_m}\right)^{1-\sigma}}{1-\sigma} h\left(1-N_t\right) & \sigma \neq 1 \\ \left(\gamma_n \ln C_{n,t} + \gamma_m \ln C_{m,t}\right) h\left(1-N_t\right) & \sigma = 1 \end{cases}, \tag{25}$$

where $h(\cdot)$ represents the utility from leisure and N_t is the number of hours worked. This class of the utility functions still guarantee the existence of BGP. Given this instantaneous utility function, the Euler equation becomes

$$r - \pi_i = \ln\beta^{-1} + g_{C_i} + (\sigma - 1)\left(\gamma_n g_{C_n} + \gamma_m g_{C_m}\right). \tag{26}$$

Note that when the EIS is one, equation (26) boils down to the Euler equation of the baseline model in Section 3.

Equation (26) sheds light on the new effects resulting from the two extensions. To focus on the implications of having multiple investment goods, we momentarily assume that the EIS is one. Recall that investment goods affect the production of all consumption goods, (24). Put differently, the ISTs affect consumption growth through the capital accumulation channel. Hence, if j-IST stagnates, consumption growth has to slow down through this channel in the equilibrium. To deliver the slowdown in the equilibrium, an equilibrium force lowers the real interest rate to encourage lower consumption growth (see equation (26) with $\sigma = 1$). When the nominal interest rate is pegged, this lower real interest rate is only obtained by higher inflation. Note that this effect resembles the classic Fisher effect: the nominal interest rate and inflation co-move in the long-run. Because of the similarity, we refer to this effect as the *Fisher-like effect*. The strength of the Fisher-like effect depends on the extent to which j-IST depresses consumption, which depends on the output elasticity of capital stock j, $\alpha\theta_j$.

[35] Gourio and Rognlie (2020) uses this formula to re-examine the impact of capital-embodied technology progress on growth.

Next, let us consider the case in which the EIS is not unitary, $\sigma \neq 1$. The change in marginal utility with respect to C_i includes two additional terms. These terms correspond to the last term in equation (26), which is omitted in the above discussion. When the EIS is less than one (i.e., $\sigma > 1$), the representative consumer prefers more consumption smoothing. Consequently, the real interest rate must adjust more significantly to incentivize the consumer to save more. Conversely, if the EIS is greater than one, the representative consumer prefers less consumption smoothing, and a smaller change in the real interest rate can substantially alter the consumer's intertemporal consumption decision.

To quantify the impacts of these new effects on aggregate inflation and consumption, we take the total derivative of equation (26) with respect to the MST shock $\hat{g}_{A_m}$ and j-ICT shock $\hat{g}_{A_j}$. The following equations are the generalization of Proposition 1:

$$\hat{\pi}_\infty = \underbrace{\gamma_m \left(-\hat{g}_{A_m}\right)}_{(A)} + \underbrace{\frac{\alpha\theta_j}{1-\alpha}\left(-\hat{g}_{A_j}\right)}_{(B)} + \underbrace{(\sigma-1)\left(\frac{\alpha\theta_{\mathrm{ICT}}}{1-\alpha}\left(-\hat{g}_{A_j}\right) + \gamma_m\left(-\hat{g}_{A_m}\right)\right)}_{(C)}. \tag{27}$$

$$\hat{g}_{C_\infty/L_\infty} = \underbrace{\gamma_m \hat{g}_{A_m}}_{(D)} + \underbrace{\frac{\alpha\theta_j}{1-\alpha}\hat{g}_{A_j}}_{(E)}. \tag{28}$$

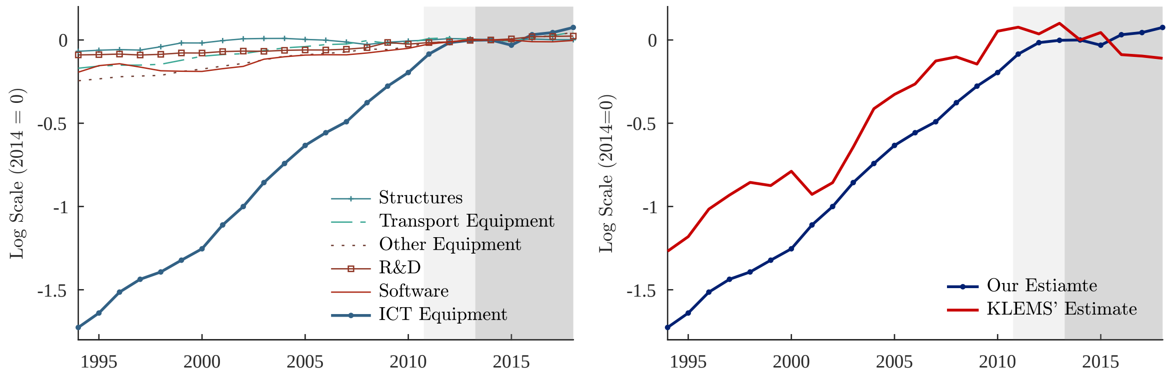
These two formulas delineate the influence of the extensions on aggregate inflation and consumption. The first term (A) on the RHS of equations (27) and (28) represents the baseline effect, operating through the relative price. The other terms (B) and (C) in equation (27) represent the new effects described above. The real consumption growth decreases due to the direct effect of the MST shock (D) and through the capital deepening effect via the j-investment good (E).

5.2 Quantification under the Extended Model

In this subsection, we first demonstrate that technology progress specific to ICT equipment has slowed down, while other ISTs have not (in Section 5.2.1). Subsequently, we quantify the impacts of these two shocks on the manufacturing good and ICT equipment on inflation and consumption (in Section 5.2.2).

5.2.1 Technology Stagnation of ICT Equipment

Figure 11a displays the various ISTs measured by the inverse of their relative prices. It is evident from Figure 11a that ICT-specific technology had advanced significantly compared to the other ISTs. Notably, ICT-specific technology progress stagnated since around 2010, as the MST stagnated.



(a) Various IST, $A_{j,t} = P_{n,t}/P_{j,t}$ (b) Comparison of ICT-Specific Technology

Figure 11: ICT-Specific Technology Stagnations

Notes: To make Figure 11a easier to see, we do not depict IST of investment goods j for which the share of investment in total investment is less than 2%. These investment goods are defense equipment; cultivated biological resources; and mineral exploration and evaluation. To construct the TFP estimate for the ICT equipment from the sectoral TFP estimates by KLEMS, we aggregate the sectoral TFP by using an appropriate weight. See Appendix A.3 for a detailed explanation.

The stagnation of ICT technology can be confirmed in the data by KLEMS. In Figure 11b, we present our estimate of ICT-specific technology progress alongside the estimate of KLEMS. Both measures indicate that the technology progress of the ICT investment-good sector has significantly stalled. Based on these findings and the robustness exercises in Section 4, we conclude that ICT-specific technology has stagnated, just like the MST. We measure the size of the ICT-ST by the difference in the growth rate of MST until 2010 and since 2014, with $\hat{g}_{A_{\text{ICT}}} = -7.2\%$. [36]

5.2.2 Quantification

We now quantify the impacts of $\hat{g}_{A_m}$ and $\hat{g}_{A_{\text{ICT}}}$ using equations (27) and (28). To apply these formulas, we need to specify the labor share parameter α and the rental cost share of ICT, θ_{ICT}. We set α to be the average labor share from KLEMS, and estimate θ_{ICT} using the methodology developed in Gourio and Rognlie (2020).

Our findings are summarized in Table 3. As mentioned earlier, the aggregate inflation rate in our data increased by 1.20 percentage points since 2014. When $\sigma = 1$, the additional Fisher-like effect (represented as the term (B) in equation (27)) induced by the ICT-IST shock increases the inflation rate by 0.26 percentage points. Thus, the two shocks are

[36] Moreover, we can show that the sectoral markup of the ICT investment good sector estimated by KLEMS has been marginally declining since 1994. This fact is not surprising given the findings by Nakamura and Ohashi (2019). For the sake of completeness, we draw the sectoral markup for the ICT good sector in Section 2 of the Online Appendix.

$\hat{\pi}_\infty$	$\sigma = 1$	$\sigma = 2$	$\sigma = 2/3$	$\hat{g}_{C_\infty/L_\infty}$	
(A)	0.57% pts	0.57% pts	0.57% pts	(D)	−0.57% pts
$(A) + (B)$	0.83% pts	0.83% pts	0.83% pts	$(D) + (E)$	−0.83% pts
$(A) + (B) + (C)$	0.83% pts	1.67% pts	0.56% pts		

Table 3: Quantification of Technology Stagnation

Notes: See equation (27) for what $(A), (B)$, and (C) in the first column represent, and equation (28) for what (D) and (E) in the fourth column represent.

capable of accounting for a significant proportion of the inflation uptick in Japan. When $\sigma = 2$ (the consumer prefers more consumption smoothing), the term (C) provides an additional inflationary pressure, and the model predicts that the shocks increase inflation by 1.67 percentage points. These figures should not be taken at face value because these additional Fisher-like effects in our extended model have not been empirically established yet. Therefore, we take the qualitative features of the extended model more seriously and treat the quantitative features with caution.

When $\sigma < 1$, the additional Fisher-like effects are considerably mitigated. Nevertheless, even if we set σ to a conventional value used in the literature, say 2/3 following Bansal and Yaron (2004), we can still explain a significant proportion of the observed rise in inflation. When $\sigma = 2/3$, the shocks increase aggregate inflation by 0.56 percentage points, which accounts for roughly 40% of the increase in inflation. Consequently, our result is robust in this dimension as well.

With the additional shock $\hat{g}_{A_{\text{ICT}}}$, the extended model now better accounts for the growth slowdown in Japan since 2014 compared to the baseline model. The growth rate of consumption per effective labor g_{C_t/L_t} declines by 1.43 percentage points in data. As shown in Section 3.2, the MST stagnation can explain approximately 40% of the observed decline in $g_{C/L}$. Moreover, the extended model can account for roughly 60% of the observed decline due to ICT-IST shock $\hat{g}_{A_{\text{ICT}}}$ (represented as the term (E) in equation (27)). Thus, we conclude that our baseline results hold true in this extended model.

6 Conclusion

Japan emerged from long-lasting deflation during the 2010s, which has been widely perceived as a much-desired success of various monetary policies by the BOJ. However, we argue that this perception is challenged by a puzzle: the apparent success was accompanied by the stagnation of real consumption, not revitalization. This paper offers a resolution to this puzzle.

We propose that this puzzle can be elucidated by viewing the phenomenon as a manifestation of stagflation, resulting from the technology stagnation specific to the manufacturing good sector. The technology stagnation increases the relative price of the manufacturing good, which translates into a higher aggregate inflation when the nominal interest rate is pegged. Our quantification reveals that the model can account for approximately half of the observed rise in inflation and 40% of the observed decline in real consumption growth.

An important lesson from our analysis is that the rise in the headline inflation rate in Japan might not be an informative signal regarding the Japanese economy. Even though for many years the Japanese economy has been waiting for inflation to go back to normal, the cause behind the rise in inflation needs to be carefully scrutinized. This is because inflation is, of course, affected by various factors including not-so-evident ones, such as technology stagnation.

A Data Appendix

A.1 Construction of Consumption Sequences

To construct consumption sequences, we utilize Supporting Table 11 of the flow tables in the Annual Report 2018 of JSNA.[37] This table comprises three excel files that provide nominal consumption, real consumption, and deflators. In these excel files, consumption is classified into four categories: durable goods, semi-durable goods, non-durable goods, and services. Let $\mathcal{C}$ denote the set of these categories.

A.1.1 Real Consumption Growth

To construct the real consumption sequences of the non-manufacturing good, we first compute the growth rates of real consumption for semi-durable goods, non-durable goods, and services, excluding both the imputed and actual rents from the consumption growth rate of services. We then aggregate these using weights proportional to their nominal expenditure.

A.1.2 Inflation

This subsection outlines how we construct the inflation rates of the manufacturing and non-manufacturing goods, excluding impacts of the VAT hike. For explanation, we define the following terms. Let $\tilde{P}_{i,t}$ denote the after-VAT price level of consumption i at year t, and $P_{i,t}$ denote its before-VAT price level. Note that Supporting Table 11 provides the value of $\tilde{P}_{i,t}$ for each consumption category mentioned above. Our goal is to obtain $P_{i,t}$ for each i and year t.

During our sample period, the Japanese government increased the VAT in 1997 and 2014 during our sample period. The increases became effective on April 1 of those years. The VAT hikes were not necessarily applied uniformly to all categories of consumption. So, we must take into account this fact to construct $P_{i,t}$. Motivated by the institutional details, we assume that the VAT uniformly rose for consumption goods, except for services. With this assumption, the following relation between $P_{i,t}$ and $\tilde{P}_{i,t}$ for for $i \neq$ services holds:

$$\tilde{P}_{i,t} = \begin{cases} \left[(1+\tau_{t-1})\,\frac{1}{4} + (1+\tau_t)\,\frac{3}{4}\right] P_{i,t} & t \in \{1997, 2014\} \\ (1+\tau_t)\, P_{i,t} & \text{otherwise} \end{cases}, \tag{29}$$

where τ_t is the VAT rate of the last month in year t. The term in the square brackets in equation (29) accounts for the fact that the VAT hike only came into effect in April for

[37] These supporting tables are retrieved from this URL.

both instances of the hike. Taking the log difference of equation (29), we can compute the inflation rates by adjusting the VAT hike $\pi_{i,t}$, except for services.

To construct the inflation of services, we use the aggregate inflation rate adjusted for the VAT hikes by the Statistics Bureau of Japan. This adjusted inflation rate explicitly takes into account the item-level institutional issues, such as non-taxability and transitional measures, which are mostly applicable to services.[38] We denote the difference between the aggregate inflation, including impacts of VAT hikes and the one excluding them, as Δ_t. Then, the difference Δ_t should satisfy the following equation:

$$\sum_{i \in \mathcal{C}} s_{i,t-1} \tilde{\pi}_{i,t} - \sum_{i \in \mathcal{C}} s_{i,t-1} \pi_{i,t} = \Delta_t. \tag{30}$$

Since we already know the VAT-adjusted inflation rates except services, we can recover the inflation rate of services by solving equation (30) in terms of $\pi_{\text{Service},t}$:

$$\pi_{\text{Service},t} = \frac{\sum_{i \in \mathcal{C}} s_{i,t-1} \tilde{\pi}_{i,t} - \sum_{i \notin \{\text{Service}\}} s_{i,t-1} \pi_{i,t} - \Delta_t}{s_{\text{Service},t}}.$$

Finally, we aggregate the inflation rates of semi-durable goods, non-durable goods, and services by using weights that are proportional to the nominal expenditure to construct the inflation of the non-manufacturing good:

$$\pi_{n,t} = \sum_{i \neq m} \frac{s_{i,t-1}}{\sum_{k \neq m} s_{k,t-1}} \pi_{i,t}.$$

A.2 Construction of Investment Sequences

To construct investment sequences, we use Supporting Table 14 of flow tables in Annual Report 2018 of JSNA.[39] We classify the investment goods into nine subcategories: other buildings and structures, transport equipment, information and communication technology (ICT) equipment, other machinery and equipment, defense equipment, cultivated biological resources, R&D, mineral exploration and evaluation, and computer software. Supporting Table 14 itself provides the sufficient information for constructing nominal and real investment in the above subcategories.

[38] The data is only available and explained in Japanese. See the website on this URL. The excel file that contains the data can be retrieved from this URL.

[39] The data can be retrieved from the same URL mentioned in Footnote 37.

A.3 KLEMS

We primarily use two excel files: Capital input and Growth accounting.[40] Since the KLEMS industry classification and the JSNA classification are different, it is necessary to tie them together. In KLEMS' data, there are 100 sectors. Let $\mathcal{S}$ denote the set of these sectors. We select subsets $\tilde{\mathcal{C}}, \tilde{\mathcal{I}} \subset \mathcal{S}$, such that the sectors in $\tilde{\mathcal{C}}$ produce durable consumption goods and the sectors in $\tilde{\mathcal{I}}$ produce the ICT investment goods. Set $\tilde{\mathcal{C}}$ comprises fix sectors: (1) household electric appliances; (2) miscellaneous electronic equipment; (3) image and audio equipment; (4) communication equipment; (5) electronic data processing machines, digital and analog computer equipment, and accessories; and (6) motor vehicles. Set $\tilde{\mathcal{I}}$ comprises three sectors: (1) image and audio equipment; (2) communication equipment; and (3) electronic data processing machines, digital and analog computer equipment, and accessories.

We construct the TFP for the manufacturing good, $g_{A_{m,t}^{\text{KLEMS}}}$, and the ICT equipment, $g_{A_{\text{ICT},t}^{\text{KLEMS}}}$, by aggregating the sectoral TFP of $i \in \tilde{\mathcal{C}}$ and $j \in \tilde{\mathcal{I}}$. Let $g_{A_{i,t}^{\text{KLEMS}}}$ denote the growth rate of sectoral TFP of sector $i \in \mathcal{S}$. These TFP are given by

$$g_{A_{m,t}^{\text{KLEMS}}} = \sum_{i \in \tilde{\mathcal{C}}} \omega_{i,t} g_{A_{i,t}^{\text{KLEMS}}}, \quad g_{A_{m,t}^{\text{KLEMS}}} = \sum_{j \in \tilde{\mathcal{I}}} \varpi_{j,t} g_{A_{j,t}^{\text{KLEMS}}},$$

where $\omega_{i,t}$ is the share of household consumption expenditure for $i \in \tilde{\mathcal{C}}$ in total household consumption expenditure in set $\tilde{\mathcal{C}}$ and $\varpi_{j,t}$ is the share of gross fixed capital formation (GFCF) of good $j \in \tilde{\mathcal{I}}$ in the total GFCF in set $\tilde{\mathcal{I}}$. The industry-by-industry IO table provides information regarding how much of the goods produced by each sector n is purchased for final consumption of households and GFCF.[41]

We also construct the aggregated markup for the manufacturing good, $\mu_{m,t}$, and ICT investment good, $\mu_{\text{ICT},t}$, in a similar manner. Let $\mu_{i,t}$ denote the level of markup of sector $i \in \mathcal{S}$. We then aggregate these sectoral markup, $\mu_{\text{ICT},t}$.

$$\mu_{m,t} = \sum_{i \in \tilde{\mathcal{C}}} \omega_{i,t} \mu_{i,t}, \quad \mu_{\text{ICT},t} = \sum_{j \in \tilde{\mathcal{I}}} \varpi_{j,t} \mu_{j,t}.$$

A.4 Inflation of the Manufacturing Good across Major Cities

In this section, we explain how to construct the data used in Section 3.2 in detail. We cover 49 major cities of Japan, which consist of 47 prefectural capital cities and 2 other important cities designated by government ordinance before 2005. To obtain the regional inflation rates

[40] All the data, except sectoral markup, can be retrieved from the website of the RIETI. The data on sectoral markup is only available in Japanese and can be retrieved from this webpage.

[41] The industry-by-industry IO tables are retrieved from this URL.

that are conceptually as close as possible to the national inflation rate of the manufacturing good used in our analysis, we use the weighted averages of the inflation rates for "household durable goods" and "recreational durable goods" reported in CPI by major city. The former consists of home appliances and furniture and the latter primarily corresponds to computer hardware and audio-visual equipment. As earlier, we aggregate these inflation rates by using the weights proportional to the corresponding consumption expenditure.

We mainly use CPI and the family income and expenditure survey (FIES).[42] CPI provides information on the price indexes of these durable goods by major city indexed by a. However, the city-level indexes are not chain-liked annually and the weights are updated every five years. Let $\tilde{P}^a_{i,t}$ be the price index of $i \in \mathcal{D} \equiv \{\text{household durables}, \text{recreational durables}\}$ at date t of city a. FIES provides information regarding the corresponding consumption expenditure, denoted by $V^a_{i,t}$. Specifically, we use the average consumption expenditure for households of two or more persons. The after-VAT inflation rate of the manufacturing good in city a is calculated in the following manner:

$$\tilde{\pi}^a_{m,t} = \sum_{i \in \mathcal{D}} \frac{V^a_{i,\bar{t}(t)}}{\sum_{k \in \mathcal{D}} V^a_{k,\bar{t}(t)}} \tilde{\pi}^a_{i,t},$$

where $\bar{t}\,(t)$ is the base year used in CPI for year t.

Further, we calculate the growth rates of real consumption of the manufacturing good by city as the difference between their inflation rates and the growth rates of relevant consumer spending:

$$g_{C^a_{i,t}} \equiv g_{V^a_t} - g_{\tilde{P}^a_{i,t}},$$

where $V^a_t = \sum_{i \in \mathcal{D}} V^a_{i,t}$. To eliminate the effects of the VAT on the inflation rate $\tilde{\pi}^a_{m,t}$, we use the same method as that described in Section A.1.2. Let $\pi^a_{m,t}$ denote such an inflation rate for city a at date t.

B Non-Horizontal Supply Curve

In this section, we verify that our theoretical results in Section 3.2 hold true in a model where the asset supply curve (or saving function) is not horizontal with respect to a real interest rate. This investigation additionally offers insights regarding the results in Section 5. Although there are many ways to derive an upward sloping supply function, we choose a classic overlapping generations model for an expositional reason. We focus on steady-state analysis and abstract away from the nominal rigidity.

[42] The data can be retrieved from this URL.

The supply side of the economy is almost identical to that in Section 2. Since we abstract away from the nominal rigidity, the real wage relative to the price of the non-manufacturing good corresponds to the TFP, $W_t/P_{n,t} = A_t$. As in Section 2, the relative price of the manufacturing good corresponds to the inverse of the MST, $A_{m,t}^{-1}$.

In contrast to the representative consumer model in the main text, we consider consumers who live for two periods. At date t, a new consumer is born and the generation t consumer inelastically supplies labor $(1-\xi)L$ and ξL units of labor at dates t and $t+1$, respectively. Thus, the total labor supply at date t is always L. As in the benchmark model in Section (2), there are two consumption goods: manufacturing and non-manufacturing goods, and the only asset traded is the government bond. At date t, the consumer born at date t solves the following maximization problem:

$$\begin{aligned}
\max \quad & \sum_{k=0,1} \beta^t \left(\frac{\prod_{i\in\{n,m\}} \left(c_{i,t+k}^t\right)^{\gamma_i}}{1-\sigma} \right)^{1-\sigma} \\
s.t. \quad & \sum_{i\in\{n,m\}} P_{i,t} c_{i,t}^t + b_t = w_t \xi L \\
& \sum_{i\in\{n,m\}} P_{i,t+1} c_{i,t+1}^t = R_t b_t + w_{t+1}(1-\xi) L.
\end{aligned}$$

The government sets its interest rate, and the net supply of bond is zero, $b_t = 0$. Further, the good market clearing conditions are $\sum_{k=0,1} c_{i,t}^{t-k} = C_{i,t}$.

It is easy to derive the equilibrium of this economy. The Cobb-Douglass demand function implies that $P_{i,t}c_{i,t}^t = \gamma_i w_t \xi L$ and $P_{i,t+1}c_{i,t+1}^t = \gamma_i w_{t+1}(1-\xi)L$. Since the real wage is A_t and the relative price of the manufacturing good is $A_{m,t}^{-1}$, we obtain

$$c_{n,t}^t = \gamma_n \xi A_t L \quad c_{m,t}^t = \gamma_m \xi A_{m,t} A_t L \tag{31}$$

$$c_{n,t+1}^t = \gamma_n (1-\xi) A_{t+1} L \quad c_{m,t+1}^t = \gamma_m (1-\xi) A_{m,t+1} A_{t+1} L. \tag{32}$$

Thus, the individual consumption growth rate, $\ln c_{i,t+1}^t / c_{i,t}^t$, is $\ln(1-\xi)/\xi + g_A$ for $i = n$ and $\ln(1-\xi)/\xi + g_A + g_{A_m}$ for $i = m$.

The asset supply curve scaled by the nominal GDP is given by

$$\frac{b_t}{P_t Y_t} = \frac{\xi - (1-\xi)\bar{g}_A \beta^{-\frac{1}{\sigma}} \left(R_t/\Pi_{n,t+1}\right)^{-\frac{1}{\sigma}} \left(\bar{g}_{A_m}^{\gamma_m}\right)^{\frac{\sigma-1}{\sigma}}}{1 + \beta^{-\frac{1}{\sigma}} \left(R_t/\Pi_{n,t+1}\right)^{\frac{\sigma-1}{\sigma}} \left(\bar{g}_{A_m}^{\gamma_m}\right)^{\frac{\sigma-1}{\sigma}}}, \tag{33}$$

where $\Pi_{n,t+1}$ is the inflation rate of the non-manufacturing good and $\bar{g}_A$ and $\bar{g}_{A_m}$ are the gross growth rates of A_t and $A_{m,t}$ respectively. This saving function is an increasing function if $\sigma \leq 1$. When $\sigma > 1$, the function increases locally around the equilibrium interest rate.

The bond market clearing condition determines the real interest rate, $R_t/\Pi_{n,t+1}$.

Consider the case in which $\sigma = 1$. Then, the asset supply function (33) boils down to

$$\frac{b_t}{P_t Y_t} = \frac{\xi\beta - (1-\xi)\,\bar{g}_A\left(R_t/\Pi_{n,t+1}\right)^{-1}}{1+\beta}, \tag{34}$$

which is an increasing function with respect to the real interest rate. Suppose that a negative technology shock occurs on the manufacturing good so that $\bar{g}_A$ declines to $\bar{g}'_A$. Note that this shock does not influence the saving decision of the households when $\sigma = 1$. The market clearing condition implies that Π_n remains unchanged while the relative price of good m increases. Consequently, the aggregate inflation rate increases. We obtain the same comparative static result mentioned in the main text when $\sigma = 1$. Thus, we verified that the results in Section 3.2 hold true in a model in which the asset supply curve is not horizontal.

Furthermore, equation (34) offers an intuitive perspective on the results from the extended model in Section 5. Recall that when $\sigma > 1$ (the EIS is less than one), the MST technology stagnation $\hat{g}_{A_m} < 0$ becomes more inflationary. Conversely, if $\sigma < 1$, the opposite holds. These results can be understood by analyzing the supply curve of the economy. If $\sigma \neq 1$, then the MST stagnation $\hat{g}_{A_m}$ shifts the asset supply curve. When $\sigma > 1$, the negative shock shifts the supply curve to the right. This shift occurs because a rise in future price drives households, motivated by the desire to smooth out their consumption, to save more. Consequently, the market-clearing real interest rate declines, thereby exerting inflationary pressures on the economy. When $\sigma < 1$, the substitution effect due to the rise in price dominates and households are encouraged to increase today's consumption. Consequently, the shock shifts the supply curve to the left. In this case, the market-clearing real interest rate rises and this rise leads to disinflation of the non-manufacturing good. Thus, the overall effect of the shock on the aggregate inflation is mitigated.

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