Bad Inflation*

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VERY VERY Preliminary

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Abstract

This study explores the connection between growth and the long-run inflation rate. In normal times, the central bank can achieve its target inflation rate at any time by adjusting the nominal interest rate in response to changes in the natural rate of interest r^*, which is determined by technology, preference and so on. So, the connection between growth and inflation is elusive. However, when the central bank is constrained by the zero lower bound constraint on the nominal interest rate, the connection becomes tight. In this situation, technological stagnation leads to a decline in the natural rate of interest r^*, which in turn induces higher inflation. We argue that this well-known, but under-appreciated, point has played an important role for explaining the recent rise of inflation in Japan. We build a multi-goods frictionless monetary model to quantify the effect of the technological stagnation on inflation for Japan. We document that Japan has experienced technological slowdown in the last decade, which are reflected in the movement in the relative prices of consumer durables and ICT. We find that the depressed TFP growth of these goods explains 67% of the observed increase in the inflation rate, and induce lower growth rates for real GDP and consumption, which is observed in data. Our study suggests the danger of mechanically targeting a specific inflation rate and raises an alarming bell for simple policy evaluation of "Kuroda bazooka" purely based on the rise of inflation.

1 Introduction

The relationship between economic growth and the inflation rate has long been considered theoretically elusive. In a monetary model such as the New Keynesian (NK) model, monetary neutrality

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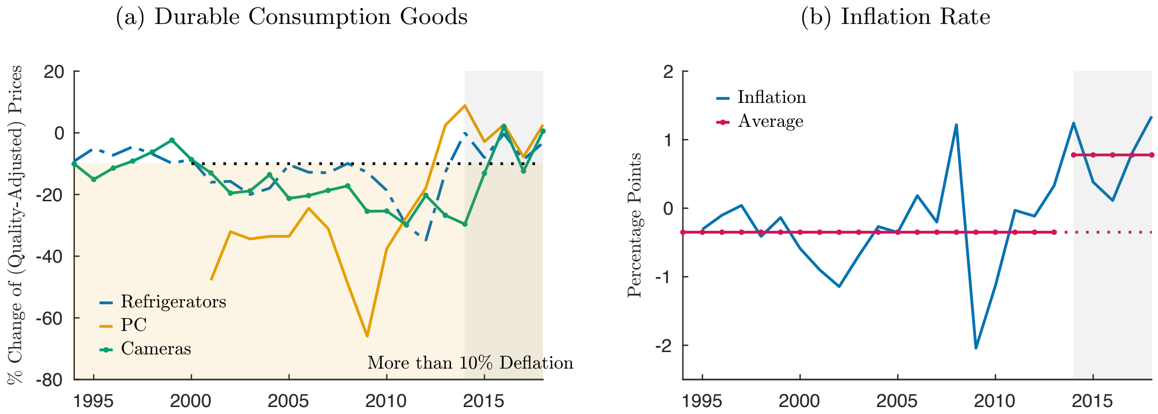
Figure 1: Motivating Facts



Notes: See Section 3.1 for construction of inflation.

is established in the long run, and the natural rate of interest is determined independently of the central bank's policy. Therefore, the central bank can freely divide the natural rate of interest into the inflation rate and the nominal rate of interest. This logic implies that even if there is a change in economic growth, the central bank can achieve any inflation rate it wants by adjusting the nominal interest rate.

However, it has become unclear whether this argument is valid in the developed economies. The best example of this is Japan. The policy interest rate in Japan has been hovering around zero for more than 20 years. As a result, there is no room to appropriately adjust the nominal interest rate if there is any change in economic growth. When the central bank is faced with a zero interest rate constraint, factors that do not affect long-run inflation in normal times may affect long-run inflation. In this study, we construct a frictionless monetary model to materialize this logic and analyze the inflation rate of the Japanese economy.

Figure 1 provides motivation for our analysis. Figure 1a plots several price sequences of durable goods in the CPI. The three price sequences had been falling by more than 10% on average until 2010. However, since 2014, no such price declines have been seen any more. Interestingly, Figure 1b shows that this is also the period when the inflation rate started to increase and the nominal interest rate has been near zero. Motivated by these observations, this paper analyzes the effect of such a long-term price increase on the inflation rate.

We extend the standard growth model to a frictionless monetary model with multiple consumption goods and multiple investment goods. Our model has the same standard properties as other monetary models. In particular, along the BGP of the model (or steady state), the supply side of the economy determines the real interest rate. So, The central bank can achieve the desired inflation rate as long as it can adjust its policy rate appropriately.

However, when the policy rate is constrained, long-run changes in the supply and demand sides of the economy affect the inflation rate. In order to capture this channel quantitatively, we derive sufficient statistics for the change in the long-run inflation rate. According to this sufficient statistics, the change in the inflation rate is an affine function of the growth rates in TFP of each good. The coefficients of this function are all estimable parameters or variables that can be directly observed. Therefore, this sufficient statistic can be used readily for quantitative analysis.

When monetary policy is constrained, stagnation of TFP will lead to an increase in the inflation rate. This logic behind the rise of inflation works as follows. The stagnation of TFP lowers the natural rate of interest. When monetary policy is constrained, the only way to achieve a lower natural rate is an increase in the inflation rate. Note that this type of inflation should not be considered to be a good inflation. Rather it is *bad inflation*. Conversely, accelerating TFP can induce deflation, which is good for the economy (*good deflation*). The idea of good deflation and bad inflation has been shared and discussed by policymakers. For example, here is a quote from ex BOJ Governor, Hayami.

> Though it is true that prices of a number of products have been declining, this is against the backdrop of various revolutionary changes including the so-called IT revolution, that is, the progress of technological innovation in information and telecommunications, as well as the revolution in distribution networks represented by the emergence of so-called "category killers." Such phenomena cannot necessarily be regarded as pernicious price declines. [Hayami (2000)][1]

In his speech, he pointed out a possibility that it is necessarily bad to have deflation especially when deflation reflects technological advances. Our model gives a rationale for his argument especially when the central bank cannot adjust its nominal interest rate freely.

After constructing the model, we begin by analyzing Japan's data since 1994, which can be summarized as follows. Inflation has been at a very low level since 1994, but it began to rise around 2013. The average inflation rate from 2014 is around 0.7%. The policy interest rate has remained at a very low level since 1999, and the interest rate of long-term government bonds has been below 0.2% for the past five years. This recent rise in inflation is thought to be attributed to the Bank of Japan's (BOJ) expansionary monetary policy. However, during this same period, the economy has experienced a major and largely unnoticed change. As shown in Figure 1a, the relative prices of durable goods and ICT goods had been falling at a very fast rate, but these declines began to moderate around 2010, and after 2014, the prices of these goods have completely stopped falling relative to other goods. According to our model, changes in the relative prices of these two

[1] The transcript is available from the following URL, https://www.boj.or.jp/en/announcements/press/koen_2000/ko0003b.htm/.

goods represent stagnation in their TFP and contribute to higher inflation when monetary policy is constrained. We examine the extent to which these two goods alone can explain the rise in Japan's inflation rate.

In an analysis using sufficient statistics, we need to estimate the growth rate of TFP for each good. We estimate them using equations derived from our model. More specifically, our model implies that the relative price of a good represents its relative TFP levels. Using this relationship and the Solow residuals as the estimating equation, we estimate the growth rates of TFP. Put differently, we extend the standard growth accounting method by incorporating the relative prices.

After a brief discussion of the fit of the model to the data, we quantitatively analyze the impact of these two goods, durable goods and ICT goods, on the rise of inflation rate in Japan after 2013 using sufficient statistics result. Our model suggests that more than 65% of the increase in inflation since 2014 is due to stagnant TFP growth of these two goods. Put differently if the growth rate of TFP did not fall after 2013, Japan's inflation rate would be almost zero. We conclude that the recent increase in inflation is not due to aggressive monetary policy, but to the stagnation of TFP of these two specific goods.

In support of this claim, our model can also explain the stagnation in Japan's real GDP and consumption observed in the data. The stagnation of TFP reduces the productivity of the economy and also discourage firms to invest in capital. These two effects allow our model to simultaneously explain the increase in the inflation rate, the stagnation of consumption, and the stagnation of real GDP.

In order to show that our results are robust, we provide three additional evidence. First, the core of our argument is that technological stagnation is driving up inflation. Given that many developed countries are very closely related and tied together, these technological stagnations should be a common phenomenon at least in developed countries. In fact, we show that the decline in the relative prices of durable goods and ICT goods has stalled in many developed countries, as it has in Japan.

Second, our estimation requires the assumption that the relative price reflects TFP. Given modern production networks, it is possible that these relative prices contain information other than TFP. We compare our estimates with those of KLEMS, which estimates TFP without using relative prices. We find that KLEMS' estimates of productivity in ICT-related sectors suggest a larger stagnation in growth rates than our benchmark estimates. This evidence gives us additional credibility of our results.

Finally, we discuss whether exchange rate fluctuations have affected relative prices. To do so, it is useful to use the information in PPI. In the PPI dataset, there are three types of computer prices: domestically produced computer prices; imported yen-based computer prices and; imported contract currency-based computer prices. Although the nominal and real effective exchange rates have been fluctuating, these three types of computer prices have move qualitatively almost the same. Therefore, the impact of exchange rates on our analysis is also limited.

The rest of the paper is organized as follows. In Section 2, we introduce our frictionless monetary model. In Section 3, we introduce our main datasets and give various facts about Japanese economy. In Section 4, we discuss how to map our model to data, and we quantify the effect of TFP stagnation on the long-run inflation rate in Section 5. After providing robustness exercises in Section 6, we conclude by discussing implication of our study for monetary policy in Section 7.

2 Model

In this section we introduce our accounting model. We begin our discussion by describing the model in Section 2.1. We then proceed by characterizing the economy and derive various sufficient statistics results used later sections in Section 2.3. We discuss various implication obtained by our accounting model in Section 2.4.

2.1 Economy

The model presented here is a generalization of Greenwood et al. (1997) and Whelan (2003) by incorporating many consumption and investment goods. In terms of exposition, the model is closer to Whelan (2003).

Households

Time is discrete and indexed by $t \in \{0, 1, 2, \cdots\}$. There is a representative agent in this economy, and their utility function is

$$U = \sum_{t=0}^{\infty} \beta^t L_t \ln \prod_{i \in \mathcal{C}} d_{i,t}^{\gamma_i}, \tag{1}$$

where L_t is the (effective) number of workers, and $d_{i,t}$ is the stock of consumption good i per capita at date t, and $\mathcal{C}$ is the set of the consumption goods. We assume that the effective number of workers grow exogenously and $\sum_{i \in \mathcal{C}} \gamma_i = 1$. The law of motion of good i is

$$D_{i,t} = C_{i,t} + (1 - \delta_i) D_{i,t-1}, \tag{2}$$

where $D_{i,t}$ is the total durable stock of good i of the economy, $D_{i,t} = L_t d_{i,t}$, $C_{i,t}$ is the total purchase of good i, δ_i is the depreciation rate for good i and $D_{i,-1}$ is assumed to be zero. When δ_i^D is equal to one, then good i becomes perishable. Otherwise, good i is a durable good. The household accumulates the consumer durables by buying the consumption goods $\{C_{i,t}\}_{i\in\mathcal{C}}$ whose prices are $p_{i,t}$. We assume that there exists at least one perishable good.

The household can accumulate capital stocks and rents them to producers. Let $\mathcal{I}$ denote the set of the investment goods. The law of motion of capital good $i \in \mathcal{I}$ is given by

$$K_{i,t+1} = I_{i,t} + (1-\delta_i) K_{i,t},$$

where δ_i is the depreciation rate of capital i. The rental rate of capital good i is denoted by $r_{i,t}$. The flow budget constraints are given by

$$\sum_{i\in\mathcal{C}} p_{i,t}C_{i,t} + \sum_{i\in\mathcal{I}} p_{i,t}I_{i,t} + B_{t+1} = \sum_{i\in\mathcal{I}} r_{i,t}K_{i,t} + W_tL_t + R_tB_t, \tag{3}$$

where B_t is the government bond and W_t is the wage rate per effective unit. The household maximizes its utility (1) subject to the flow budget constraints (3) and the initial capital stocks, $K_{i,0}$. where $\sum_{i\in\mathcal{C}} \gamma_i = 1$. The household provides the labor inelastically.

Firms

Let $\mathcal{N}$ be the union of set $\mathcal{C}$ and $\mathcal{I}$, and an element of $\mathcal{N}$ is called sector. In each sector, there is a representative firm which produces output. The firm produces its output by using the following technology:

$$Y_{n,t} = A_{n,t} \prod_{i\in\mathcal{I}} K_{i,n,t}^{\theta_i\alpha} L_{n,t}^{1-\alpha}, \tag{4}$$

where $K_{b,n,t}$ is the amount of capital good b rented to the firm in sector n, and $L_{n,t}$ is the labor input for sector n, and $A_{n,t}$ represents the technology level of sector n. Note that we assume that all the firms have the identical production function except for their technology levels, $\{A_{n,t}\}_{n\in\mathcal{N}}$. The firms buy capital and labor inputs in competitive factor markets, and $r_{a,t}$ and w_t denote the rental rate of capital good a and the wage rate, and sell their products in competitive product markets.

Because the market perfection assumption and the assumption that the firms have the same production function except sectoral TFP, the capital labor ratios are equalized and the output prices satisfy the following:

$$\frac{K_{b,n,t}}{L_{n,t}} = \frac{K_{b,t}}{L_t} \tag{5}$$

$$\frac{p_{n,t}}{p_{m,t}} = \frac{A_{m,t}}{A_{n,t}}. \tag{6}$$

Government

We assume that the government sets its logged nominal interest rate $\ln R_t$ to r. We are agnostic about the government's motive behind this policy. Also the government does not issue any debt, $B_t = 0$.

Market Clearing Conditions

We impose the following market clearing conditions at equilibrium:

$$Y_{n,t} = \begin{cases} C_{n,t} & n \in \mathcal{C} \\ I_{n,t} & n \in \mathcal{I} \end{cases}$$

$$K_{i,t} = \sum_{n \in \mathcal{N}} K_{i,n,t} \quad a \in \mathcal{I}$$

$$L_t = \sum_{n \in \mathcal{N}} L_{n,t}$$

$$B_t = 0.$$

Equilibrium, Macro Variables, and Balanced Growth Path

A competitive equilibrium for this economy is defined as usual. A competitive equilibrium is a duple of the price system $\left((p_{i,t})_{i \in \mathcal{N}}, (r_{i,t})_{i \in \mathcal{I}}, w_t\right)$ and allocations $\left((C_{i,t})_{i \in \mathcal{C}}, (I_{i,t}, K_{i,t})_{i \in \mathcal{I}}, (K_{b,n,t})_{b \in \mathcal{I}, n \in \mathcal{N}}, (L_{n,t})_{n \in \mathcal{N}}\right)$ such that: (1) given the prices, $\left((C_{i,t})_{i \in \mathcal{C}}, (I_{i,t}, K_{i,t})_{i \in \mathcal{I}}\right)$ solves the utility maximization problem; (2) given the prices, $\left((K_{b,n,t})_{b \in \mathcal{I}}, L_{n,t}\right)$ solves the profit maximization problem of the firm in sector n and; (3) all the market clearing conditions are satisfied.

In the empirical analysis below, we focus our analysis on a *balanced growth path* (BGP) of the economy. When we analyze a BGP of the economy, we assume that the sectoral TFP of sector n grow at a constant, but not necessarily the same rate. A BGP is a particular type of a competitive equilibrium in which all the endogenous variables grow at constant, but not necessarily the same, rates. For notational convenience and avoiding notational clutter, let g_X denote the growth rate of variable X along the BGP and Y denote the value of variable Y along the BGP. By allowing a slight abuse of notation, let g_{X_t} denote the growth rate of variable X at date t.

We assume that the growth rates of the sectoral TFP satisfy the following inequality:

Assumption 1. *The sectoral TFP growth rate g_{A_i} satisfies the following equality.*

$$g_{A_i} + \frac{\alpha}{1-\alpha} \sum_{i \in \mathcal{I}} \theta_i g_{A_i} > \ln(1-\delta_i) + \max\{\ln \beta, -g_L\}. \tag{7}$$

Also the growth rate of the number of effective workers g_L is bounded by $\ln\beta^{-1}$:

$$g_L \leq \ln\beta^{-1}. \tag{8}$$

These regularity assumptions ensure that the sectoral shares in value added and nominal consumption are well-defined along a BGP. Since the model here is a natural extension of Greenwood et al. (1997) and Whelan (2003), we relegate the detail discussion and characterization of BGP to Appendix C.

2.2 Macro Economic Variables

The equilibrium objects do not involve the real aggregate GDP and inflation, but sectoral output and prices. In the neoclassical growth model, there is only one good, and the sectoral output corresponds to the real GDP naturally. Since there are many goods in in the economy, there does not exist such an obvious mapping to the real GDP, consumption, and other macroeconomic variables. In this paper, we define them as if statistical agency of Japan defines in this economy.[2] To that end, it is convenient to define the following notations. The growth rate of the real GDP denoted by $g_{V_t^*}$ is given by

$$g_{V_t^*} = \sum_{n\in\mathcal{N}} s_{n,t-1} g_{Y_{n,t}}, \tag{9}$$

where $s_{n,t-1}$ is the share of good n in value added at date $t-1$. This definition of the real GDP is consistent with the method employed by Japan and European countries. Similarly, the growth rate of the aggregate consumption denoted by g_{C_t} is defined as follows:

$$g_{C_t} = \sum_{i\in\mathcal{C}} s_{c_i,t-1} g_{Y_{i,t}}.$$

The growth rate g_C differs from the real GDP growth rate $g_{V_t^*}$ since they use different weights. Also let g_{c_t}denote the growth rate of the aggregate consumption per effective worker.

We turn to define CPI and wage rate. The CPI inflation rate as the statistical agency in Japan (and European countries) do. The CPI inflation rate is the weighted average of the real consumption growth by using the shares in total consumption:

$$\pi_t = \sum_{i\in\mathcal{C}} s_{c_i,t-1} g_{p_{i,t}}, \tag{10}$$

where $s_{c_i,t-1}$ is the share of good i in total consumption at date $t-1$. So, the share $s^c_{i,t-1}$ is equal

[2]European countries use the same method to calculate real GDP as Japan. Unlike Japan, the United States and Canada use the Fisher quantity index.

to $s_{i,t-1}/\sum_{j\in\mathcal{C}} s_{j,t-1}$ for all $i \in \mathcal{C}$. Finally we define the hourly wage denoted by w_t as follows:

$$w_t = \frac{W_t L_t}{H_t},$$

where H_t is the total hours worked in this economy. We assume that both the effective labor input and hours are given exogenously. Let q_t denote L_t/H_t, which represents the quality of labor. Since the effective and hours worked are exogenously given, the quality q_t is also exogenously given.

2.3 Sufficient Statistics Along the BGP[3]

Now we provide a mapping from the primitives of the model to the endogenous variables of interest:

Proposition 1. *Suppose that Assumption 1 holds. There exists a unique BGP, and along the BGP,*

$$\pi = -\sum_{i\in\mathcal{C}} s_{c_i} g_{A_i} - \frac{\alpha}{1-\alpha}\sum_{i\in\mathcal{I}} \theta_i g_{A_i} + \ln\beta + r \tag{11}$$

$$g_w = r + \ln\beta + g_q \tag{12}$$

$$g_c = \sum_{i\in\mathcal{C}} s_{c_i} g_{A_i} + \frac{\alpha}{1-\alpha}\sum_{i\in\mathcal{I}} \theta_i g_{A_i} \tag{13}$$

$$g_{ALP} = \sum_{i\in\mathcal{N}} s_i g_{A_i} + \frac{\alpha}{1-\alpha}\sum_{i\in\mathcal{I}} \theta_i g_{A_i}, \tag{14}$$

where the consumption and GDP shares, $\left((s_{c_i})_{i\in\mathcal{C}}, (s_i)_{i\in\mathcal{N}}\right)$ *are only a function of the exogenous parameters of the model.*

For the proof for Proposition 1 and the expressions for the consumption and GDP shares, see Appendix C.

There are four points that are worth mentioning about Proposition 1. First, equation (13) and (14) are a generalization of the results in Greenwood et al. (1997) and Whelan (2003) by allowing many investment goods and consumption goods. Equation (13) and (14) consists of three effects: the direct effect from the sectoral TFP; the capital deepening effect; and the effect of labor augmentation. The direct effect represents the effect of how much sectoral TFP raises aggregate consumption per effective worker and ALP at fixed factors of production. The capital-deepening effect, the second terms in equation (13) and (14), represents how the sectoral TFP affect them indirectly through the reactions of endogenous capital accumulation. If the capital good i accumulates more quickly, the sectoral outputs grow faster. The multiplicative, $\alpha\theta_i$, represents the output elasticity of capital good i. The rise of the outputs further increases the capital stocks, which induce

[3] In this section, we use the properties of the BGP and get an implication for the aggregate CPI. For its full characterization, see Appendix C.

further increases of sectoral outputs. The cumulative effect corresponds to $1/(1-\alpha)\alpha\theta_i$. The parameters $\left(\alpha, (\theta_i)_{i\in\mathcal{I}}\right)$ govern the strength of this capital deepening effect. When θ_i is higher (namely the output elasticity of good i is higher), then the capital deepening effect associated with asset class a is high. When α is higher (namely all the capital goods have the higher output elasticities), then the capital deepening effect get larger. The last effect simply comes from the fact that the economy has effectively more workers.

Second, equation (11) is a generalization of the Euler equation obtained in the standard New-Keynesian (NK) model. To understand this point, note that equation (11) can be written as

$$g_c = \ln\beta + r - \pi, \tag{15}$$

When there is no growth, $g_c = 0$, then equation (15) boils down to the Euler equation which holds at a steady state of the standard NK model. As in the standard NK model, the supply side of the economy determines the growth rate of consumption g_c along the BGP or steady-state, which consequently determines the real interest rate $r - \pi$.[4]

Third, the growth rate of the nominal wage g_w is independent of the sectoral TFP while inflation is dependent of them. When a growth rate of TFP growth increases, inflation will fall if everything else is fixed. This effect drives up nominal wages. At the same time, the increase in the TFP growth rate raises the growth rate of the real wages through capital deepening. B these effects cancel each other out, the nominal wage rate is determined independently of the sectoral TFP.

Finally, while that utility function is given by equation (1), the coefficients $\{\gamma_i\}_{i\in\mathcal{C}}$ does not appear at all in Proposition 1. This is because: π corresponds to the CPI inflation rate, which does not correspond to the welfare-based price indexes, and; the supply side of the economy is determined independently of the demand side of the economy. For the supply side of the economy, the relevant parameters are $\left(\alpha, (\theta_i)_{i\in\mathcal{I}}\right)$, not $(\gamma_i)_{i\in\mathcal{C}}$.

2.4 Implication for Long-run Inflation

Now we explore various implications from Proposition 1. We begin by showing the standard implication for the monetary policy:

Proposition 2. *The government can chooses an appropriate interest rate r in order to achieve any inflation rate along the BGP unless the zero lower bound constraint on the nominal interest rate does not bind.*

Put differently, Proposition 2 says that the government can undone the effects from any changes in the economy (e.g. shifts of growth rate of sectoral TFP) on inflation. This point can be seen

[4] Unlike the standard NK model, note that equation (15) only holds along the BGP,.

more vividly by taking the total derivative of equation (15).

$$\partial g_c = \partial \ln \beta + \partial r - \partial \pi,$$

where $\partial \ln \beta$ captures the change in time-preference.[5] Any shifts of ∂g_c and/or $\partial \ln \beta$ can be undone by setting the nominal interest rate as

$$\partial r = \partial g_c - \partial \ln \beta.$$

This equation implies that the connection between the growth rate of the economy and inflation is elusive. While the (permanent) rise of prices of some categories seem to increase aggregate inflation, such an intuition is invalidated according to our model and NK models generally.

Above argument makes it clear that when the government cannot adjust its monetary policy, any shifts of ∂g_c and $\partial \ln \beta$ affect the long-run inflation rate. This situation become increasingly relevant especially for Japan. After 1999, the short-term policy interest rate has been near zero, and barely moved. So, it is natural at least for Japan to assume that $\partial r = 0$. Moreover, a lot of developed countries have faced a similar economic situation as Japan, and the interest rates for some developed countries have been low. So in the current economic situations, it is appropriate and necessary to examine how the supply side of the economy affects inflation and nominal wage.

For that purpose, we can use Proposition 1 again. By taking the total derivative of equation (11) and letting $\partial r = 0$, we obtain the sufficient statistics of the change in long-run inflation:

$$\partial \pi = -\sum_{i \in \mathcal{C}} s_{c_i} \partial g_{A_i} - \frac{\alpha}{1-\alpha} \sum_{i \in \mathcal{I}} \theta_i \partial g_{A_i} + \partial \ln \beta + \sum_{i \in \mathcal{C}} g_{A_i} \partial s_{c_i}. \tag{16}$$

The first term and the second term express the direct effect and capital deepening effect in terms of change. The last term represents the composition effect.The last term is tiny since the shares ∂s_{c_i} barely move for small shocks.[6] Because of this reason, we ignore the last term from now on.

This sufficient statistics result implies that in order to know how a growth rate of sectoral TFP affect long-run inflation rate, it suffices to know the size of the shock for the stagnated sector, ∂g_{A_i}, the share in consumption s_{c_i}, and the production parameters, (α, θ_i) . Note that all the information needed for such an exercise can be observable directly or estimated (See Section 4 below).

Equation (16) also formalizes the economic argument made by ex BOJ governor Hayami. When

[5] In this model, the discount factor is a parameter, but the literature provides various ways to endogenize β. For example, see Braun and Nakajima (2012) which studies how the idiosyncratic capital risks affect the discount factor for the representative agent. See Fujita and Fujiwara (2021) which explores the connection of the demographic change in Japan and the natural rate of interest.

[6] We provide a robustness exercise where we explicitly take into account the composition effect. Our results hardly change by incorporating the composition effect.

the monetary policy does not respond to the shocks, the supply and demand side of the economy can affect long-run inflation. When a growth rate of a sectoral TFP improves for some sector, $\partial g_{A_i} < 0$, then long-run inflation declines. This result is quite intuitive. When productivity growth increases, the growth rates of real GDP and consumption increase. To encourage high consumption growth by the household, the real interest rate goes up. Since the nominal interest rate does not respond to it, inflation rate will rise in order to increase the real interest rate. So in this case, we have good deflation as ex BOJ governor Hayami told in his speech on March 2000. When we have stagnation of sectoral TFP, the economy experiences opposite. Long-run inflation rate will raise and the welfare of the economy goes down, bad inflation. In the quantification exercises below, we examine how technology improvement or stagnation estimated from data affects long-run inflation. We conclude this section by introducing the following proposition.

Proposition 3. *Suppose that Assumption 1 holds and the monetary policy is constrained,* $\partial r = 0$. *Then:*

$$\partial\pi = -\sum_{i\in\mathcal{C}} s_{c_i}\partial g_{A_i} - \frac{\alpha}{1-\alpha}\sum_{i\in\mathcal{I}}\theta_i\partial g_{A_i} + \partial\ln\beta + \sum_{i\in\mathcal{C}} g_{A_i}\partial s_{c_i} \tag{17}$$

$$\partial g_w = \partial\ln\beta + \partial g_q \tag{18}$$

$$\partial g_C = \sum_{i\in\mathcal{C}} s_{c_i}\partial g_{A_i} + \frac{\alpha}{1-\alpha}\sum_{i\in\mathcal{I}}\theta_i\partial g_{A_i} + \partial g_L + \sum_{i\in\mathcal{C}} g_{A_i}\partial s_{c_i} \tag{19}$$

$$\partial g_{V^*} = \sum_{i\in\mathcal{N}} s_i\partial g_{A_i} + \frac{\alpha}{1-\alpha}\sum_{i\in\mathcal{I}}\theta_i\partial g_{A_i} + \partial g_L + \sum_{i\in\mathcal{N}} g_{A_i}\partial s_i, \tag{20}$$

3 Empirical Context

In this section, we use our model and the sufficient statistics results in Proposition 3.

3.1 Dataset

For our empirical analysis, we use publicly available data about Japan. Our main sources are the national account of Japan for 2018 (JSNA) and the Japan Industrial Productivity Database 2021.[7] JIP is constructed explicitly by mimicking the compilation method by the EU-KLEMS. So, JIP is comparable to the EU-KLEMS dataset. [8]

We use JSNA in order to construct set $\mathcal{C}$ and $\mathcal{I}$. Set $\mathcal{C}$ consists of: food; non-durable consumption; durable consumption; and service (excluding imputed rents). JSNA has the information about

[7]JSNA is constructed based on SNA 2008 and the benchmark year is 2011. JSNA can be downloaded from the following URL, https://www.esri.cao.go.jp/en/sna/data/kakuhou/files/2018/2018annual_report_e.html.

[8]The latest JIP can be downloaded from this URL, https://www.rieti.go.jp/en/database/JIP2021/index.html.

these consumption deflators and nominal expenditures.[9] So, we let the empirical counterparts of these prices, $\{p_{n,t}\}_{n\in\mathcal{N}}$, be the corresponding consumption deflators reported in JSNA. We make an adjustment so that the value added taxes (VAT) are excluded from these prices.[10] We also compute the shares in consumption $\{s_{c_i,t}\}_{i\in\mathcal{C}}$ based on the information in JSNA.

Set $\mathcal{I}$ consists of: other buildings and structures (structures); transport equipment; information and communication technology equipment (ICT); other equipment; defense equipment; cultivated biological resources; and IPP. The empirical counterparts of these prices are the corresponding investment deflators. The shares in investment are also computed from JSNA.

In order to compute the shares in value added $\{s_{n,t}\}_{n\in\mathcal{N}}$, we begin by specifying the aggregate nominal consumption and investment. Following Greenwood et al. (1997), we exclude housing from our analysisThe aggregate consumption is the total nominal consumption excluding housing, imputed rents and NFISH. The aggregate investment is the total gross fixed capital formation (GFCF) except the residential investment. The consumption share is the aggregate consumption divided by the sum of the aggregate consumption and investment. The share of consumption good n in valued added can be obtained by multiplying the share of the good in consumption goods, $s_{c_n,t}$ by the share of all consumption goods. The aggregate inflation rate is the weighted average of these prices by using the lagged shares in consumption. We make an additional adjustment so that the level of inflation of the initial observation stays the same as one in CPI. The second adjustment is innocuous since the aggregate consumption deflator and CPI almost are almost identical up to a constant, and we are primarily interested in the change in inflation, not the level of inflation.

JIP provides a real GDP growth rate excluding housing, which is our measure for the aggregate GDP growth rate. We also use the labor service index excluding housing as our measure for the labor input L_t. We also make use of the labor quality index q_t in JIP.

3.2 Facts about Japanese Economy After 1994

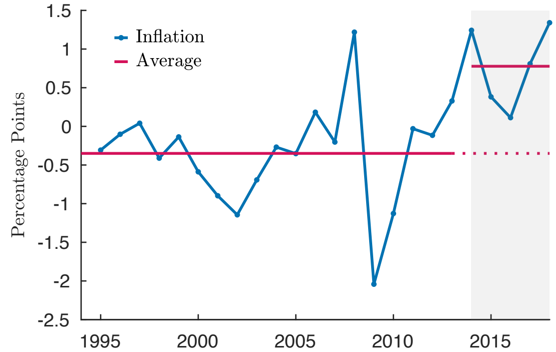
We begin by documenting the movement of inflation in Japan. As depicted in Figure 2, the inflation rate of Japan has been low in the last two or three decades. However, since Kuroda took over as Bank of Japan Governor in 2013, the inflation rate has started to show positive values. The average inflation rate until 2013 is -0.35%, but after 2013, the inflation rate rose to 0.77% on average.

This increase in inflation is considered to be the result of Governor Kuroda's expansionary monetary policy. Or more generally, the rise of inflation is often attributed to so-called Abenomics. (Hausman and Wieland (2015a)) Figure 3a and 3b depict various interest rates in Japan. The short-term policy interest rate has been near zero since 1997. Recently the BOJ started to buy

[9] See Appendix XXX for the detail of the construction of the consumption deflators.

[10] The Japanese government raised its VAT in 1997 and 2014. For the detail of our adjustment, see Appendix A.3.

Figure 2: Inflation

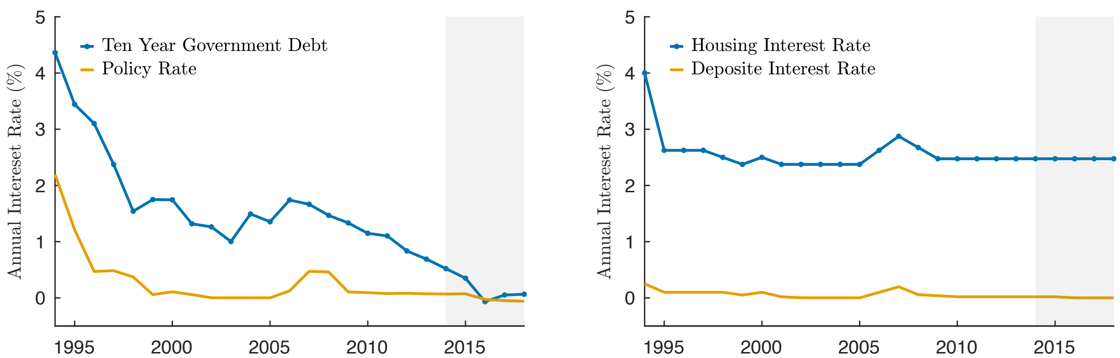


Notes: The first solid line represents the average level of inflation until 2013, and the second solid line depicts the average after 2013.

Figure 3: Various Interest Rates

(a) Policy and Government Debt Interest Rate

(b) Housing and Deposit Interest Rates in Japan



Notes: We measure the housing interest rate by median interest rates for floating rates provided by major banks. The data can be downloaded from BOJ's website.

longer term government debts, which pushed down longer-term interest rates. In the last five years, the interest rate for the ten year government bond has been close to zero.[11] While these policy interest rates have been low, the typical interest rates that households in Japan care have not respond. According to Figure 3b, both the deposit and housing interest rates have been constant. Figure Judging from 3b, it is not clear how the aggressive monetary policy by Governor Kuroda induced the rise of inflation in Japan.[12]

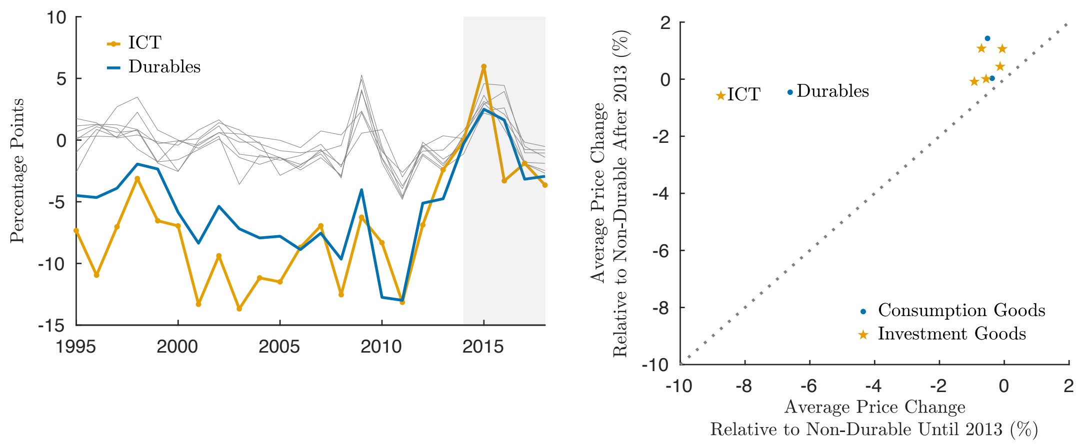
We argue that inflationary factors were quietly arising at the same time. Figure 4a depicts the relative prices for consumption and investment goods. To compute the relative prices, we divide each price by the price for non-durable consumption. Each line represents the growth rate of each relative price. The growth rates of most goods do not change much between before and after 2013.

[11] In the US, the interest rate for the ten year government bond after 2014 and before the COVID-19 crisis is more than 2%.

[12] See Hausman et al. (2019) which explores a reason why there was little pass-through to the housing interest rate.

Figure 4: Growth Rate of Relative Prices

(a) Time-Series (b) Average Growth Rates



However, the price movements of durable goods and ICT have changed significantly. Until 2010, the prices of durable goods and ICT have been significantly declining compared to other goods. For example, until 2010, the relative price of ICT had been falling by almost 10% on average. This rapid decline is due to rapid quality improvement for ICT goods. The same argument is made for the durable good. Figure 4a makes it clear that these relative price declines have completely stopped since 2014. Intuitively speaking, these rises of the relative prices contribute to the rise of inflation. According to our theory, this intuition is justified when the monetary policy is constrained, $\partial r = 0$, which is reasonable assumption for Japan. In the quantitative exercise below, we relate the rise of these relative prices, and explore the quantitative implication for the rise of inflation after 2014 in Japan.

The model has various predictions on other macro economic variables. Figure 4a and 24 depict the growth rate and the level of hourly wage rate in Japan. Both figures do not display a systematic pattern for the wage rate. Figure 6d shows the level of the average labor productivity (ALP) and the aggregate consumption per effective worker. Until 2013, the growth rates of ALP and consumption are almost the same level. Since around 2014, the growth rate of consumption has been slower than that of ALP. This fact also casts a standard interpretation of the recent rise of inflation. Figure 6d suggests that the rise in inflation does not appear to be driven by a strong demand side. In the coming section, we explore whether our model can explain these facts about Japan consistently.

4 Mapping Model to Data

In this section, we estimate the growth rates of sectoral TFP by using our structural model. After discussing whether the model can fit the data well, we quantify the effects of the rises of the relative

Figure 5: Other Macroeconomic Variables

(a) Growth Rate of Hourly Wage

(b) Hourly Wage Level

(c) Growth Rates of ALP and Consumption

(d) ALP and Consumption Level

prices of the durable and ICT goods on inflation.

4.1 Estimating Equations

Now we estimate the sectoral TFP growth rates by using our structural model. The method is similar to one used in Greenwood et al. (1997), Whelan (2003), and more recently Gourio and Rognlie (2020). We derive our estimating equations by using the firms' optimal conditions. Our estimating equations consists of two equations. The first equation is the Solow residual. The growth rate of the aggregated Solow residual denoted by g_{R_t} is defined as[13]

$$g_{R_t} \equiv \sum_{n \in \mathcal{N}} s_{n,t-1} \left(g_{Y_{n,t}} - \alpha \sum_{b \in \mathcal{I}} \theta_b g_{K_{b,n,t}} - (1-\alpha) g_{L_{n,t}} \right). \tag{21}$$

[13]Technically speaking, we use the real GDP in JIP so that the correct weight is not $s_{n,t-1}$ but $\bar{s}_{n,t} = (s_{n,t} + s_{n,t-1})/2$. For avoiding notational clutter, we keep using $s_{n,t-1}$, but the actual computation is done with the relevant weights.

By using the condition derived by using the firms' optimality, equation (33), the Solow residual can be written in terms of aggregate variables:[14]

$$g_{R_t} = g_{V_t^*} - \alpha \sum_{b \in \mathcal{I}} \theta_b g_{K_{b,t}} - (1 - \alpha)\, g_{L_t}. \tag{22}$$

Note that conditional on the production function parameters $\left(\alpha, (\theta_i)_{i \in \mathcal{I}}\right)$, all the other variables in the RHS of equation (22) is observable. Using the functional form assumption of the production function, equation (4), the Solow residual g_{R_T} can be also written as the weighted average of the sectoral TFP:

$$g_{R_t} = \sum_{n \in \mathcal{N}} s_{n,t-1} g_{A_{n,t}}, \tag{23}$$

which constitutes the first estimating equation.

To obtain the second type of the estimating equations, we again use the firms' optimality conditions. Recall that in a competitive equilibrium, the relative price of good n reflects the relative TFP, (22). Taking log-difference of equation (6), for all $n \in \mathcal{N}_{-m}$,

$$g_{p_{n,t}} - g_{p_{m,t}} = g_{A_{m,t}} - g_{A_{n,t}}. \tag{24}$$

Note that the growth rates of the relative prices, $g_{p_{n,t}} - g_{p_{m,t}}$, are observable. Equation (24) constitutes the second estimating equations. If we have an estimate of $\left(\alpha, (\theta_i)_{i \in \mathcal{I}}\right)$, we can estimate the growth rates of sectoral TFP by solving the two sets of the estimating equations, (23) and (24).

4.2 Parameter Estimation

Now we discuss how we estimate the parameters $\left(\alpha, (\theta_i)_{i \in \mathcal{I}}\right)$. Note that parameter α corresponds to the aggregate labor share for the economy. JIP has an time-series estimate of the aggregate labor share so that we set the value of its mean to parameter α.

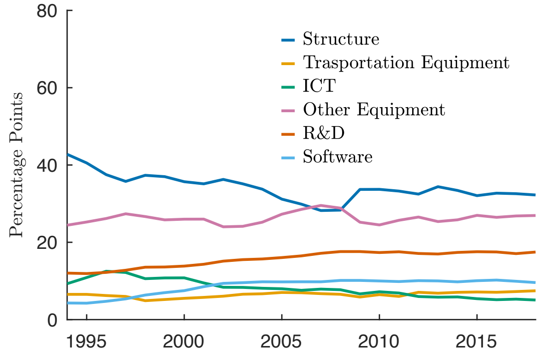
To estimate parameter θ_i, we use the methodology used in Gourio and Rognlie (2020). Gourio and Rognlie (2020) expresses θ_i in terms of observables by using the condition which holds along the BGP.

$$\theta_i = \left(1 - \frac{\sum_{j \in \mathcal{I}} s_j}{\alpha}\right) s_i^K + \frac{\sum_{j \in \mathcal{I}} s_j}{\alpha} s_i^I, \tag{25}$$

where s_i^K is the share of capital good i in the total nominal capital stock, and s_i^I is the share of investment good i in the total nominal investment. Since each term in the RHS of equation (25) has its empirical counterpart in JSNA, we can estimate a time-series of θ_i. Figure 6 depicts the time-series estimates of $(\theta_i)_{i \in \mathcal{I}}$. While initially the time-series estimates of θ_i moved, but after 2005

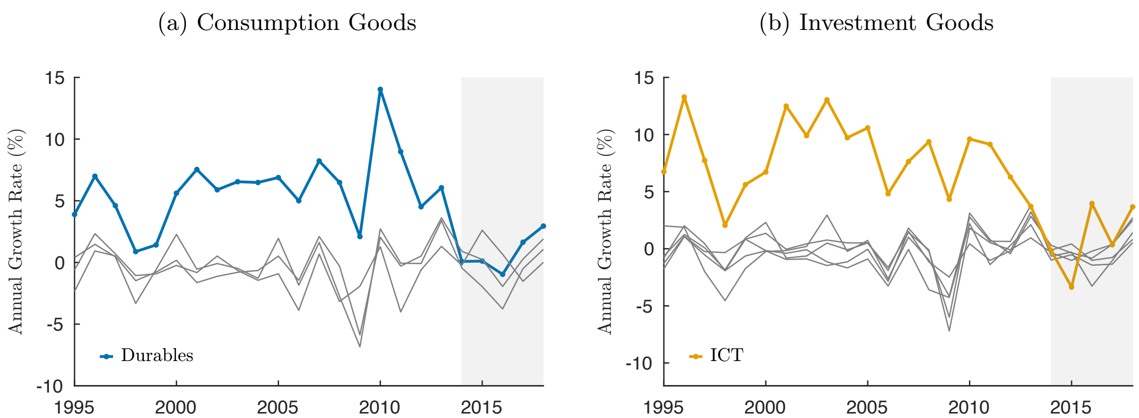
[14] Note that we use equilibrium conditions, and do not use the conditions which only holds along the BGP.

Figure 6: Time-Series Estimate of $(\theta_i)_{i\in\mathcal{I}}$



Notes: We only plot the time-series of θ_i for structure, transportation equipment, ICT, other equipment, R&D, and Software. Other investment goods, defense equipment, cultivated assets, and other intellectual property product, have very small θ_i . For these goods, the time-series of θ_i is less than 3%.

Figure 7: Growth Rate of TFP



Notes: Each solid line represents our estimate of the growth rate of TFP.

the estimate get stabilized. So, we set the values of their mean to parameter $(\theta_i)_{i\in\mathcal{I}}$.

4.3 Estimation of Sectoral TFP

Since we obtain our estimate for $\left(\alpha, (\theta_i)_{i\in\mathcal{I}}\right)$, we can estimate the growth rates of sectoral TFP, $\left(g_{A_{n,t}}\right)_{n\in\mathcal{N}}$. Figure 7 depicts those growth rates. With the exception of durable goods and ICT goods, the growth rates are at about the same level. In addition, there have been no changes in the average growth rates before and after 2014. On the other hand, the TFP growth rates of durable goods and ICT goods were higher than that of other goods until 2014; the growth rates after 2014 were almost the same as that of other goods. This result is driven by the movement of relative prices (see Figure 4a.) We interpret that these goods experienced a negative shock on their growth rates.

4.4 Model Fit

Before quantifying the effect of TFP stagnation of consumer durable and ICT, we show that our model with the estimated growth rates of sectoral TFP can fit the data well. In particular, we investigate whether our model can successfully reproduce the differences in growth rates of various variables before and after 2014. We use our sufficient statistics result in Proposition 3 to compute the differences in growth rates. Let the variable $\mathbf{d}g_{A_i}$ be the difference in the average growth rate of g_{A_i} before and after 2014. Our model predicts the change in the average growth rate of the following endogenous variables as follows:[15]

$$\begin{aligned}
\mathbf{d}\pi &= -\sum_{i\in\mathcal{C}} s_{c_i}\mathbf{d}g_{A_i} - \frac{\alpha}{1-\alpha}\sum_{i\in\mathcal{I}}\theta_i\mathbf{d}g_{A_i} + \mathbf{d}\ln\beta \\
\mathbf{d}g_w &= \mathbf{d}\ln\beta + \mathbf{d}g_q \\
\mathbf{d}g_{C/L} &= \sum_{i\in\mathcal{C}} s_{c_i}\mathbf{d}g_{A_i} + \frac{\alpha}{1-\alpha}\sum_{i\in\mathcal{I}}\theta_i\mathbf{d}g_{A_i} \\
\mathbf{d}g_{ALP} &= \sum_{i\in\mathcal{N}} s_i\mathbf{d}g_{A_i} + \frac{\alpha}{1-\alpha}\sum_{i\in\mathcal{I}}\theta_i\mathbf{d}g_{A_i},
\end{aligned} \tag{26}$$

where the nominal shares s_{c_i} and s_i are set to the average value of them. The change in the discount rate $\mathbf{d}\ln\beta$ is chosen so as to explain the difference in the average growth rate of inflation in data. We compare the changes in the growth rates of these endogenous variables, with the corresponding empirical counterparts in the data.

The result is summarized by the following Table. Since the change in the discount factor $\mathbf{d}\ln\beta$ is chosen to satisfy the observed change in the average inflation, we can (by construction) predict the observed change in inflation. Moreover, the model can successfully replicate the observed changes of the growth rates of the real variables, g_{ALP} and g_c. Note that the fact that the model can reproduce these changes is not mechanical. The change in ALP by equation 26 is derived by the assumption that the economy had reached the BGP before 1994 and the economy immediately jumps to the new BGP after 2013. If the actual economy is not well-approximated by the BGP, then the model cannot predict the change in the growth rate of ALP well. The model has implication for nominal hourly wage too. But, as explained in Section 3.2, the nominal wage in data does not exhibit a clear pattern. Finally notice that the model predicts that the growth rate of consumption declines more than one of ALP, which is shown in Figure 6d). Overall, we argue that the model can reproduce the observed changes well.

[15] As argued above, we ignore the composition effects, $\sum_{i\in\mathcal{C}} g_{A_i}\partial s_{c_i}$ and $\sum_{i\in\mathcal{N}} g_{A_i}\partial s_i$.

Table 1: Model Fit

Variable	Description	Data	Model (BGP)	Change (Fraction)
			Internal	
$\mathbf{d}\pi$	Inflation	1.13%	1.13%	(100%)
$\mathbf{d}g_{GDP/L}$	GDP Per L_t	-0.63%	-0.37%	(60%)
			External	
$\mathbf{d}g_{C/L}$	Consumption Per L_t	-1.56%	-0.38%	(25%)
$\mathbf{d}g_w$	Nominal Wage	(-1.00%)	0.22%	(22%)
$\mathbf{d}g_w - \mathbf{d}\pi$	Real Wage	(-0.13%)	-0.90%	(68%)

5 Quantification

Now we quantify the effect of depressed TFP growth of consumer durable and ICT on the long-run inflation rate. As in the previous section, we use our sufficient statistics result in Proposition 3 to quantify the effect:

$$
\begin{aligned}
\mathbf{d}\pi^{\text{Tech}} &= -s_{c_{\text{Durable}}}\mathbf{d}g_{A_{\text{Durable}}} - \frac{\alpha}{1-\alpha}\theta_{\text{ICT}}\mathbf{d}g_{A_{\text{ICT}}} \\
\mathbf{d}g_w^{\text{Tech}} &= 0 \\
\mathbf{d}g_{C/L}^{\text{Tech}} &= s_{c_{\text{Durable}}}\mathbf{d}g_{A_{\text{Durable}}} + \frac{\alpha}{1-\alpha}\theta_{\text{ICT}}\mathbf{d}g_{A_{\text{ICT}}} \\
\mathbf{d}g_{ALP}^{\text{Tech}} &= s_{\text{Durable}}\mathbf{d}g_{A_{\text{Durable}}} + \frac{\alpha}{1-\alpha}\theta_{\text{ICT}}\mathbf{d}g_{A_{\text{ICT}}}.
\end{aligned}
$$

The results are summarized in Table 2. The depressed TFP for these sectors greatly lower the long-run inflation rate in Japan. The model predict that these negative supply shocks increased inflation after 2013 by 0.76%. So, these two shocks explain 67% of the observed increase in inflation in Japan. This result has a big policy implication. A conventional story behind the recent rise of inflation is that the BOJ (at least partially) successfully increased inflation in Japan by aggressive monetary policy, known as Kuroda bazooka (Hausman and Wieland (2015b)). Our model suggests a very different story: the BOJ's monetary policy is effectively constrained, and the negative TFP shocks hits the Japanese economy, which is why inflation raised in Japan. The model can also predict substantial declines in the growth rate of consumption per effective labor and ALP.

Now we provide two counter-factual analysis. In the first scenario, we consider the case where

Table 2: Quantification

	Quantification			Decomposition			
				Durable		ICT	
Variable	Data	Model	(Fraction)	(Weight)	($-\mathbf{d}g_{A_i}$)	Weight	$-\mathbf{d}g_{A_i}$
$\mathbf{d}\pi$	1.13%	**0.76%**	(67%)	0.54%		0.23%	
				(0.10)	(5.4%)	(0.03)	(6.9%)
$\mathbf{d}g_{C/L}$	-1.56%	-0.77%	(50%)	-0.54%		-0.23%	
				(0.10)	(5.4%)	(0.03)	(6.9%)
$\mathbf{d}g_{GDP/L}$	-0.63%	-0.59%	(94%)	-0.54%		-0.23%	
				(0.07)	(5.4%)	(0.03)	(6.9%)

TFP of consumer durable and ICT did not fall after 2013. In the second scenario, we examine the case where TFP of these sectors did not improve in the first place before 2014.

If the growth rates of TFP for these sectors did not decline, then the inflation rate after 2013 would be 0.01%. So, according to our model, the fact that Japan has experienced a consistent inflation after 2013 is attributed to the technology stagnation. If the growth rates of TFP for these sectors did not improve in the first place, then the inflation rate before 2014 would be 0.41%. The actual average inflation before 2014 is -0.35%. So, Japan would experience a positive inflation in this scenario.

6 Robustness

In order to show that that our results are robust, we provide various exercises in this section. We begin by documenting that the technology slowdown we observe in Japan is common across the developed countries. In the second robustness exercise, we compare our estimates of sectoral TFP with ones estimated by JIP (KLEMS.) We also examine whether exchange rate appreciation induced by the aggressive monetary policy in Japan has played a role for affecting the prices.

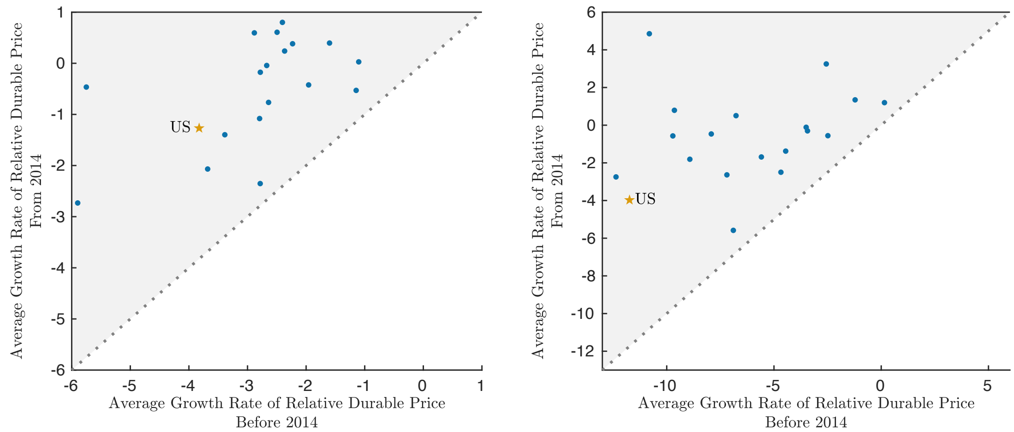
6.1 Cross-Country Validation

We analyzed the impact of technological stagnation of consumer durable and ICT on the long-run inflation rate for Japan. If technological innovation is becoming more difficult for Japan, then other advanced economies should be facing the same difficulties as Japan. To confirm this point, we analyze the relative prices of durable goods and ICT goods in the countries that joined the OECD before 1995.

Both Figure 8a and 8b show that after 2014, the decline in the relative prices of durable goods and ICT goods slowed down significantly across the countries. The degree of slowdown varies by

Figure 8: Average Changes of Relative Prices

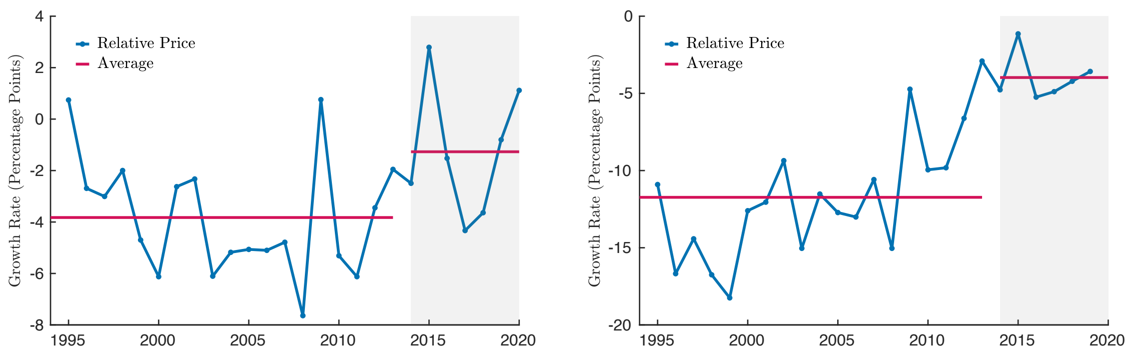
(a) Consumer Durable (b) ICT



Notes: In order to draw these figures, we download the relevant data from OECD Stat. Each dot represents a country.

Figure 9: Growth Rates of Relative Prices of the US

(a) Consumer Durable (b) ICT



Notes: Figure 4a depicts the growth rates of the prices divided by the price of non-durable consumption.

country, but for many countries the relative prices of durable goods and ICT goods have almost no longer fallen since 2014 on average.

Figure 9a and 9b depict the time-series of the relative prices of consumer durable and ICT for the US. The two straight lines represent the average growth rates before and after 2013. The US experienced more significant slowdown of ICT than Japan, but less so of consumer durable. What is common is that qualitatively the US experienced the same technology slowdown of these sectors in the last decade.[16] So, this cross-country evidence gives more credibility to our analysis based on technology slowdown of consumer durable and ICT.

[16] These figures make it clear that our benchmark year 2014 might not be suitable for other developed countries. But as shown in Figure 8a and 8b, these countries have experienced slowdown.

Table 3: Comparison

	JIP		Our Estimate
Period	CT	IT	ICT
1994-2013	5.3%	8.3%	8.1%
2014-2018	–9.4%	0.0%	1.2%
Change	−14.7%	−8.3%	−6.9%

Notes: We pick "Communication equipment Electronic data processing machines (47)" for CT and "digital and analog computer equipment and accessories" for IT.

6.2 Comparison to TFP estimated by JIP

Our estimation of sectoral TFP is based on the assumption that the relative prices reflect the relative levels of sectoral TFP, equation (6). There are many other reasons why these relative prices might move. So, our estimating assumption might not hold perfectly.

In this subsection, we compare our estimates of TFP for ICT with ones estimated by JIP (KLEMS). JIP estimates its growth rates of sectoral TFP without using the relative prices. Instead, JIP estimates TFP by measuring all the inputs under the assumption that all the markets are competitive. In particular, JIP estimates are not subject to the critique.

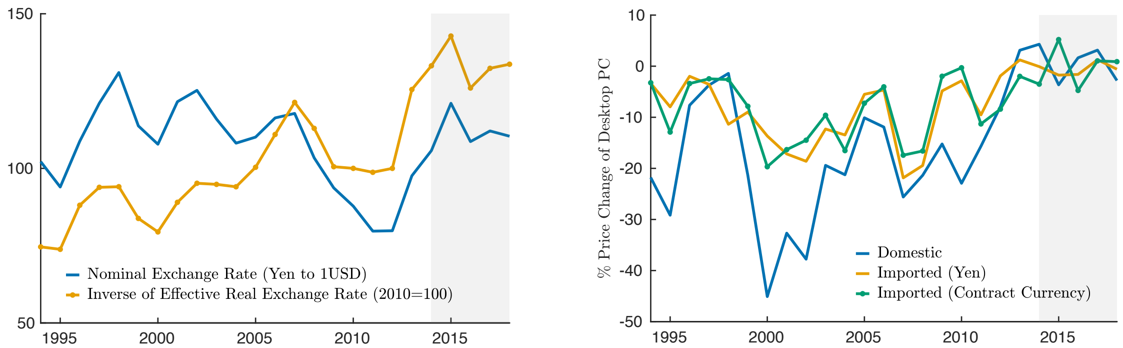
Industry classification differs between JSNA and JIP. So, we compare our estimate of TFP for ICT industry with the following two industries that seem to be closest to ICT goods: Communication equipment Electronic data processing machines (CT) and; digital and analog computer equipment and accessories (IT). Table 3 summarizes the comparison. Both JIP and our estimates show technology stagnation of these sectors. Moreover, the JIP estimates show greater technological stagnation for both industries. For example, the growth rate of TFP for IT sector declined by −8.3%. So, our result that the ICT sector has experienced technological slowdown holds robustly.

As a additional evidence supporting our result, we plot the exchange rates in Figure 10a and the inverse of the real effective exchange rate in Figure 10a. So, yen depreciates if the values increase. The BOJ's accommodative monetary policy has depreciated the nominal exchange rate. But after 2014, yen stopped depreciating further. While these exchange rates have fluctuated a lot, the various relative producer prices of desktop computer reported in PPI move in roughly the same way. All the relative prices declined substantially especially before 2010. In particular, the relative price for domestic computer fell rapidly compared to the relative prices of imported desktop computers. But after 2013, the relative prices become stable. Also note that both the relative price for imported desktop computer based on yen and one based on contract currently have moved in

Figure 10: Relative PPI

(a) Exchange Rates

(b) Relative Price of Desktop Computer



Notes: In order to draw these figures, we use the latest CGPI (PPI) of Japan. We download the various price data for desktop computers (PR01'PRCG15_2500850046) and notebook computers (PR01'PRCG15_2500850047).

almost the same way. So, we conclude that there is a limited effect on the relative prices from exchange rate fluctuation.

7 Conclusion

We construct a model in which technological stagnation can affect the long-run inflation rate, and show that most of Japan's inflation since 2014 has been caused by technological stagnation. This study has the following implications for monetary policy. When monetary policy is constrained by the zero lower bound constraint on the nominal interest rate, channels that would otherwise have no effect can affect the long-run inflation rate. Therefore, even when the targeted inflation rate is achieved, it is important to carefully understand the mechanism behind it. One point not discussed in this study is the question of why the level of Japan's inflation rate is lower than that of other developed countries. These issues, which are not addressed in this study, will be left for future research.

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