

## Measuring the Impact of Population Aging on Tax Revenue: Evidence from Japan and Korea\*

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**Abstract** This paper assesses empirically the tax implications of population aging in Japan and Korea. We achieve the research objectives by taking two approaches: (1) a vector autoregression (VAR) analysis; and (2) an estimated dynamic stochastic general equilibrium (DSGE) framework. Based on data from 1973 to 2015, the VAR results for both countries reveal that an aging shock decreases GDP, hours, consumption, and investment. As the tax bases fall, so do tax revenues. Conditioned on estimated DSGE models, the second approach is to characterize Laffer curves at two steady states: the current (as of 2015) and aged (as of 2060) states. We find that the adverse effect of population aging on tax revenues is more serious for Korea than for Japan. Even in the aged state, Japan has room to generate tax revenues comparable to the current state, whereas combinations of tax rates satisfying this property do not exist for Korea.

**Keywords** Population Aging, Fiscal Policy, Vector Autoregression, Laffer curve

**JEL Classification** J11, E62, H20, C32, E13

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## 1. INTRODUCTION

A substantial degree of population aging is under way in Japan and Korea. Figure 1 reports aging trends in major Western advanced economies along with Japan and Korea by showing how the percentage of the population aged 65 and older in these countries changes over time.<sup>1</sup> As made explicit in the figure, the Japanese and Korean societies are aging at a significantly more rapid rate than the others. Most of the Western countries took more than 40 years to complete the transition from an aging society to an aged society, but it took less than 25 years for Japan and Korea to do so. A similar but less pronounced tendency is observed in both countries' transformations from aged societies to super-aged societies. The future trend of population aging is shown in Figure 2, which plots the OECD's projections of the elderly share from 2015 to 2060. The speed of population aging in both countries seen up to now pales in comparison with future projections.

One much-discussed consequence of population aging is the possibility of slower economic growth due to a decline in labor supply. In the absence of policy responses such as changes to the legal age of retirement, population aging tends to lower labor force participation, which in turn inhibits economic growth. For instance, Chapter 3 of the IMF's 2004 World Economic Outlook by Callen et al. (2004) documents that per capita GDP growth is negatively correlated with changes in the elderly share, based on large samples for 115 countries. Regarding the relationship between population aging and labor supply, Burniaux et al. (2003) report a substantial decrease of labor supply in Japan, Italy, and Germany, attributable to the aging trend.

Of particular importance are the implications of the slower growth and decreased labor supply on tax revenues. The decline in labor supply may erode the labor income tax base such that labor tax revenues shrink at a given tax rate. In addition, economic theory posits that the marginal product of capital diminishes, and in turn investment falls, as labor hours decrease. Thus capital tax revenues may plunge as well. The adverse effects of population aging on the government revenue side deserve careful scrutiny, particularly for countries like Japan and Korea, both of which face unprecedented rates of aging. Despite the potential importance of the issue, however, little is known about the extent to which tax revenues may be affected.

This paper attempts to assess empirically the tax implications of the aging

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<sup>1</sup>According to the criterion of the United Nations, a society is classified as "aging", "aged", and "super-aged" if the share of elderly population exceeds 7%, 14%, and 20%, respectively.

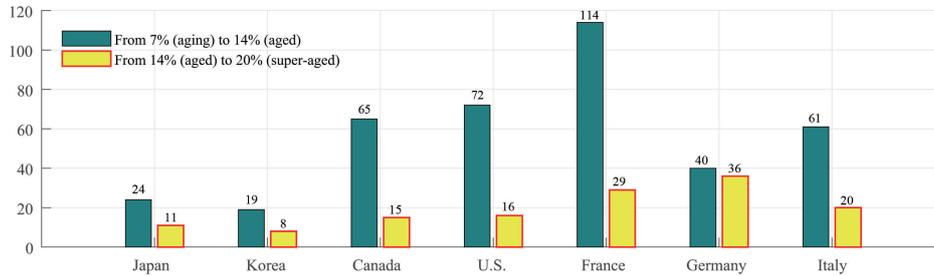


Figure 1: International comparison of changes in the percentage of the population aged 65 and older. This figure reports the years taken for the share of elderly population to increase from 7% to 14% (bars without lines) and from 14% to 20% (bars with solid lines). Source: OECD Statistics and Korean Statistical Information Service.

trend in Japan and Korea. In order to achieve the research objectives, we take two approaches: (1) an econometric model using a vector autoregression (VAR) analysis; and (2) a model-simulation technique based on an estimated dynamic stochastic general equilibrium (DSGE) framework. The first approach is designed to explore how population aging has affected tax revenues as well as tax bases for Japan and Korea. This task begins by estimating an annual VAR model consisting of six variables—the elderly share, and per capita GDP, hours, consumption, investment, and tax revenues—spanning from 1973 to 2015. We then identify the structural shock caused by population aging by utilizing a recursive ordering scheme, placing the elderly share first in the ordering and thus assuming that the aging shock is not affected by the macroeconomic variables within the year.

The VAR results for Japan reveal that the identified aging shock significantly decreases GDP, hours, consumption, and investment. As the tax bases fall, so do tax revenues. We also find a similar response pattern for Korea, but with several differences regarding the size of the responses. In response to the aging shock, the responses of GDP, consumption, and investment are all negative, with greater absolute sizes than those of Japan. The aging shock also decreases hours and tax revenue in Korea, although not to a statistically significant extent. The absolute size of these responses, however, is smaller than their Japanese counterparts. Before proceeding, it is worth emphasizing that for both countries, per capita labor hours decline in response to the aging shocks. This empirical finding is notable because it enables a structural analysis on the subject using a

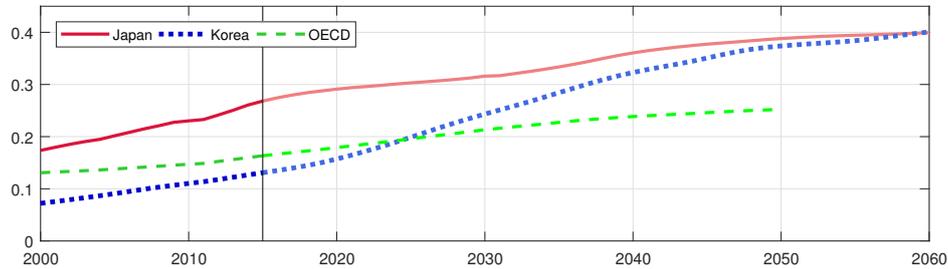


Figure 2: OECD's projections of the share of the population aged 65 and older, between 2015 and 2060. The actual and projected shares for Japan (solid line), Korea (dotted line), and the OECD average (dashed line) are reported. Note that the projected share for the OECD average is available only up to 2050.

DSGE model, which is the second approach in this paper. As mentioned earlier, a fall in *aggregate* labor supply is at the crux of the transmission mechanism of how population aging affects the macroeconomy. In conventional DSGE models assuming an infinitely-lived representative agent, however, what matters for economic fluctuations is *per capita* hours worked. This discrepancy in the concept of labor hours makes it impractical to fit the key transmission of population aging into the conventional modeling framework. Our empirical finding, however, provides a rationale against the impracticality.

Based on a DSGE model, the second approach utilizes the notion of the Laffer curve, suggesting that there is possibly an inverted U-shaped relationship between tax rates and revenues with a revenue maximizing tax rate. The Laffer curve concept has been extensively applied to various countries, including Trabandt and Uhlig (2011) and D'Erasmus et al. (2016) to the United States and European economies, Park (2012) to the G-7 countries, and Nutahara (2015) to Japan. When applying the idea to Japan and Korea, we take a different strategy from the existing literature regarding how to obtain the model's structural parameters. While the previous studies rely on calibrated parameters, our strategy is to calculate Laffer curves within the context of estimated models of the Japanese and Korean economies. Specifically, we use a neoclassical growth model augmented with real frictions such as habit formation in consumption, investment adjustment costs, and capacity utilization, which are often advocated as critical features for improving the model's fit to data. The model also includes distortionary taxes on labor and capital income as well as consumption taxes. We estimate the model via Bayesian methods with Japanese and Korean data com-

parable to those used for the VAR analysis. Following Park (2012), our primary exercise conditioned on the estimated models is to characterize Laffer curves at two steady states: the current (as of 2015) and aged (as of 2060) states. In doing so, the aged state is constructed by utilizing the labor-aging relationship that the VAR estimates suggest.

Two main findings emerge from the Laffer curve analysis. First, the capital and labor tax Laffer curves at the current state differ somewhat in position and shape between the countries. The capital tax Laffer curve of Korea shows more curvature than that of Japan, indicating a higher revenue-generating capacity for Korea. Meanwhile, the labor tax Laffer curve of Korea is shifted to the left, but with a similar curvature to that of Japan. There is, however, a common finding in both countries, in that they can raise tax revenues by the combination of higher labor tax rates and lower capital tax rates. Second, our results suggest that the adverse effect of population aging on tax revenues is more serious for Korea than for Japan. A consequence of this finding is that, even in the aged state, the fiscal authority of Japan has room to generate tax revenues comparable to the current state. In contrast, combinations of tax rates satisfying this property do not exist for Korea once the economy is transformed into the aged state.

A cautionary note should be made in interpreting the Laffer curve results between the two states. Our accounting embeds the assumption that current households' behavior and government policies will remain in effect over the projection period. Thus, the analysis of Laffer curves in the aged state precludes economic agents from modifying their behavior in response to population aging, which possibly mitigates the reduced labor hours in the aged state. Consequently, the empirical results on Laffer curves can be regarded as lower bound estimates for the effects of population aging.

The paper is organized as follows. Section 2 discusses the related literature. We present the VAR model and the results in Section 3. Section 4 describes the DSGE model, and its estimation procedure and results are provided in Section 5. Section 6 reports the results associated with Laffer curves and explores how population aging affects the tax revenues of both countries. Finally, Section 7 concludes.

## 2. RELATED LITERATURE

The macroeconomic consequences of population aging have received research interest in recent years. For instance, Fiori and Ferraro (2016) study the consequences of demographic change for the effects of tax cuts in the US over

the post-WWII period. In particular, they use a structural VAR model to measure the dynamic effects of changes in average marginal tax rates. Zokalj (2016) utilizes panel data on 25 EU countries in 1995-2014 considering the demographic variables as endogenous and apply the system GMM to obtain the elasticity of several public finance categories with respect to population aging.

Ma and Tran (2016) use dynamic general equilibrium, overlapping generations (OLG) model calibrated to data from Japan and the US. They calculate fundamental-based fiscal limit using the Laffer curve approach, and then measure fiscal space in terms of budgetary room between the current revenue and the maximum revenue defined by the peak of Laffer curves. Their analyses conclude that there are significant contractions in fiscal space in Japan and the US when the two countries enter late stage population transition in 2040. In a similar vein, Hsu and Yamada (2017) propose a general equilibrium life-cycle model to investigate the effects of aging, especially analyzing reforms of insurance benefits and tax financing tools in Japan.

In his seminal work, Lee (2016) performs a meta-analysis on how population aging affects the economic growth. This article employs various empirical approaches, including the partial- and general equilibrium models as well as the OLG model, in order to draw on a robust conclusion about the macroeconomic consequences of population aging.

Before proceeding, it should be clearly noted that a more conventional modelling approach in order to assess the macroeconomic consequences of population aging is OLS models, as Ma and Tran (2016) and Lee (2016). Our modelling framework for addressing this issue is quite different. By taking a DSGE model, one dimension in which our model suffers is that it does not take into account the important generational and distributional effects emphasized in the previous studies. OLS models tend to permit rich dynamics in demographics, intra-generational heterogeneity, bequest motives, and so on. While we cannot assess the distributional effects of population aging in our model, our model can be regarded as a more simplified framework than Jaimovich et al. (2013), endowed with households consist of two different age groups—the young and the prime-aged.

### 3. ESTIMATING THE EFFECTS OF POPULATION AGING USING VARS

In the present section we begin by providing econometric evidence on the macroeconomic effects of population aging for Japan and Korea, using a VAR

model. Our VAR model is estimated with annual data over the period 1973–2015, and with three lags.<sup>2</sup> There are six variables in the VAR specification, all of which are logged and differenced prior to estimation: the share of the population over 65 years old, real per capita GDP, per capita hours worked, real per capita consumption, real per capita investment, and real per capita total tax revenues.<sup>3</sup> Following the OECD classification, per capita hours worked is calculated as follows:

$$\begin{aligned} & \frac{\text{Total hours worked}}{\text{Working-age population, aged 15–74}} \\ = & \frac{\text{Total employment} \times \text{Hours worked per employee}}{\text{Working-age population, aged 15–74}} \end{aligned} \quad (1)$$

Notice that the working age population is defined as those aged 15 and 74. Total tax revenues are the sum of consumption tax revenues and income tax revenues from capital and labor. Consumption, investment and hours are included as tax bases on which the consumption, capital and labor taxes are levied, respectively. Details of the data construction are provided in Appendix A.

Before proceeding, it is worth noting that our choice of the share of elderly population as the proxy for population aging is to isolate demographic shifts caused solely by the aging trend. The elderly share is the measure that is used to categorize a society as “aging,” “aged,” or “super-aged.” Of course, there are alternative indicators of population aging such as the dependency ratio or life expectancy. As documented in Yoon et al. (2014), however, both of the alternative measures are likely to capture changes in age composition as a whole, not just those brought about by the aging trend.

We identify population aging shocks by assuming a recursive ordering, with the order of the variables listed as above. This particular ordering of the variables has the implication that population aging does not react contemporaneously to shocks to other macroeconomic variables in the system. The assumptions on the contemporaneous relations between the variables can be rationalized as follows: as illustrated in Lucas (2002), the aging trend may be a consequence of maturity of industrialization, associated typically with a decreasing birth rate and an

<sup>2</sup>The selection of the lag length is based on information criteria such as AIC and BIC.

<sup>3</sup>Kim and Hur (2017) document that the results of VAR-based analyses for fiscal policy hinge critically upon how the trend in data is treated. Our choice of the log-difference specification, instead of one with detrended-levels, is guided by the rationale that population aging is an irreversible change and thus have more non-stationary effects in nature.

increasing life expectancy. This suggests that population aging is driven primarily by sociocultural factors and the development of medical technologies, rather than by business cycles. Therefore, it seems plausible to posit that population aging is not affected contemporaneously by shocks affecting the aggregate variables. Ordering output before the other macro variables is a conventional setup in the existing fiscal policy literature, such as Blanchard and Perotti (2002) and Ramey (2011). As mentioned above, hours, consumption and investment are the tax bases, and thus are ordered prior to the corresponding tax revenue.

Figure 3 displays the impulse responses to the aging shock identified from our VAR, associated with Japan (left panels) and Korea (right panels).<sup>4</sup> In each panel, the solid line is the OLS point estimate, and the dashed lines represent 95% bands obtained from a bootstrap procedure with 1,000 replications. Focusing first on the results for Japan, a positive aging shock increases the share of elderly population, with the impulse response remaining significantly different from zero, even up to 6 years. The positive aging shock is associated with significant decreases in GDP, hours, consumption, and investment. The negative response of GDP is not statistically significant at impact, but soon becomes significantly different from zero between 2 to 10 years. A similar response pattern is observed for consumption and investment.

A notable finding is that a positive aging shock results in a fall in hours worked per capita, which is statistically significant from 3 to 7 years after the shock. As made clear in equation (1), there is no *a priori* prediction of how population aging affects hours worked per person. *Ceteris paribus*, population aging is associated with more retirees in general and decreases the ratio between total employment and the working-age population of those aged 15 to 74, inducing a lower level of hours worked per capita. Even in this situation, however, hours worked per person can be higher if hours worked per employee increases enough to offset the negative impact of population aging. As discussed in Yoon et al. (2014), this can occur when households and governments engage in behavioral responses, including higher female participation in the labor force and an increase in the legal age of retirement, that boost labor market participation. Our VAR results suggest that the former effect dominates such that per capita hours worked decreases in response to a positive aging shock. Consistent with the falls in the tax bases, the aging shock decreases tax revenue, which remains statistically significant from 3 years and onward.

Turning to the responses for Korea, we find that the results are qualitatively

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<sup>4</sup>The impulse responses reported in this figure are in levels, which are calculated by cumulatively summing up the log-difference impulse responses from the VAR model.

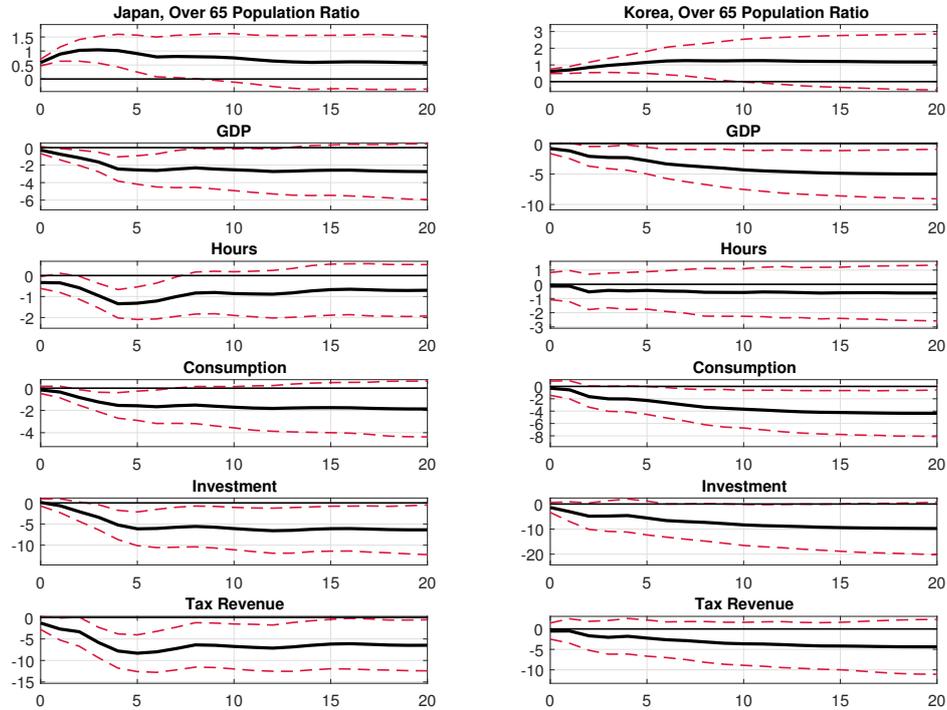


Figure 3: VAR impulse responses to an aging shock. This figure displays the impulse responses to the aging shock identified from the VAR model of Japan (left panels) and Korea (right panels). In each figure, the solid line indicates the OLS point estimates, and the dashed lines are 95% error bands calculated using a bootstrap procedure with 1,000 replications. The x-axis measures years.

similar to those for Japan. Following a positive aging shock, the share of elderly population increases gradually, with the response remaining significantly different from zero for the first 9 years. Yet the response pattern of the variable is more persistent than that of Japan. In response to the aging shock for Korea, the responses of GDP, consumption, and investment are all negative, and are greater in magnitude compared to the corresponding results for Japan. Although not being statistically significant, the aging shock decreases hours and tax revenue. The absolute size of these responses, however, is smaller for Korea.

Based on the data of Japan and Korea, our VAR results reveal that population aging has negative impacts not only on macroeconomic performance, but also on tax revenues. There is evidence in the existing literature demonstrating

adverse effects of population aging on economic growth. For instance, Callen et al. (2004) analyze data of 115 countries over the period 1960–2000 and find that per capita GDP growth is negatively correlated with changes in the share of elderly population. However, relatively less attention has been given to the implications of aging trends for tax revenues. In the subsequent sections we turn to a more structural analysis of how population aging affects tax revenues, based on Laffer curves.

#### 4. THE DSGE MODEL

This section describes the model economy upon which Laffer curves for labor and capital income taxation are characterized. The model is a neoclassical growth model augmented with real frictions such as habit formation in consumption, investment adjustment costs, and capacity utilization, which are often advocated as critical features in improving the model's fit to data. The economy consists of a representative household, a representative firm, and the government.<sup>5</sup>

##### 4.1. HOUSEHOLDS

The representative household chooses sequences  $\{c_t, n_t, b_t\}_{t=0}^{\infty}$  to maximize expected lifetime utility, given by

$$E_0 \sum_{t=0}^{\infty} \beta^t u_t^b \left\{ \frac{1}{1-\eta} \left[ (c_t - hC_{t-1})^{1-\eta} (1 - \kappa(1-\eta)n_t^{1+\frac{1}{\varphi}})^{\eta} - 1 \right] \right\}, \quad (2)$$

where  $\beta$  is the subjective discount factor,  $\eta$  is the inverse of intertemporal elasticity of substitution,  $\varphi$  is the Frisch elasticity of labor supply, and  $h \in [0, 1)$  is the habit parameter in consumption. The  $\kappa$  parameter captures the degree of disutility from work.  $c_t$  and  $n_t$  denote consumption and labor hours at time  $t$ , respectively. In the absence of habit formation ( $h = 0$ ), the utility function in (2) becomes the constant Frisch elasticity (CFE) preference considered in Trabandt and Uhlig (2011). When  $h > 0$ , the preference posits that the household derives utility from consumption relative to a habit stock defined in terms of lagged aggregate consumption as well as from government consumption, and derives disutility from hours worked.  $u_t^b$  is an AR(1) preference shock that follows

<sup>5</sup>Given the substantial degree of trade openness for Korea, empirics based on a closed-economy setup can pose a potential caveat. This modelling choice, however, is inevitable in analyzing data for the Japanese and Korean economies with a unified framework.

$$\log(u_t^b) = \rho_b \log(u_{t-1}^b) + \sigma_b \varepsilon_t^b, \quad \varepsilon_t^b \sim N(0, 1).$$

The household's choices at time  $t$  are constrained by

$$(1 + \tau_t^c)c_t + i_t + b_t = R_{t-1}b_{t-1} + (1 - \tau_t^n)w_t n_t + (1 - \tau_t^k)R_t^k v_t \bar{k}_{t-1} - \Psi(v_t)\bar{k}_{t-1} + z_t,$$

where  $R_t$  is the gross interest rate on bonds purchased and  $b_t$  is one-period riskless government bonds.  $\bar{k}_t$  is physical capital,  $v_t$  is the utilization rate of capital, and  $R_t^k$  denotes the gross rate of return from capital at time  $t$ .  $\tau_t^k$ ,  $\tau_t^n$ , and  $\tau_t^c$  are tax rates on capital income, labor income, and consumption, respectively.  $i_t$  is the household's gross investment,  $z_t$  is government lump-sum transfers, and  $w_t$  denotes wages.

We assume that physical capital is owned by households whose law of motion is given as

$$\bar{k}_t = (1 - \delta)\bar{k}_{t-1} + \left[1 - k_i\left(\frac{u_t^i i_t}{i_{t-1}}\right)\right] i_t, \quad (3)$$

where  $k_i(\cdot)$  is the investment adjustment cost function with the properties  $k_i(1) = k_i'(1) = 0$  and  $k_i''(1) > 0$  as in Christiano et al. (2005) and Smets and Wouters (2007). Effective capital,  $k_t$ , is linked to the physical capital stock by  $k_t = v_t \bar{k}_{t-1}$ . We posit that utilization requires a cost of  $\Psi(v_t)$  per unit of physical capital, and  $v = 1$  and  $\Psi(1) = 0$  hold in the steady state. Following Smets and Wouters (2007), we define the capital utilization cost parameter,  $\psi \in [0, 1)$ , in order to satisfy  $\frac{\Psi''(1)}{\Psi'(1)} = \frac{\psi}{1-\psi}$ . Finally,  $u_t^i$  is an AR(1) investment-specific shock that follows

$$\log(u_t^i) = \rho_i \log(u_{t-1}^i) + \sigma_i \varepsilon_t^i, \quad \varepsilon_t^i \sim N(0, 1).$$

#### 4.2. FIRMS

The representative firm rents capital and labor from the household to maximize profit given by

$$u_t^a (v_t \bar{k}_{t-1})^\alpha n_t^{1-\alpha} - w_t n_t - R_t^k v_t \bar{k}_{t-1}, \quad (4)$$

where  $\alpha \in [0, 1]$  and  $u_t^a$  denotes a technology shock that is assumed to follow the AR(1) process:

$$\log(u_t^a) = \rho_a \log(u_{t-1}^a) + \sigma_a \varepsilon_t^a, \quad \varepsilon_t^a \sim N(0, 1).$$

Consequently, total output at time  $t$  is given by  $y_t = u_t^a (v_t \bar{k}_{t-1})^\alpha n_t^{1-\alpha}$ .

### 4.3. FISCAL POLICY

The fiscal authority's outlays—government spending and transfers—are financed by levying proportional taxes on consumption, labor income and capital returns, as well as by issuing one-period debt. The flow budget constraint of the government therefore reads as:

$$b_t + \tau_t^k R_t^k v_t k_{t-1} + \tau_t^n w_t n_t + \tau_t^c c_t = R_{t-1} b_{t-1} + g_t + z_t, \quad (5)$$

where  $g_t$  denotes government spending. The feedback rules of the tax rates and government outlays are specified to be consistent with the existing literature [Kliem and Kriwoluzky (2014), Zubairy (2014), Leeper et al. (2017)]. In particular, each fiscal instrument evolves according to the following rules:

$$\hat{g}_t = \rho_g \hat{g}_{t-1} - (1 - \rho_g) \gamma_g \hat{s}_{t-1}^b, \quad (6)$$

$$\hat{\tau}_t^k = \rho_k \hat{\tau}_{t-1}^k + (1 - \rho_k) \left( \phi_k \hat{y}_t + \gamma_k \hat{s}_{t-1}^b \right) + \sigma_k \varepsilon_t^k, \quad (7)$$

$$\hat{\tau}_t^n = \rho_n \hat{\tau}_{t-1}^n + (1 - \rho_n) \left( \phi_n \hat{y}_t + \gamma_n \hat{s}_{t-1}^b \right) + \sigma_n \varepsilon_t^n, \quad (8)$$

$$\hat{\tau}_t^c = \rho_c \hat{\tau}_{t-1}^c + (1 - \rho_c) \left( \phi_c \hat{y}_t + \gamma_c \hat{s}_{t-1}^b \right) + \sigma_c \varepsilon_t^c, \quad (9)$$

$$\hat{z}_t = \rho_z \hat{z}_{t-1} - (1 - \rho_z) \phi_z \hat{y}_t, \quad (10)$$

where a hat ( $\hat{\cdot}$ ) denotes percentage deviations of a variable from its steady state and  $s_t^b$  is the debt-to-GDP ratio at period  $t$ , defined as  $s_t^b \equiv b_t/y_t$ . Each of the exogenous tax disturbances,  $\varepsilon_t$ , is distributed *i.i.d.*  $N(0, 1)$ . The fiscal policy rules from (6) through (10) are associated with three features. First, they include an autoregressive term to allow for serial correlation. Second, all instruments are allowed to react to the ratio of government debt to GDP to ensure fiscal solvency. Third, there is an automatic stabilizer component in the tax variables, which plays a role in mitigating macroeconomic volatility.

### 4.4. MARKET EQUILIBRIUM

The aggregate resource constraint is given by

$$y_t = c_t + i_t + g_t. \quad (11)$$

Equilibrium is characterized by the household's and firm's optimality conditions, the government's budget balance, the bond market clearing condition ( $b_t = 0$ ), and the aggregate resource constraint.

## 5. ESTIMATION OF THE DSGE MODEL

This section delineates the estimation procedure of the DSGE model described in Section 4, and the associated results. We estimate the model with Japanese and Korean annual data from 1973 to 2015 using Bayesian inference methods (see An and Schorfheide, 2007, for a survey). The sample period choice is driven by the data availability. We use the random walk Metropolis-Hastings algorithm to simulate posterior draws.<sup>6</sup>

### 5.1. ESTIMATION PROCEDURE

**Data** The estimation uses six observables: the log difference of real per capita consumption, investment, tax variables—capital, labor and consumption tax revenues—and log hours worked. All data are extracted from OECD Statistics. See Appendix A for details of the data construction.

The six observables are related to the model variables as

$$\begin{bmatrix} dl \text{ Cons}_t \\ dl \text{ Inv}_t \\ dl \text{ KTaxRev}_t \\ dl \text{ NTaxRev}_t \\ dl \text{ CTaxRev}_t \\ l \text{ Hours}_t \end{bmatrix} = \begin{bmatrix} \bar{\gamma} \\ \bar{\gamma} \\ \bar{\gamma} \\ \bar{\gamma} \\ \bar{\gamma} \\ \bar{n} \end{bmatrix} + \begin{bmatrix} \hat{c}_t - \hat{c}_{t-1} \\ \hat{i}_t - \hat{i}_{t-1} \\ \hat{T}_t^k - \hat{T}_{t-1}^k \\ \hat{T}_t^n - \hat{T}_{t-1}^n \\ \hat{T}_t^c - \hat{T}_{t-1}^c \\ \hat{n}_t \end{bmatrix}, \quad (12)$$

where  $l$  and  $dl$  denote the log and log difference of the corresponding variable, respectively.  $\bar{\gamma}$  is the common annual trend growth rate to real consumption, investment and the tax variables, and  $\bar{n}$  is the average logged hours over the sample period.  $T_t^k$ ,  $T_t^n$  and  $T_t^c$  denote the model-implied tax revenues associated with capital, labor and consumption, respectively.

**Prior Distribution** We calibrate a few parameters that are difficult to identify from the data, and apply them to both countries. Table 1 summarizes the calibrated parameters. The discount factor,  $\beta$ , is set to 0.96, and the capital income share of total output,  $\alpha$ , is 0.482. The depreciation rate for capital,  $\delta$ , is set to 0.1 such that the annual depreciation rate is 10%.

Steady-state fiscal variables are calibrated to the mean values of the corresponding country over the period. For Japan, government consumption as a share of GDP is 0.163 and the government debt to GDP share is 2.114. The average

<sup>6</sup>We simulate a million draws, with the first 600,000 used as a burn-in period and every 20th thinned, leaving a sample size of 20,000.

Parameter	Description	Common	Country-specific	
			Japan	Korea
$\beta$	Subjective discount factor	0.96		
$\alpha$	Share of capital in the production function	0.482		
$\delta$	Steady state capital depreciation	0.1		
<hr/>				
$\overline{g/y}$	Government consumption to output ratio		0.163	0.121
$\overline{b/y}$	Annual government debt to output ratio		2.114	1.201
$\tau^k$	Steady state capital tax rate		0.301	0.219
$\tau^n$	Steady state labor tax rate		0.171	0.095
$\tau^c$	Steady state consumption tax rate		0.045	0.100
$\kappa$	Disutility from work		4.27	1.88

Table 1: Calibrated parameters for the DSGE model of Japan and Korea. The time unit is one year.

federal capital tax rate is 0.301, the labor tax rate is 0.171, and the consumption tax rate is 0.045. These values for Korea over the sample period are 0.121 ( $\overline{g/y}$ ), 1.201 ( $\overline{b/y}$ ), 0.219 (average  $\tau^k$ ), 0.095 (average  $\tau^n$ ), and 0.1 (average  $\tau^c$ ).

The parameter governing disutility from work,  $\kappa$ , is also calibrated to match the population aging status of each country. More specifically, the values are set proportional to each countries' share of the population over 65 years old, with the reference  $\kappa$  value for the U.S. in Trabandt and Uhlig (2011). Over the sample period, the mean shares of the population over 65 are 0.12, 0.15 and 0.07 for the U.S., Japan and Korea, respectively. Given that Trabandt and Uhlig (2011) use a  $\kappa$  value of 3.46 for the U.S., we set these parameters for Japan and Korea to be 4.27 and 1.88, respectively.

Columns 2 through 4 in Table 2 list the prior distributions for the estimated parameters. The priors are chosen to cover the range of parameter values considered in the calibrated exercise of Trabandt and Uhlig (2011). The prior of the inverse of intertemporal elasticity of substitution (IES),  $\eta$ , follows a Gamma distribution with a mean of 1.5 and a standard deviation of 0.4. Notice that the mean of the prior distribution is centered between 2 and 1, which, respectively, correspond to the benchmark and alternative parameter values used in Trabandt and Uhlig (2011). Following the same tactic, the prior mean of the Frisch labor supply elasticity parameter,  $\varphi$ , is set to be 2, the average of Trabandt and Uhlig's (2011) parameters of 1 and 3. Priors for the parameters associated with real frictions—habit formation, investment adjustment costs, and capacity utilization—are drawn from Leeper et al. (2017).

The priors for the fiscal parameters are chosen to be fairly diffuse, reflecting a lack of evidence in the existing literature of Japan and Korea regarding these

Parameter	Prior		Posterior: Japan		Posterior: Korea	
	Fnc.	Mean (Std.)	[5%, 95%]	Median	[5%, 95%]	Median
<b>Preference and technology</b>						
$\eta$	G	1.5 (0.4)	[0.91, 2.21]	0.67	[0.61, 0.75]	0.77
$\theta$	G	2 (0.5)	[1.25, 2.89]	2.96	[2.23, 3.92]	3.32
$h$	B	0.5 (0.2)	[0.17, 0.83]	0.84	[0.77, 0.88]	0.60
<b>Frictions</b>						
$\psi$	B	0.6 (0.15)	[0.35, 0.85]	0.34	[0.23, 0.47]	0.32
$s$	N	6 (1.5)	[3.5, 8.5]	4.86	[3.33, 6.86]	1.61
<b>Fiscal policy</b>						
$\phi_k$	N	0 (0.5)	[-0.82, 0.82]	0.41	[-0.13, 0.90]	0.49
Labor tax resp. to output	N	0 (0.5)	[-0.82, 0.82]	0.53	[0.20, 1.16]	0.85
$\phi_h$	N	0 (0.5)	[-0.82, 0.82]	-0.33	[-1.00, 0.51]	0.60
Cons. tax resp. to output	N	0 (0.5)	[-0.82, 0.82]	0.50	[0.06, 0.99]	-0.26
$\gamma_k$	N	0 (0.5)	[-0.82, 0.82]	-0.85	[-1.09, -0.59]	-0.19
Labor tax resp. to debt/GDP	N	0 (0.5)	[-0.82, 0.82]	0.05	[-0.53, 0.70]	0.16
$\gamma_h$	N	0 (0.5)	[-0.82, 0.82]	0.94	[0.64, 1.32]	0.74
Cons. tax resp. to debt/GDP	N	0 (0.5)	[-0.82, 0.82]	0.10	[-0.76, 0.91]	0.73
$\gamma_c$	N	0 (0.5)	[-0.82, 0.82]			
Govt. spending resp. to debt/GDP	N	0 (0.5)	[-0.82, 0.82]			
$\gamma_g$	N	0 (0.5)	[-0.82, 0.82]			
Transfers resp. to debt/GDP	N	0 (0.5)	[-0.82, 0.82]			
$\gamma_z$	N	0 (0.5)	[-0.82, 0.82]			
<b>Serial correlation in disturbances</b>						
$\rho_a$	B	0.5 (0.2)	[0.17, 0.83]	0.98	[0.95, 0.99]	0.92
Technology	B	0.5 (0.2)	[0.17, 0.83]	0.55	[0.31, 0.86]	0.50
$\rho_b$	B	0.5 (0.2)	[0.17, 0.83]	0.38	[0.18, 0.58]	0.69
Preference	B	0.5 (0.2)	[0.17, 0.83]	0.59	[0.45, 0.68]	0.45
$\rho_i$	B	0.5 (0.2)	[0.17, 0.83]	0.34	[0.15, 0.54]	0.50
Investment	B	0.5 (0.2)	[0.17, 0.83]	0.90	[0.81, 0.97]	0.90
$\rho_k$	B	0.5 (0.2)	[0.17, 0.83]	0.30	[0.07, 0.62]	0.55
Capital tax rate	B	0.5 (0.2)	[0.17, 0.83]	0.51	[0.18, 0.83]	0.48
Labor tax rate	B	0.5 (0.2)	[0.17, 0.83]			
$\rho_n$	B	0.5 (0.2)	[0.17, 0.83]			
Labor tax rate	B	0.5 (0.2)	[0.17, 0.83]			
$\rho_c$	B	0.5 (0.2)	[0.17, 0.83]			
Consumption tax rate	B	0.5 (0.2)	[0.17, 0.83]			
$\rho_g$	B	0.5 (0.2)	[0.17, 0.83]			
Government spending	B	0.5 (0.2)	[0.17, 0.83]			
$\rho_z$	B	0.5 (0.2)	[0.17, 0.83]			
Transfers	B	0.5 (0.2)	[0.17, 0.83]			
<b>Std. of shocks</b>						
$\sigma_a$	IG	0.5 ( $\infty$ )	[0.09, 2.07]	4.48	[3.48, 6.04]	6.45
Technology	IG	0.5 ( $\infty$ )	[0.09, 2.07]	0.67	[0.54, 0.85]	0.85
$\sigma_b$	IG	0.5 ( $\infty$ )	[0.09, 2.07]	9.64	[6.21, 14.72]	5.03
Preference	IG	0.5 ( $\infty$ )	[0.09, 2.07]	14.98	[12.37, 18.53]	14.91
$\sigma_i$	IG	0.5 ( $\infty$ )	[0.09, 2.07]	4.12	[3.37, 5.17]	13.77
Investment	IG	0.5 ( $\infty$ )	[0.09, 2.07]	5.15	[4.34, 6.26]	5.01
$\sigma_k$	IG	0.5 ( $\infty$ )	[0.09, 2.07]			
Capital tax rate	IG	0.5 ( $\infty$ )	[0.09, 2.07]			
$\sigma_n$	IG	0.5 ( $\infty$ )	[0.09, 2.07]			
Labor tax rate	IG	0.5 ( $\infty$ )	[0.09, 2.07]			
$\sigma_c$	IG	0.5 ( $\infty$ )	[0.09, 2.07]			
Consumption tax rate	IG	0.5 ( $\infty$ )	[0.09, 2.07]			
<b>Common annual trend growth rate to real consumption, investment, and capital, labor, and consumption tax revenues</b>						
$\bar{\gamma}$	N	2 (1.0)	[0.36, 3.64]	2.16	[1.82, 2.52]	3.49
Common growth rate	N	2 (1.0)	[0.36, 3.64]			

Table 2: Prior and posterior distributions for model parameters. The parameters for the Inverse Gamma distribution correspond to  $s$  and  $v$ , where  $f(x|s, v) = v^s \Gamma^{-1}(s) x^{-s-1} \exp(-v/x)$ .

parameters. We follow Kliem and Kriwoluzky (2014) by assuming normal distributions for the fiscal instruments' responses to debt and GDP with a mean of 0 and standard deviation of 0.5.

Identical priors are imposed on the persistence and standard deviation parameters of the shock processes. Following Smets and Wouters (2007), we adopt a Beta distribution with a mean of 0.5 and a standard deviation of 0.2 for the autoregressive coefficients for the exogenous stochastic disturbances. The priors for the shock standard deviations follow inverse-gamma distributions with a mean of 0.5 and a standard deviation of infinity, as in Justiniano and Preston (2010). Finally, the prior on the common growth rate,  $\bar{\gamma}$ , is quite disperse and is chosen to follow a normal distribution with a mean of 2 and standard deviation of 1.

## 5.2. POSTERIOR PARAMETER ESTIMATES

The last four columns of Table 2 provide the median and 90th percentiles from the posterior distributions associated with Japan and Korea. Overall the data seem to be informative in identifying the parameters, as the 90% intervals are different from those of the priors, with the exceptions of a few shock persistence parameters.<sup>7</sup>

First of all, Figure 4 plots the prior and posterior distributions of the inverse of IES (left panel) and Frisch labor supply elasticity (right panel) for both economies. As mentioned explicitly in Trabandt and Uhlig (2011), these are the most important parameters determining the shape of the Laffer curves. The left panel shows that the posteriors are tightly estimated relative to the prior distribution, indicating that the data are quite informative in identifying the parameter. Although this tendency is not observed in the right panel, the posterior distributions for both economies deviate substantially from the prior, which suggests information gain from the data.

The median estimates for the inverse of IES are 0.67 for Japan and 0.77 for Korea. These estimates are somewhat smaller than the calibrated values in Trabandt and Uhlig (2011). Our results are nonetheless broadly consistent with the evidence from the estimated DSGE models of the Japanese and Korean economies. For instance, Elekdag et al. (2006) obtain a median parameter value

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<sup>7</sup>In particular, the persistence parameters of transfers for both countries and that of government spending for Korea are not well identified from the estimation. This is likely to stem from the absence of government spending and transfers as observables. Excluding these variables for estimation purposes is largely driven by the fact that the raw data lack information to disaggregate government spending and transfers.

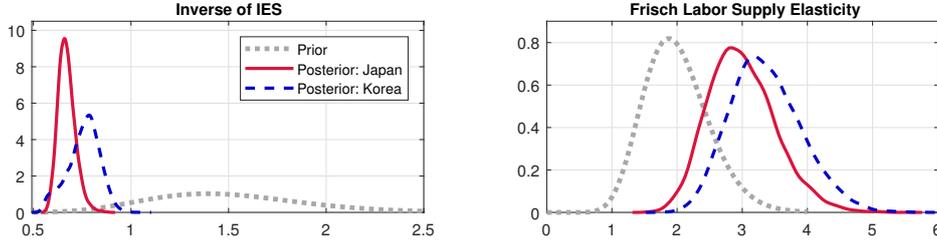


Figure 4: Prior (dotted lines) and posterior (solid lines for Japan; dashed lines for Korea) distributions of the inverse of IES (left panel) and Frisch labor supply elasticity (right panel) parameters.

of 0.74 by estimating a DSGE model with Korean data from 1990 to 2003. Regarding the Japanese case, our estimates are smaller than those of Sugo and Ueda (2008) with a mean of 1.25 and 90th interval of [0.96, 1.52], based on the data between 1981 and 1995. Turning to the Frisch labor supply elasticity, the median estimates for Japan and Korea are 2.96 and 3.32, respectively. These results are comparable to the alternative value of 3 employed by Trabandt and Uhlig (2011). Before proceeding, it is worth noting that the parameters' estimates vary in size between the economies. For both parameters, posterior estimates for Korea tend to be larger than those for Japan.

Our estimations yield a higher degree of habit formation for Japan than for Korea, as the median estimates for the economies are 0.84 and 0.60, respectively. The posterior estimates for investment adjustment cost are substantially larger for the Japanese economy. The median estimate is 4.86, whereas its Korean counterpart is 1.61. Unlike these parameters, the capital utilization parameters are estimated to be similar between the economies.

Turning to the fiscal policy parameter estimates, the results reveal a similarity as well as a difference in the policy behavior between the economies. A common finding for both economies is that labor taxes play a crucial role in stabilizing output, as the  $\phi_n$  coefficients are estimated away from zero to positive values. In terms of the method of fiscal financing, we find that different combinations of fiscal instruments stabilize government debt for each economy. Government spending and capital taxes are the primary means of debt stabilization in Japan, as the 90% posterior intervals for  $\gamma_g$  and  $\gamma_k$  do not encompass zero. In contrast, Korea relies on reducing government outlays—government spending and transfers—to stabilize debt, consistent with the findings of Hur and Lee (2017). Lastly, the common growth rate is estimated to be higher for Korea than

for Japan, as their posterior median estimates are 3.49 and 2.16, respectively.

## 6. IMPACTS OF POPULATION AGING ON TAX REVENUE: THE LAFFER CURVES

With estimates of the model's "deep parameters" in hand, this section quantifies the effects of population aging on tax revenues. The task begins by formulating Laffer curves evaluated at the model's steady state. Based on the formulas, the next step is to obtain Laffer curves in the *current* state, which describes the economies in 2015. We then move on to calculate Laffer curves in the *aged* state as of 2060, and compare them to those of the current state.

### 6.1. FORMULATING LAFFER CURVES

In the model, equilibrium capital, investment, consumption and output as a share of hours worked at the steady state are determined by deep parameters and the capital tax rate as follows:

$$\bar{R} = 1/\beta, \quad (13)$$

$$\bar{R}^k = \frac{1 - \beta(1 - \delta)}{\beta(1 - \tau^k)}, \quad (14)$$

$$\bar{w} = \left[ (1 - \alpha)^{1-\alpha} \alpha^\alpha (\bar{R}^k)^{-\alpha} \right]^{1/(1-\alpha)}, \quad (15)$$

$$\bar{k}/\bar{n} = \frac{\alpha \bar{w}}{(1 - \alpha) \bar{R}^k}, \quad (16)$$

$$\bar{\Omega}_L = (\bar{k}/\bar{n})^\alpha - \bar{R}^k \bar{k}/\bar{n} - \bar{w}, \quad (17)$$

$$\bar{y}/\bar{n} = (\bar{k}/\bar{n})^\alpha - \bar{\Omega}_L, \quad (18)$$

$$\bar{i}/\bar{n} = \delta \bar{k}/\bar{n}, \quad (19)$$

$$\bar{c}/\bar{n} = \bar{y}/\bar{n} (1 - \bar{g}/\bar{y}) - \bar{i}/\bar{n}, \quad (20)$$

where the term  $\bar{\Omega}_L$  in equation (17) is defined to ensure the firm's zero profit condition as in Christiano et al. (2005). With the CFE preference, steady state hours worked are obtained by solving the following equation:

$$\bar{n} = \left\{ \kappa(1 - \eta) + \left[ \frac{\kappa \eta (1 + 1/\varphi) (1 - h) (1 + \tau^c)}{(1 - \tau^n) \bar{w}} \right] \frac{\bar{c}/\bar{n}}{\bar{y}/\bar{n}} \right\}^{-\frac{\varphi}{1+\varphi}}. \quad (21)$$

Notice that, once solved, the steady state hours worked,  $\bar{n}$ , decrease with the parameter governing disutility from work,  $\kappa$  (i.e.,  $\partial \bar{n} / \partial \kappa < 0$ ). The steady state

level of capital and consumption can then be recovered by  $\bar{k} = \bar{k}/n \times \bar{n}$  and  $\bar{c} = \bar{c}/n \times \bar{n}$ . Finally, capital, labor and consumption tax revenues are calculated by the following equations:

$$\bar{T}^k = \tau^k \bar{R}^k \bar{k}, \quad (22)$$

$$\bar{T}^n = \tau^n \bar{w} \bar{n}, \quad (23)$$

$$\bar{T}^c = \tau^c \bar{c}, \quad (24)$$

and the total tax revenue at the steady state,  $\bar{T}$ , is defined as the sum of the three tax revenues in (22) through (24) such that  $\bar{T} = \bar{T}^k + \bar{T}^n + \bar{T}^c$ .

We focus on capital and labor tax Laffer curves.<sup>8</sup> Each Laffer curve is calculated by changing the corresponding tax rate from 0 to 1 and solving equations (13) through (24), while all the other tax rates and parameters are fixed.

## 6.2. LAFFER CURVES IN THE CURRENT STATE

Figure 5 plots both countries' capital and labor tax Laffer curves in the current state. In each figure, posterior median estimates for Japan (solid lines) and Korea (dashed lines) are reported.<sup>9</sup> The current state corresponds to the year 2015, which is the end of the sample period for empirical analyses. When calculating the Laffer curves in the current state, we employ the model's calibrated and estimated parameter values as shown in Tables 1 and 2, except for the tax rates, which use the 2015 values instead of the sample means. As of 2015, the tax rates for Japan are 0.207 ( $\tau^k$ ), 0.191 ( $\tau^n$ ), and 0.08 ( $\tau^c$ ), while those for Korea turn out to be 0.161 ( $\tau^k$ ), 0.115 ( $\tau^n$ ), and 0.10 ( $\tau^c$ ). To facilitate comparison, the Y axis of each Laffer curve is scaled so that total tax revenues under the current effective tax rates become 100.

The figure shows that both capital and labor Laffer curves are somewhat different in position and shape between the countries. The capital Laffer curve of Korea shows more curvature than that of Japan, indicating a higher revenue-generating capacity. Accordingly, the total tax revenue of Korea can rise up to 111.5 percent of the current revenue by raising the capital tax rate to 35.7

<sup>8</sup>The omission of the consumption tax Laffer curve is rationalized by our finding that there is no inverted U-shaped relationship between consumption tax rates and revenues, consistent with the findings of Trabandt and Uhlig (2011). Although not reported herein, we confirm that the Laffer curve for consumption taxes monotonically increases with consumption tax rates, with no peak.

<sup>9</sup>For clarity, the figure reports only the median of the Laffer curves. Although not reported herein, we find that posterior estimates for the Laffer curves are somewhat tight. The corresponding graphs with error bands are available upon request.

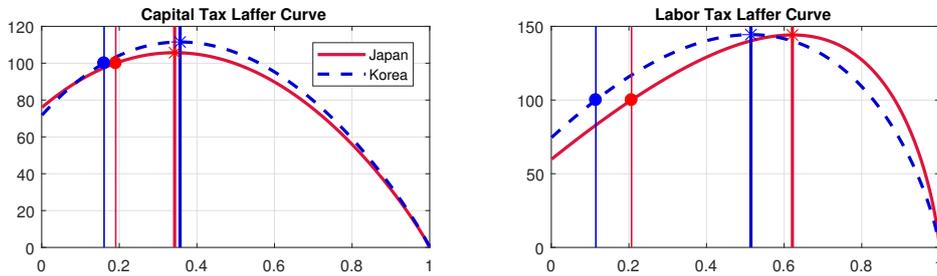


Figure 5: The capital tax (left panel) and labor tax (right panel) Laffer curves in the current state (as of 2015). The Laffer curves display the total tax revenues when capital and labor tax rates are varied between 0% and 100%, respectively, while other taxes and parameters remain constant. In each figure, the posterior median estimates for Japan (solid line) and Korea (dashed line) are reported. The total tax revenues are normalized to 100 under the current tax rates, marked with circles. The points with stars indicate the revenue-maximizing tax rates and the associated tax revenues.

percent, while the maximum tax revenue for Japan is 105.7 percent when a tax rate of 34.3 percent is applied. A different pattern, however, is observed for the labor tax Laffer curves. The labor tax Laffer curve of Korea is shifted to the left, but with a similar curvature to that of Japan. The results indicate that the total tax revenues of Korea and Japan can reach up to 144.4 and 144.2 percent of the current revenues by raising the effective labor tax rates to 51.5 and 62.1 percent, respectively. Overall, the results in this paper are qualitatively similar to the ones in Trabandt and Uhlig (2011) because they also find that capital tax rate hikes generate substantially smaller increases in revenue than labor tax increases.

Having delineated the disparity in the Laffer curves between the two countries, we then examine to what extent the shape of the Laffer curves is affected by the country-specific estimates for the inverse of IES and Frisch labor elasticity parameters. Figure 6 displays the actual Laffer curves of Japan (solid lines) and Korea (dashed lines), together with the two counterfactual ones for Japan. In the figure, each Laffer curve is calculated at the median of the posterior parameter estimates. The first counterfactual Laffer curves (dash-dot lines) are obtained under the assumption that if the Japanese model economy is endowed with the inverse of the IES value of Korea. To make the results consistent with this assumption, the model is solved by plugging in the Korean estimates for the inverse of the IES parameter, while all the other parameters use the Japanese estimates.

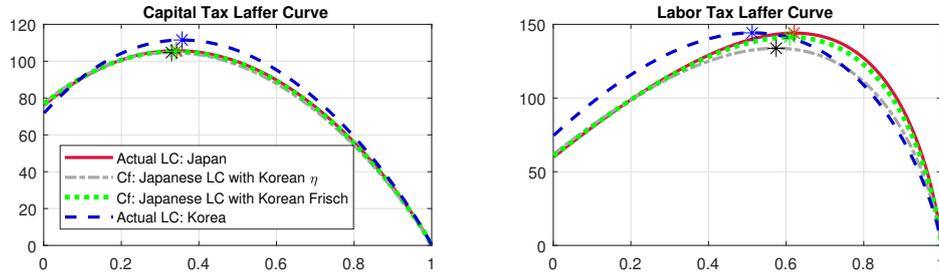


Figure 6: The actual and counterfactual Laffer curves in the current state (as of 2015) for capital tax (left panel) and labor tax (right panel). The Laffer curves display the total tax revenues when capital and labor tax rates are varied between 0% and 100%, while other taxes and parameters remain constant. In each figure, the actual Laffer curves for Japan (solid line) and Korea (dashed line) as well as the counterfactual Laffer curves for Japan with the Korean estimates of the inverse of IES (dash-dot line) and the Frisch labor supply elasticity (dotted line), evaluated at the median of posterior parameters, are reported. The points with stars indicate the revenue-maximizing tax rates and the associated tax revenues.

The second counterfactual (dotted lines) is analogous to the first one, but instead for the Frisch elasticity of labor supply.

Focusing first on the capital tax Laffer curves, the counterfactual ones have peaks to the left compared to their actual counterparts. Recall that both parameters are estimated to be higher for Korea than for Japan. Hence, the changes in the counterfactual Laffer curves are consistent with the finding in Trabandt and Uhlig (2009), in that the peaks of capital tax Laffer curves move to the left as either the inverse of IES or the Frisch labor elasticity increases. Differences in these parameter estimates between the countries, however, can hardly be the source of the discrepancy in the shapes of the capital tax Laffer curves, as the counterfactuals appear quite similar to the actual ones. Turning to labor taxes, more dramatic differences are seen between the actual and counterfactual Laffer curves. Like the capital tax case, the peaks of the labor tax Laffer curves shift to the left as one of the parameters becomes larger. Notice that the same pattern across various values of  $\eta$  and  $\varphi$  is reported in Trabandt and Uhlig (2009). Another notable finding is that the counterfactual Laffer curves feature peaks with lower tax revenues than the actual ones. The revenue-creating capacity of labor taxes in Japan would be limited considerably if the economy were endowed with parameter values for  $\eta$  or  $\varphi$  that are higher than the actual estimates.

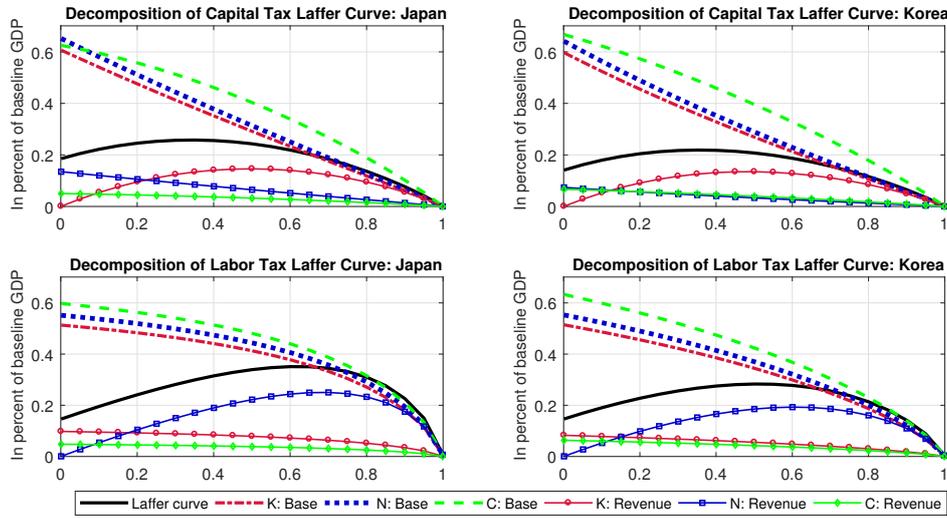


Figure 7: Decomposition of the capital tax and labor tax Laffer curves in the current state (as of 2015), evaluated at the median of posterior parameters. In each figure, the Laffer curve (solid line), tax bases (dash-dot line for capital; dotted line for labor; dashed line for consumption), and tax revenues (solid line with circles for capital; solid line with squares for labor; solid line with diamonds for consumption) are reported. Each object is normalized as a share of steady-state GDP associated with the current tax rates.

Figure 7 decomposes the Laffer curves into three tax bases and tax revenues in order to reveal why the Laffer curves are shaped in that way. Regardless of the country and tax type, two common findings are made by the decomposition. First, the tax bases keep falling as the tax rates increase. This is because higher tax rates discourage private agents from accumulating capital and supplying labor. Second, the decomposition reveals that the Laffer curves inherit the shape of their corresponding tax revenues. The capital tax revenues, for instance, display an inverted U-shape with respect to the capital tax rate, while the labor and consumption tax revenues decrease monotonically as the capital tax rate rises. Among these, the capital tax revenue curves dominate in shaping the total revenue curves such that the capital tax Laffer curves are also inverted U-shaped. An analogous argument is applicable to the labor tax Laffer curves.

So far the analyses on Laffer curves have been carried out by altering one tax rate while the others are fixed. Although this type of analysis is useful, a more comprehensive insight can be obtained by changing both the labor and capital

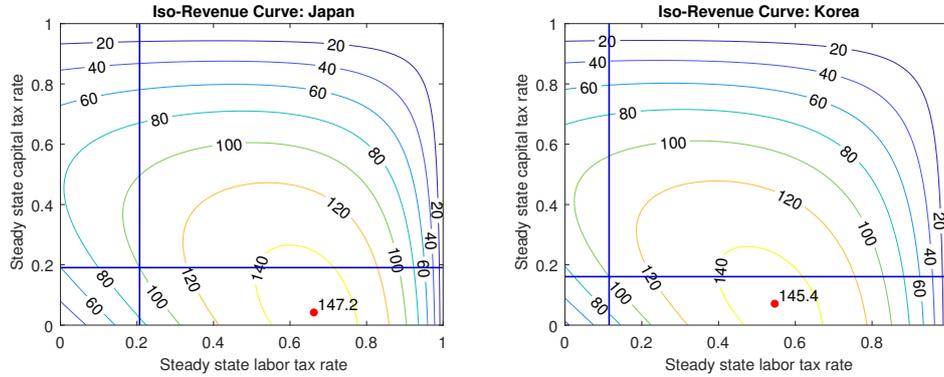


Figure 8: Iso-revenue curves in the current state (as of 2015) for Japan (left panel) and Korea (right panel). In each figure, the vertical and horizontal lines indicate the current labor and capital tax rates, respectively.

tax rates—often referred to as a “Laffer hill” or an “iso-revenue curve.” Figure 8 plots both countries’ iso-revenue curves in the current state. For both countries, the results show that revenue is maximized by the combination of higher labor tax rates and lower capital tax rates. By doing so, tax revenues in Japan and Korea can reach a maximum of 147.2 and 145.4 percent, respectively, of the revenues associated with the current tax rates.

### 6.3. LAFFER CURVES IN THE AGED STATE

This section conducts a comparative analysis of how population aging affects tax revenues by focusing on the Laffer curve relationship established in the previous section. To this end, we calculate Laffer curves for the aged state and compare them to those in the current state. We set the aged state to be the year 2060, the last year covered by the OECD population projection.

As aforementioned, the crucial setup in conducting this exercise is to capture aging trends with changes in a preference parameter governing agents’ disutility from supplying labor,  $\kappa$ . This necessitates setting the parameter values associated with the aged state for each country. We calibrate the  $\kappa$  values in the aged state by relying on information from the VAR-based results in Section 3. In particular, we take the following steps. First, we calculate the impact elasticity of labor hours with respect to the share of elderly population. Since the VAR model is in logs, this can be done by taking the ratio of the impulse responses of hours and those of the elderly share at the impact period. The estimated elasticities for

Japan and Korea are -0.57 and -0.20, respectively. Second, we measure percentage changes in the share of elderly population between 2015 and 2060, provided in the OECD population projection. The share of elderly population is projected to grow from 26.8% (2015) to 39.9% (2060) in Japan and from 13.1% (2015) to 40.1% (2060) in Korea. Accordingly, the percentage changes in the elderly population ratio are 48.9% and 206.3% for Japan and Korea, respectively. As the third step, we calculate percentage changes in labor hours caused by the aging trend by multiplying the impact elasticities of labor hours with respect to the share of elderly population in step 1 and the percentage changes in the elderly share in population obtained from step 2. The results imply that the aging trend will reduce labor hours by about 28% in Japan and about 42% in Korea. Lastly, we reverse engineer the  $\kappa$  values in the aged state that match the reduced labor hours in the steady state. For Japan and Korea, the values turn out to be 6.60 and 3.84, respectively.

Before presenting the results, it is necessary to note that the analysis of Laffer curves in the aged state precludes any feedback from economic agents to population aging. Our accounting embeds the assumption that current household behavior and government policies will remain in effect over the projection period. In reality, however, households and governments may react to the aging trend by adjusting the labor supply pattern (e.g., higher labor-force participation of women) or via policy reforms (e.g., raising the legal age of retirement). All these responses are likely to mitigate the reduced labor hours in the aged state. Consequently, the empirical results presented below can be regarded as a lower bound on the projection.

Figure 9 plots the capital tax Laffer curves in the aged state (dashed lines) and compares them to those in the current state (solid lines). A common observation in both countries is that tax revenues are shrunk substantially by population aging. The adverse effect, however, is more pronounced for Korea. In the aged state, the tax revenues at the current tax rates and at the peak of the Laffer curve are 57.8 and 64.6 percent, respectively, of tax revenues in the current state. The corresponding values for Japan are 72.1 and 76.2, which are somewhat higher than the estimates for Korea.

A similar, but more conspicuous, tendency is observed in Figure 10, showing the labor tax Laffer curves in the aged state (dashed lines) and in the current state (solid lines). The tax revenue in the aged state of Japan is estimated to be 72.2 under the current tax rate and 104.1 under the revenue-maximizing tax rate. The fact that maximized tax revenue exceeds 100 indicates that the country is capable of generating tax revenues equal or greater than those in the current

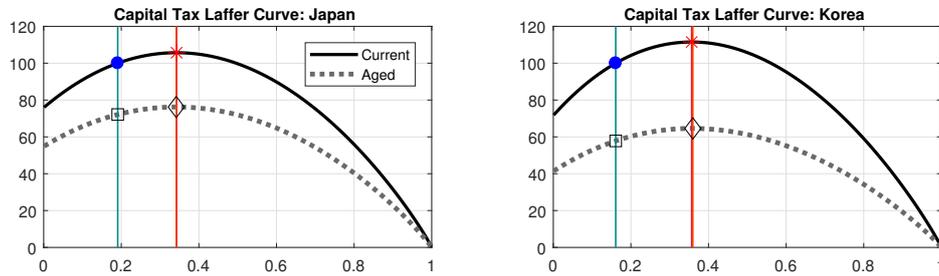


Figure 9: The capital tax Laffer curves in the current state (as of 2015) and the aged state (as of 2060) for Japan (left panel) and Korea (right panel). The Laffer curves display the total tax revenues when the capital tax rate is varied between 0% and 100%, while other taxes and parameters remain constant. In each figure, the posterior median estimates for the Laffer curves associated with the current state (solid line) and the aged state (dashed line) are reported. The points with circles and squares indicate the current tax rates and the associated tax revenues, for the current and aged states, respectively. The points with stars and diamonds are the revenue-maximizing tax rates and the associated tax revenues, for the current and aged states, respectively.

state by raising labor tax rates. This is not the case, however, for Korea, whose maximum tax revenue on the labor tax Laffer curve is only 83.7.

Figure 11 depicts both countries’ iso-revenue curves in the aged state. As with their current-state counterparts, both countries can achieve maximum tax revenues by raising the labor tax rate and cutting the capital tax rate, as the peak of the curves appears in the lower right hand side corner of each graph. Nevertheless, there exists a critical difference between the iso-revenue curves of the two countries. The Japanese iso-revenue curve has an area around its peak endowed with tax revenues higher than 100. This suggests that, even in the aged state, there still is room for the Japanese fiscal authorities to generate tax revenues comparable to the current state. In sharp contrast, combinations of tax rates satisfying this property do not exist for Korea once the economy is transformed into the aged state. Tax revenues in the aged state of Korea consistently fall short of 100.

In sum, the results indicate that the adverse effect of population aging on tax revenues is more serious for Korea than for Japan. The key transmission mechanism behind the finding is the reduced labor hours accompanying the aging trend. As demonstrated in our calibration procedure for  $\kappa$  in the aged state, the

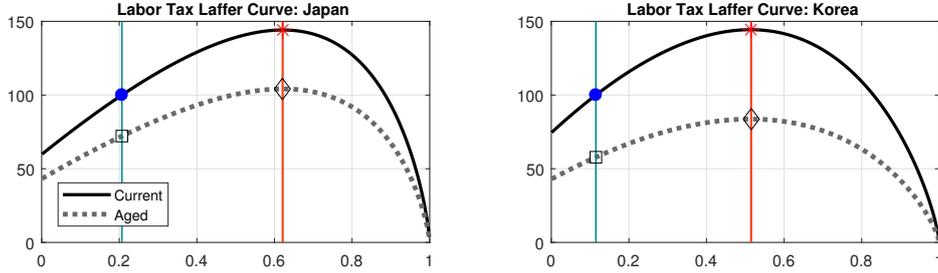


Figure 10: The labor tax Laffer curves in the current state (as of 2015) and the aged state (as of 2060) for Japan (left panel) and Korea (right panel). The Laffer curves display the total tax revenues when the labor tax rate is varied between 0% and 100%, while other taxes and parameters remain constant. In each figure, the posterior median estimates for the Laffer curves associated with the current state (solid line) and the aged state (dashed line) are reported. The points with circles and squares indicate the current tax rates and the associated tax revenues, for the current and aged states, respectively. The points with stars and diamonds are the revenue-maximizing tax rates and the associated tax revenues, for the current and aged states, respectively.

projected fall in labor hours due to population aging is much more dramatic for Korea. This is caused primarily by the country's strikingly high pace of aging

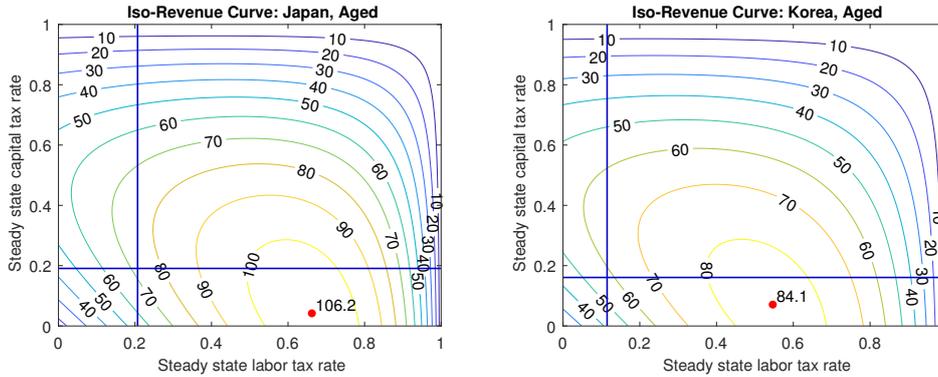


Figure 11: Iso-revenue curves in the aged state (as of 2060) for Japan (left panel) and Korea (right panel). In each figure, the vertical and horizontal lines indicate the current labor and capital tax rates, respectively.

over the projection period as depicted in Figure 2.

## 7. CONCLUSION

This paper employs two methodologies in order to examine the quantitative effect of population aging on tax revenues in Japan and Korea. The VAR analysis reveals negative impacts of population aging on macro aggregates as well as on tax revenues in both countries. Concerning the forward-looking aspect of the issue, we characterize Laffer curves corresponding to the current and aged states, and find that the deleterious effect of population aging on tax revenues is more pronounced for Korea than it is for Japan.

As noted earlier, there is a potential caveat to our approach using Laffer curves. It possibly overestimates the adverse effect of population aging by ruling out economic agents' endogenous choices that alleviate the problem. Earlier works, such as Karam et al. (2010) and Gonzalez-Eiras and Niepelt (2012), demonstrate that population aging can foster economic growth in the presence of policy reforms. Investigating this issue requires embedding the political economy aspect as a feature of the model. We leave this work for future research.

## APPENDIX

## A. DATA

The estimation of the VAR and DSGE models in this paper uses the annual data of Japan and Korea over the period 1973-2015. Unless otherwise noted, all the series are obtained from the Organisation for Economic Co-operation and Development Statistics (henceforth “OECD.Stat”). All the raw data are nominal variables measured in each country’s currency. Nominal data are converted to real values by dividing by the GDP deflator (“Total domestic expenditure, deflator,” 2011=1) and population (“Working-age population, aged 15-74”). All fiscal variables are for the general government. Each data series is extracted from the table and row numbers as per each country’s relevant data file as follows:

- Consumption: “Private final consumption expenditure, volume”
- Investment: “Gross fixed capital formation, total, volume”
- Capital Tax Revenues: “Taxes on income, profits and capital gains of corporates” (series number 1200)
- Labor Tax Revenues: “Taxes on income, profits and capital gains of individuals” (series number 1100)
- Consumption Tax Revenues: “Taxes on goods and services” (series number 5000)
- Hours Worked: Hours worked are constructed from the following variables:
  - *Emp*: “Total employment” (measured in persons)
  - *H*: “Hours worked per employee, total economy” (measured in hours)

Hours worked are then defined as

$$\text{Hours worked} = \text{Emp} \times H.$$

We also construct average effective tax rates for both countries. The tax rates for capital and labor income, and consumption are constructed as follows:

- Average effective tax rates for capital income are calculated by dividing the amounts of proportional tax on corporate income by the amounts of

corporate income (tax base). The information provided by OECD.Stat is insufficient to compute the average effective tax rates for capital income. Hence, we construct the tax rate series relying on outside sources as described below.

- Japan: Following Gunji and Miyazaki (2011), we calculate the tax rates on capital incomes by using the National Tax Agency Annual Statistics Reports from the National Tax Agency of Japan. Constrained by the data availability, we construct the tax rate series from 1980 to 2015.
- Korea: Analogous to the construction for Japan, we use the National Tax Statistical Yearbook from the National Tax Service of Korea over the period 1982-2015.
- Average effective tax rates for labor income use “All-in average personal income tax rates at average wage by family type (One-earner married couple, Two children)” from OECD.Stat. The series is available over the period 2000-2015 for both Japan and Korea.
- Average effective consumption tax rates are the average VAT rates over 1977-2015 in Korea and over 1989-2015 in Japan, drawn from Buydens (2016).

Lastly, the historical series and projection values for the share of population over 65 years old are calculated by dividing “Population (hist&proj) 65+” by “Population (hist&proj) All ages.”

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