Population Aging, Transition to Service Economy, and Effects of Monetary Policy*

Jaeho Lee
Bank of Korea

This paper examines how the transition to the service economy induced by population aging affects the effectiveness of monetary policy. Using the euro-area panel data, I estimate that a 1 percentage point increase in the proportion of the population aged 65 or over is associated with the rise (decline) in the service (manufacturing) sector share by 1.11 (0.96) percentage points. Both empirical and theoretical analyses also find that monetary policy has a less significant impact on the service sector than on the manufacturing sector. Finally, these findings reveal that the output effects of monetary policy can decrease by 1.48 to 2.27 percent when the share of the population 65 or over rises by 1 percentage point.

JEL Codes: D40, E52, J11.

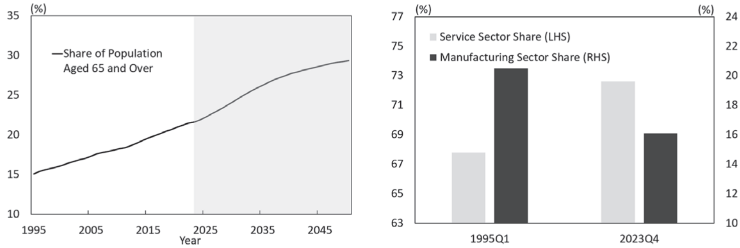
1. Introduction

The shift from manufacturing to services, commonly referred to as deindustrialization, has been a long-standing trend lasting for decades and is propelled by a set of interconnected factors. For instance, with the increasing affluence of societies, there has been a noticeable change in consumer preferences toward services like health care, education, entertainment, and leisure activities. Additionally, advancements in information technology have played a crucial role in fostering the creation of new services, thereby facilitating the growth of the service sector.

The swift aging of the population also promotes industry restructuring, driven by the differences in consumption baskets between the young and old. The euro area, in particular, has experienced population aging earlier than any other region, and this trend is likely to

*Author contact: jaeho.lee@bok.or.kr.

Figure 1. Population Aging and Transition to Service Economy in Euro Area



A. Population Aging Trend B. Changes in Each Sector Share

Note: The shaded area in A indicates the forecast period.
Source: Eurostat.

continue. Figure 1A shows the share of the people aged 65 or over in the euro area, which is expected to approach 30 percent by 2050. Furthermore, the literature finds that young and old individuals have heterogeneous consumption bundles. Specifically, older individuals spend a larger portion of their income or wealth on services (e.g., housing and health services) but less on manufactured goods (e.g., vehicles and clothes) compared with younger individuals. Due to these consumption patterns, population aging can accelerate the transition to the service economy. Figure 1B plots the euro area's declining share of manufacturing and rising share of services from the first quarter of 1995 to the fourth quarter of 2023.

The shift to services undermines the effectiveness of monetary policy due to the weaker interest rate channel in the service industries. More precisely, two channels, i.e., the firm-side and consumer-side interest rate channels, are mainly related to the weak responsiveness of the service sector to monetary policy. Firstly, focusing on the firm-side channel, the manufacturing industries utilize more capital goods including machinery and equipment than the service industries. Fluctuations in interest rates can affect the cost of financing, thereby shaping the firm's choices regarding capital expenditures. In periods of low interest rates, firms may display a heightened propensity to invest in new equipment and machinery. Increased investment causes demand for durable goods and also raises a firm's production capacity. Furthermore, from the consumer side, manufacturing goods like automobiles and appliances frequently involve financing, unlike services. Variations in interest rates can alter the cost of financing, potentially affecting consumer expenditure on durable goods. In times of low interest rates, consumers are more prone to securing loans, thereby stimulating demand within the durable goods sector.

To put it all together, it can be inferred that a rapidly aging population, which increases (decreases) the share of the service (manufacturing) sector, contributes to reducing the effectiveness of monetary policy. Previous studies have argued that population aging reduces the effectiveness of monetary policy through various channels. However, unlike existing studies, this paper focuses on the weakening of the interest rate channel of monetary policy due to the transition to the service economy. Thus, I aim to answer the following questions: "How do demographic shifts change the industrial structures?" and "How do these structural changes affect the output effects of monetary policy?"

To tackle these questions, this paper estimates how much the aging of the population affects the size of the service and manufacturing industries. Then, I check the cross-industry effects of monetary policy. Finally, using these results, I compute to what extent population aging reduces the output effects of monetary policy through the transition to the service economy.

First, the effects of population aging on the industrial structures in the euro area are estimated using the balanced panel data. The panel data include 10 countries that are selected based on the gross domestic product (GDP) level and 11 industries in the euro area. The main finding is that a 1 percentage point increase in the proportion of the population who are 65 years old or over is associated with the rise (decline) in the service (manufacturing) sector share by 1.11 (0.96) percentage points.

After that, the monetary policy shocks in the euro area are identified to estimate the cross-industry impacts of monetary policy. To do that, this paper estimates a vector autoregression (VAR) model and obtains the structural shocks to monetary policy. Here, all the methodologies are based on Peersman and Smets (2001) in which they employ recursive and short and long-run restrictions in estimating the structural vector autoregression (SVAR) model. For robustness checks, I also utilize the monetary policy surprises of Altavilla et al. (2019), which provides asset price changes before and after monetary policy announcements. These measures help us to identify monetary policy shocks during the zero lower bound (ZLB) period.

Then, using the identified monetary policy shocks above, this study estimates the output effects of monetary policy on 11 industries. The key takeaway is that the service industries are less sensitively affected by the monetary policy shocks than the manufacturing industries. For example, with the monetary policy shocks from the VAR model with the recursive restriction, I find that a 1 percentage point increase in the benchmark interest rate two quarters ago causes a decline in the growth rate of the total, manufacturing, and service industries' output in the current quarter by 0.19, 0.44, and 0.13 percentage points, respectively.

Finally, this paper estimates how the output effects of monetary policy in the euro area change due to the shifts to the service economy caused by population aging, using the estimation results above. The empirical findings suggest that when the proportion of the population aged 65 or over increases by 1 percentage point, the service (manufacturing) sector share rises (declines) by 1.11 (0.96) percentage points, and the effects of monetary policy decline by 1.48 percent to 1.96 percent due to the cross-industry heterogeneity of the impacts of monetary policy. In line with these findings, the output effects of monetary policy turn out to be weaker in the countries of the euro area that have a higher service industry share.

This study builds a two-agent New Keynesian (TANK) model to better understand the mechanisms behind the results in the empirical analysis. I also quantitatively estimate the decline in monetary policy effectiveness with an aging population using this model. The model has two sectors, i.e., the manufacturing and service sector, and two types of households, i.e., young households or workers and old households or retirees. Young and old households have distinct consumption baskets, which means they have different consumption weights on manufacturing goods and services. Due to these heterogeneous consumption patterns, population aging accelerates the transition to the service economy. Firms in the manufacturing industries are assumed to be more capital-intensive than those in the service industries. As a result, changes in the proportion of each sector led by population aging affect the output impacts of monetary policy. This model finds that the output effects of monetary policy decrease by 2.27 percent when the old population share increases by 1 percentage point.

Both empirical and theoretical results reveal that the output effects of monetary policy can decrease by 1.48 to 2.27 percent when the share of the population aged 65 or over rises by 1 percentage point. Then, this paper computes to what extent the monetary policy effectiveness will decline in the long run, using these results and demographic projections for the euro area, and finds the monetary policy effectiveness is expected to decline by 9.0 to 13.8 percent by 2040.

I conduct two alternative parameterization experiments with this TANK model. First, in the baseline calibration, this paper assumes that the difference in capital share between manufacturing and service industries is 15 percentage points, reflecting the data in the euro area. However, in the U.S., it differs by about 30 percentage points, so it is recalibrated to match the U.S. data. In this case, the degree to which the aging of the population reduces the effectiveness of monetary policy is 12.8 percent larger than in the baseline. In addition, while the shift to the service economy reduces the effectiveness of monetary policy by weakening the cost of capital channel, it also improves the effectiveness by increasing the share of the service industries with higher price rigidity. Considering these points, I set the Calvo parameter to be the same for both industries. In this case, the effects of higher price rigidity due to an increase in the share of services disappear, and the reduction in monetary policy effectiveness due to population aging becomes 4.0 percent larger than in the baseline.

Related Literature. Three strands of literature are related to this paper: (i) population aging effects on the industrial structures, (ii) the cross-industry heterogeneity of the impacts of monetary policy, and (iii) the effects of monetary policy in an aging society. To my knowledge, there are a limited number of analyses combining these topics. Therefore, this paper bridges this gap.

First, studies such as Cravino, Levchenko, and Rojas (2022) point out that the aging of the population changes the industrial structures; in particular, the service industries grow significantly in an aging society, which is also one of the main claims of this study.

Second, previous papers show significantly different effects of monetary policy across industries, especially in the manufacturing sector (e.g., Barth and Ramey 2000 and Loo and Lastrapes 1998). Besides using the U.S. data, Ganley and Salmon (1997) and Hayo and Uhlenbrock (1999) show the cross-industry heterogeneity of the effects of monetary policy using the U.K. and Germany data, respectively. Dedola and Lippi (2005) demonstrate sizable and significant cross-industry differences in the effects of monetary policy using disaggregated industry data from five OECD countries. They reveal that the impacts of monetary policy are more substantial in the industries that produce durable goods and have greater working capital. Sterk and Tenreyro (2018) also study a redistribution channel for the transmission of monetary policy and find that expansionary open-market operations push down the real interest rate, which leads to a temporary boom in the durable goods sector. Peersman and Smets (2005) estimate the effects of monetary policy on output growth of 11 industries in seven euro-area countries. They find the monetary policy effects vary according to the durability of the goods produced in the sector, which is evidence for the conventional interest rate or cost of capital channel of monetary policy transmission. Peersman and Smets (2005) also show some indications that the capital intensity of production and the degree of openness affect the monetary policy sensitivity. The papers mentioned above estimate the cross-industry effects of monetary policy mostly using manufacturing industries' data. Unlike these papers, I compare the effects of monetary policy on the service and manufacturing sectors.

Third, the literature studies how the effects of monetary policy change as the population ages. Jones (2018) argues that population aging explains one-third of the gap between log output per capita and its trend in 2015 since demographics lower real rates, which causes the zero lower bound to bind between 2009 and 2015. Imam (2013) provides empirical evidence that demographic shifts to an older society cause monetary policy to have a more benign impact on the economy. Leahy and Thapar (2022) study whether the effects of monetary policy are dependent on the demographic structures of the population, and find that the economy's response is stronger the greater the share between 40 and 65. Kantur (2013) constructs a model that is the merger of an overlapping generation setup and New Keynesian framework and shows monetary policy is less effective as the population ages due to declines in the interest rate sensitivity of real economic activities. Wong (2016) empirically and theoretically shows that the consumption of young people is significantly more responsive to interest rate shocks than that of older people. She argues that the refinancing channel of monetary policy can explain the heterogeneity between the young and old's reactions to monetary policy. Despite the papers introduced here, there are a limited number of papers that explore the transition to the service economy induced by population aging and its effects on the impacts of monetary policy together. Therefore, this paper contributes to filling the gap.

The structure of this paper is as follows. Section 2 presents the empirical evidence for heterogeneous consumption patterns between the young and old, and the transition to the service economy in the euro area. Based on these stylized facts, I also estimate how population aging affects industrial structures. Section 3 identifies monetary policy in the euro zone and shows the cross-industry heterogeneity of the effects of monetary policy, and computes changes in the effectiveness of monetary policy due to population aging. After that, Section 4 describes the theoretical model, and Section 5 quantitatively estimates the effects of the aging population on the monetary policy effectiveness and conducts alternative parameterization experiments using this model. Finally, Section 6 concludes.

2. Population Aging and Transition to Service Economy in Euro Area

This section provides evidence for heterogeneous consumption baskets between young and old individuals and shows recent changes in the industrial structures in the euro area. Then, I estimate an empirical model to compute to what extent the aging of the population affects the industrial structures in the euro area.

2.1 Heterogeneous Consumption Baskets by Age Group

Table 1 shows the structures of consumption expenditure by age group in EU27 in 2020, suggesting that old individuals who are 60 years old or over spend more on services, e.g., *housing* and *health*

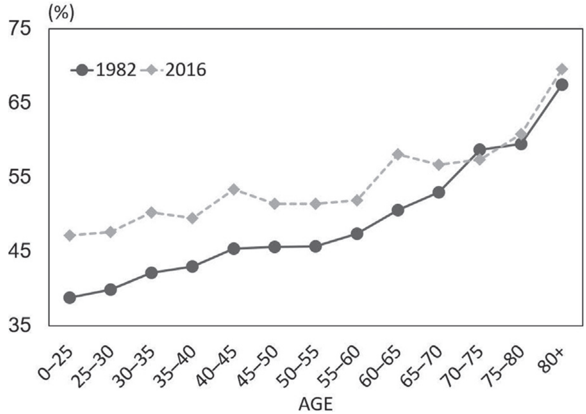
Table 1. Structure of Consumption Expenditure by Age Group in EU27 (percent)

	Under 30 Years	30–44 Years	45–59 Years	60 Years or Over
Housing, Water, Electricity, Gas, and Other Fuels	31.1	29.9	30.4	37.2
Food and Nonalcoholic Beverages	15.1	16.4	17.2	17.8
Transport	12.4	12.0	12.1	8.4
Recreation and Culture	7.1	7.2	6.9	6.1
Health	2.3	2.9	3.3	5.0
Furnishings, Household Equipment, and Routine Household Maintenance	4.6	5.0	4.8	4.9
Restaurants and Hotels	6.6	5.8	5.2	3.5
Communications	3.5	3.1	3.2	2.9
Clothing and Footwear	5.0	5.0	4.4	2.8
Alcoholic Beverages, Tobacco, and Narcotics	2.6	2.3	2.6	2.3
Education	1.3	1.2	1.3	0.2
Miscellaneous Goods and Services	8.5	9.2	8.7	8.9

Note: The consumption structure is in 2020.
Source: Eurostat.

services, than young individuals. On the contrary, their expenditure shares on manufacturing goods, e.g., *vehicles* and *clothes,* are smaller than those of young individuals. Literature provides more specific consumption weights on service and manufacturing goods of young and old individuals. Figure 2 plots Cravino, Levchenko, and Rojas (2022)'s findings, showing that households in their 60s (80s) have service expenditure shares 10–12 percentage points (20 percentage points) higher than households in their 30s.

Figure 2. Service Consumption Share by Age



Source: Cravino, Levchenko, and Rojas (2022).

2.2 Transition to Service Economy in Euro Area

Table 2 details the changes in the industrial structures based on value-added and employment in the euro area. Notable findings are that the proportion of the service industries has risen, but that of the manufacturing industries has declined from the first quarter of 1995 to the fourth quarter of 2023. Specifically, the proportion of the service industries based on value-added and employment has increased from 67.7 to 72.6 percent and 66.6 to 76.8 percent, respectively. On the contrary, the proportion of the manufacturing industries based on value-added and employment has decreased from 20.5 to 16.1 percent and 18.8 to 12.8 percent, respectively. During the same period, population aging has progressed at a fast pace: the proportion of the population aged 65 or over in the euro area has increased from 15.1 percent in 1995 to 21.6 percent in 2023, which is shown in Figure 1.

2.3 Effects of Population Aging on Industrial Structures

Given the stylized facts above, it can be inferred that population aging has contributed to the rise (decline) in the size of the service (manufacturing) industries due to the heterogeneous consumption baskets between young and old individuals. The following empirical analysis verifies the existence of this channel.

Table 2. Changes in Industrial Structure Based on Value-Added and Employment in Euro Area (percent)

	Value-Added		Employment	
	1995:Q1	2023:Q4	1995:Q1	2023:Q4
Services	67.7	72.6	66.6	76.8
Manufacturing	20.5	16.1	18.8	12.8
Agriculture	2.2	1.8	5.6	2.8
Construction	5.8	5.8	7.4	6.4
Service1	18.7	18.4	23.9	24.4
Service2	3.9	5.3	2.2	3.3
Service3	4.8	4.6	3.0	2.3
Service4	9.8	10.7	0.8	1.0
Service5	9.0	11.7	7.8	14.2
Service6	17.9	18.9	23.0	25.0
Service7	3.5	3.0	5.9	6.5

Note: Agriculture contains forestry and fishing. Service1 = Wholesale and retail trade, transport, accommodation, and food service activities. Service2 = Information and communication. Service3 = Financial and insurance activities. Service4 = Real estate activities. Service5 = Professional, scientific, and technical activities; administrative and support service activities. Service6 = Public administration, defense, education, human health, and social work activities. Service7 = Arts, entertainment, and recreation; other service activities; activities of household and extraterritorial organizations and bodies.
Source: Eurostat.

Model Specification. To check the effects of population aging on the industrial structures in the euro area, this paper regresses each industry share based on value-added or employment on a population aging variable and controls using the panel data, which consist of 10 countries and 11 industries in the euro area.[1] The specification of the panel regression model for a country i and industry j is as follows:[2]

$$Y_{i,t}^{j} = \alpha^{j} + \beta^{j} Aging_{i,t} + \delta^{j} Controls_{i,t} + \psi_{i}^{j} + e_{i,t}^{j}, \tag{1}$$

[1]Ten countries among euro-zone members are selected based on GDP level (i.e., Austria, Belgium, Finland, France, Germany, Ireland, Italy, Netherlands, Portugal, and Spain).

[2]The model specification is based on Cravino, Levchenko, and Rojas (2022), Kang (2017), and Rowthorn and Ramaswamy (1997).

where $Y_{i,t}^{j}$ is the share of an industry j based on value-added or employment in a country i, $Aging_{i,t}$ is the population aging variable that is measured as the proportion of the population aged 65 or over, $Controls_{i,t}$ is the vector containing controls, ψ_i^j is the country fixed effect, and $e_{i,t}^{j}$ is the error term.[3]

Controls. Apart from the aging population, the literature highlights additional factors influencing industrial structures. Baumol, Blackman, and Wolff (1989) argue that labor productivity is the critical determinant for industrial structure changes. Rowthorn and Ramaswamy (1997) state that changes in trade patterns can affect the country's industrial structures rather than domestic expenditures. An exchange rate that measures the price competitiveness in trade can also alter trade patterns and industrial structures. Lastly, the log GDP per capita, GDP growth, and population density are controlled to estimate the exact effects of population aging on the industrial structures. Therefore, the control vector $Controls_{i,t}$ consists of the following variables: $Productivity_{i,t}$ is the labor productivity, $Popul.Density_{i,t}$ is the population of each country divided by its land cover, $logGDPcapita_{i,t}$ is the logarithm of total GDP divided by the population, $TradeShare_{i,t}$ is the sum of export and import divided by GDP, $REER_{i,t}$ is the real effective exchange rate, and $GDPgrowth_{i,t}$ is the GDP growth rate.

Data. The shares of 11 industries based on value-added or employment are calculated using Eurostat data, and the old population ratio—i.e., the proportion of the population aged 65 or over—is from Eurostat.[4] Labor productivity is the real labor productivity per person from Eurostat and population density is computed with the country's population and its land cover, which Eurostat provides. This paper employs real export, import, and GDP data in the national account from Eurostat to calculate each country's trade share. The real effective exchange rate is compiled by the Bank for International Settlements. Lastly, the sample period is from the first

[3]The Hausman test rejects the null hypothesis that a random effects model is appropriate at a 1 percent significance level in all 11 industries' estimation.

[4]Since only annual data are available on the share of the population aged 65 or over by country in the euro area, I convert them to quarterly data using a local quadratic interpolation method since the data have a stable growth trend as shown in Figure 1.

Table 3. Effects of Population Aging on Industrial Structures (value-added)

	(1) Services	(2) Manufacturing	(3) Agriculture	(4) Construction
Aging	**1.105***** **(0.192)**	**–0.962***** **(0.234)**	**–0.066** **(0.048)**	**–0.198** **(0.117)**
Productivity	0.017 (0.074)	0.149** (0.063)	–0.005 (0.022)	–0.169*** (0.021)
Popul.Density	0.107* (0.052)	–0.106* (0.057)	0.002 (0.008)	0.017*** (0.014)
logGDPcapita	–7.726* (3.863)	–3.181 (2.895)	–2.339 (1.630)	15.460*** (2.104)
TradeShare	–0.012 (0.048)	0.056 (0.044)	–0.004 (0.007)	–0.042*** (0.009)
REER	0.219* (0.114)	–0.142 (0.092)	–0.055** (0.017)	–0.048* (0.023)
GDPgrowth	–0.163*** (0.034)	0.144** (0.045)	0.028** (0.009)	0.007 (0.011)
Constant	Yes	Yes	Yes	Yes
Obs.	1,143	1,143	1,143	1,143
R-squared	0.512	0.547	0.390	0.551

Note: Agriculture contains forestry and fishing. Standard errors in parentheses are clustered at a country level, and ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

quarter of 1995 to the fourth quarter of 2023, and all the time series are seasonally adjusted.

Results. Tables 3 and 4 present estimation results using industry shares based on value-added. Table 3 suggests that the aging of the population raises the size of the service industries but reduces that of the manufacturing, agriculture, and construction industries. To be specific, a 1 percentage point increase in the proportion of the population who are 65 years old or over is associated with the rise (decline) in the proportion of the service (manufacturing) industries by 1.11 (0.96) percentage points. These results are consistent with Cravino, Levchenko, and Rojas (2022) where a 1 percentage point increase in the fraction of the population that is over 65 is associated with a 1.3–1.5 percentage point increase in the service shares of value-added and employment. Table 4 shows the effects of population aging on the service industry structures, indicating that the aging of the population is associated with the rise in the size of most

Table 4. Effects of Population Aging on Service Industry Structures (value-added)

	(1) Service1	(2) Service2	(3) Service3	(4) Service4	(5) Service5	(6) Service6	(7) Service7
Aging	**0.016**	**–0.068**	**0.007**	**0.632*****	**0.191****	**0.249****	**0.074****
	(0.143)	**(0.073)**	**(0.048)**	**(0.119)**	**(0.067)**	**(0.085)**	**(0.025)**
Productivity	–0.072*	0.119**	–0.044**	0.045	0.011	–0.048	0.005
	(0.033)	(0.037)	(0.016)	(0.044)	(0.015)	(0.029)	(0.012)
Popul.Density	–0.010	–0.011	0.015	–0.006	0.043	0.077***	–0.002
	(0.020)	(0.011)	(0.014)	(0.030)	(0.027)	(0.017)	(0.004)
logGDPcapita	–1.963	–1.666	0.322	–4.748	3.014	–1.335	–1.236*
	(2.491)	(2.954)	(1.149)	(2.961)	(1.726)	(3.186)	(0.617)
TradeShare	0.024**	0.003	–0.003	–0.017	0.006	–0.021	–0.005
	(0.008)	(0.008)	(0.008)	(0.012)	(0.015)	(0.018)	(0.003)
REER	0.021	–0.024	0.046	0.086**	0.020	0.053	0.015**
	(0.031)	(0.019)	(0.040)	(0.038)	(0.024)	(0.047)	(0.006)
GDPgrowth	0.096***	–0.065***	–0.022**	–0.043**	–0.033**	–0.091***	–0.004
	(0.024)	(0.019)	(0.009)	(0.014)	(0.013)	(0.011)	(0.004)
Constant	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	1,143	1,143	1,143	1,143	1,143	1,143	1,143
R-squared	0.353	0.721	0.372	0.471	0.735	0.440	0.276

Note: Service1 = Wholesale and retail trade, transport, accommodation, and food service activities. Service2 = Information and communication. Service3 = Financial and insurance activities. Service4 = Real estate activities. Service5 = Professional, scientific, and technical activities; administrative and support service activities. Service6 = Public administration, defense, education, human health, and social work activities. Service7 = Arts, entertainment, and recreation; other service activities; activities of household and extraterritorial organizations and bodies. Standard errors in parentheses are clustered at a country level, and ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table 5. Effects of Population Aging on Industrial Structures (employment)

	(1) Services	(2) Manufacturing	(3) Agriculture	(4) Construction
Aging	**1.357***** **(0.277)**	**–0.659***** **(0.096)**	**–0.384***** **(0.114)**	**–0.314*** **(0.163)**
Productivity	0.179** (0.079)	–0.047 (0.042)	–0.005 (0.022)	–0.133*** (0.036)
Popul.Density	0.009 (0.059)	–0.059 (0.042)	0.034 (0.022)	0.011 (0.019)
logGDPcapita	–8.235 (4.616)	–1.586 (1.667)	–3.714** (1.413)	14.070*** (3.013)
TradeShare	0.026 (0.027)	0.008 (0.023)	–0.001 (0.008)	–0.031** (0.012)
REER	0.215** (0.086)	–0.109* (0.056)	–0.075*** (0.022)	–0.037 (0.028)
GDPgrowth	–0.093** (0.038)	0.062*** (0.018)	0.031** (0.010)	–0.002 (0.019)
Constant	Yes	Yes	Yes	Yes
Obs.	1,143	1,143	1,143	1,143
R-squared	0.760	0.765	0.740	0.474

Note: Agriculture contains forestry and fishing. Standard errors in parentheses are clustered at a country level, and $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

service industries given that the coefficients on these industries are positive and significant.

Robustness Checks. I also employ industry shares based on employment, and the results are provided in Table 5. In general, the results using the employment share are consistent with the ones using the value-added share. Specifically, a 1 percentage point increase in the proportion of the population who are 65 years old or over is associated with the increase (decrease) in the proportion of the service (manufacturing) industries by 1.36 (0.66) percentage points.

3. Population Aging and Effects of Monetary Policy

This section verifies the cross-industry heterogeneity of the impacts of monetary policy. First, monetary policy shocks in the euro area are identified, and then, this paper estimates how the monetary policy shocks differently affect each industry. Finally, I explore to what extent the aging of the population affects the output effects of monetary policy.

3.1 Identification of Monetary Policy Shocks

This paper estimates a VAR model to obtain the structural shocks to monetary policy. Alternatively, I employ high-frequency data as monetary policy surprises, i.e., asset price changes before and after monetary policy announcements.

VAR Model. The identification methods used here are based on Peersman and Smets (2001), and the structural VAR model specification is as follows:

$$Z_t = C + \sum_{j=1}^{l} A_j Z_{t-j} + BX_t + \varepsilon_t \quad \text{with} \quad \varepsilon_t \sim i.i.d.\ N(0, \Omega_\varepsilon), \quad (2)$$

where C is the constant vector; Z_t is the vector containing four endogenous variables: (i) the real GDP, (ii) the consumer prices, (iii) the domestic nominal short-term interest rate, and (iv) the real effective exchange rate; X_t is the vector including three exogenous variables: (i) the world commodity price index, (ii) the U.S. real GDP, and (iii) the U.S. nominal short-term interest rate; and ε_t is the innovation vector. Time lag l is set to be three following Peersman and Smets (2001). Variables except interest rates are expressed in the log difference from the previous period.

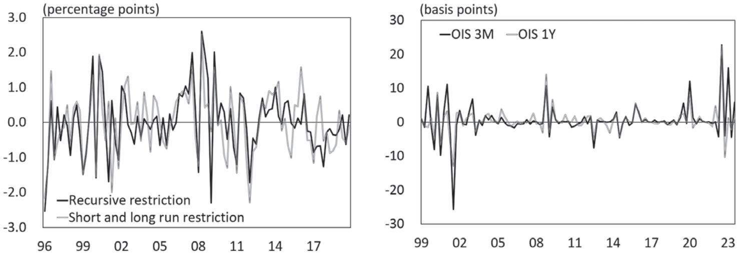
Restrictions. Monetary policy shocks are measured as the structural shocks to the nominal short-term interest rate. This paper employs two restrictions: (i) the recursive restriction and (ii) the short- and long-run restrictions. First of all, the structural shocks are identified by Cholesky decomposition. The order of variables as above is based on the standard assumption that there is a delayed response of real variables and inflation to the monetary policy shock (Christiano, Eichenbaum, and Evans 1997). Moreover, in the short- and long-run restrictions, only supply shocks have permanent effects on output, but demand, monetary policy, and exchange rate shocks cannot affect output in the long term. Furthermore, in the short term, the monetary policy and exchange rate have no contemporaneous impacts on output, and monetary policy is also not affected by the exchange rate shocks in the same period. All these assumptions are from Peersman and Smets (2001).

Data. Real GDP, consumer price index, and three-month interbank rates in the euro area are from Eurostat. Real effective exchange rates are compiled by the Bank for International Settlements. The global price index of all commodities from the International Monetary Fund is used as the world commodity price index. Real GDP in the U.S. is from the Bureau of Economic Analysis, and the U.S. nominal short-term interest rates are the three-month Treasury bill yield from the Board of Governors of the Federal Reserve System. All the time series are seasonally adjusted, with a quarterly frequency, covering the period from the first quarter of 1995 to the fourth quarter of 2019. Because of the concerns about structural breaks in the VAR model, this paper excludes the COVID-19 period from the analysis.

Robustness Checks. I also use high-frequency data to identify monetary policy shocks. The identification methods using the VAR model above have several shortcomings. For example, it is hard to identify monetary policy during the ZLB period and capture unconventional monetary policy such as forward guidance. To address these issues, this paper utilizes the monetary policy surprises of Altavilla et al. (2019), who built the Euro Area Monetary Policy Event-Study Database (EA-MPD), which contains asset price changes before and after monetary policy announcements. The underlying idea is that monetary policy does not react to fluctuations in asset prices within the day; therefore, the causal relationship flows from monetary policy to asset prices. This means the changes in the asset prices before and after policy announcements can be characterized as orthogonal changes in policy stance. Specifically, this paper exploits three-month and one-year overnight index swap (OIS) rate changes in the median quote from the window 13:25–13:35 before the press release to the median quote in the window 14:00–14:10 after it because the three-month and one-year OIS rates have the longest time series: from January 1999 to October 2023. I compute quarterly shocks by adding up daily shocks in each quarter.

Results. Figure 3 shows the monetary policy shocks identified from the VAR model estimation and asset price changes. In the left panel from the VAR model, there seem to be three large negative shocks after 2000. The periods when these large negative shocks

Figure 3. Identification of Monetary Policy in Euro Area



A. From VAR Model B. From Asset Prices

occurred are consistent with the periods when the European Central Bank (ECB) dropped its policy interest rate. The ECB reduced key rates by 2.75 percentage points from May 10, 2001 to June 5, 2003, by 3.00 percentage points from October 8, 2008 to May 7, 2009, and by 1.25 percentage points from November 3, 2011 to November 7, 2013. In the right panel from the asset prices, the relationship between the actual ECB rate decisions and identified shocks seems to be weak, suggesting that it identifies more qualitative shocks, such as changes in statement wording, in addition to rate changes. However, in both cases, there are no stochastic trends in monetary policy measures.

3.2 Cross-Industry Effects of Monetary Policy

This paper estimates the effects of monetary policy on the output growth of 11 industries in 10 countries of the euro area based on Peersman and Smets (2005).[5]

Model Specification. I estimate the following dynamic panel data model to check the cross-industry effects of monetary policy:

$$\Delta Y_{i,t}^{j} = c^{j} + \sum_{k=1}^{p} \phi_{k}^{j} \Delta Y_{i,t-k}^{j} + \sum_{k=1}^{q} \gamma_{k}^{j} MP_{t-k} + \psi_{i}^{j} + \mu_{i,t}^{j}, \qquad (3)$$

where $\Delta Y_{i,t}^{j}$ is the growth rate of an industry j output based on value-added in a country i, MP_t is the monetary policy measure, ψ_i^j

[5]The 10 countries are Germany, France, Italy, Spain, Netherlands, Belgium, Ireland, Austria, Finland, and Portugal.

is the country fixed effect, and $\mu^j_{i,t}$ is the error term. Since the country fixed effect, ψ^j_i, is correlated with the lagged dependent variables $\Delta Y^j_{i,t-k}$, standard estimators are inconsistent. To solve this problem, this paper employs a consistent generalized method of moments (GMM) estimator as in Atrellano and Bond (1991). p and q are set as two and four respectively, based on the lags in Peersman and Smets (2005). The analysis period is from the first quarter of 1995 to the fourth quarter of 2019 or the first quarter of 1999 to the third quarter of 2023, depending on which monetary policy measure is used. In this specification, the coefficients of our interest are γ^j_k for $k = 1, 2, 3, 4$, which show the cross-industry effects of monetary policy.

Results. Tables 6 and 7 provide estimation results from the analysis using identified shocks under the recursive restriction. First, Table 6 shows the effects of monetary policy on main industries, i.e., total, manufacturing, services, agriculture, and construction. In general, the monetary policy two quarters ago is significantly effective on the output growth of total, manufacturing, and service industries in the current quarter. Numerically, a 1 percentage point increase in the interest rate two quarters ago causes the growth rate of total, manufacturing, and service industries' output in the current quarter to decrease by 0.19, 0.44, and 0.13 percentage points, respectively. Here, the coefficient for the manufacturing industries is 3.4 times larger than the one for the service industries. Thus, it can be concluded that the service industries are less sensitively affected by the monetary policy shock than the manufacturing industries. Table 7 shows the effects of monetary policy on each service industry. In line with the effects on the main industries above, monetary policy two quarters ago significantly affects most service industries in the current quarter. However, the coefficients for service industries are still smaller than that for the manufacturing industries.

Table 8 also presents the effects of monetary policy on the main industry sectors using the shocks identified with the short- and long-run restrictions. In general, the estimation results are in line with the case of the recursive restriction. For instance, a 1 percentage point contractionary monetary policy shock two quarters ago decreases the growth rate of total, manufacturing, and service industries' output by 0.12, 0.29, and 0.07 percentage points, respectively. Here, the

Table 6. Effects of Monetary Policy on Main Industry Sectors (recursive restriction)

	(1) Total	**(2) Manufacturing**	**(3) Services**	**(4) Agriculture**	**(5) Construction**
MP_{t-1}	–0.0003	–0.0010	–0.0002	0.0024	–0.0008
	(0.0005)	(0.0018)	(0.0003)	(0.0020)	(0.0009)
$\boldsymbol{MP_{t-2}}$	**–0.0019*****	**–0.0044****	**–0.0013*****	**0.0012**	**–0.0007**
	(0.0005)	**(0.0018)**	**(0.0003)**	**(0.0020)**	**(0.0009)**
MP_{t-3}	–0.0013**	–0.0032*	–0.0007**	–0.0014	–0.0021**
	(0.0005)	(0.0018)	(0.0003)	(0.0020)	(0.0009)
MP_{t-4}	–0.0001	0.0006	0.0001	–0.0007	–0.0008
	(0.0005)	(0.0017)	(0.0003)	(0.0019)	(0.0008)
ΔY_{t-1}	–0.0592*	–0.1727***	0.1718***	–0.0810**	0.1477***
	(0.0334)	(0.0332)	(0.0329)	(0.0333)	(0.0333)
ΔY_{t-2}	0.0843**	–0.0364	0.2122***	–0.0551*	0.1817***
	(0.0333)	(0.0331)	(0.0329)	(0.0334)	(0.0332)
Constant	Yes	Yes	Yes	Yes	Yes
Obs.	910	910	910	910	910
Wald χ^2 (6)	28.07	35.71	125.22	10.05	76.78

Note: Agriculture contains forestry and fishing. Standard errors in parentheses are clustered at a country level, and $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 7. Effects of Monetary Policy on Service Industries (recursive restriction)

	(1) Service1	(2) Service2	(3) Service3	(4) Service4	(5) Service5	(6) Service6	(7) Service7
MP_{t-1}	–0.0008*	0.0000	0.0008	–0.0002	0.0005	–0.0004	0.0001
	(0.0005)	(0.0010)	(0.0012)	(0.0004)	(0.0007)	(0.0004)	(0.0007)
$\boldsymbol{MP_{t-2}}$	**–0.0014***	**–0.0021**	**–0.0034***	**–0.0007**	**–0.0018***	**–0.0001**	**–0.0006**
	(0.0004)	**(0.0010)**	**(0.0011)**	**(0.0004)**	**(0.0007)**	**(0.0004)**	**(0.0007)**
MP_{t-3}	–0.0013***	–0.0020**	–0.0012	0.0003	–0.0011*	–0.0002	–0.0012*
	(0.0004)	(0.0010)	(0.0011)	(0.0004)	(0.0006)	(0.0004)	(0.0007)
MP_{t-4}	0.0006	–0.0018*	0.0007	–0.0008**	–0.0009	0.0005	–0.0001
	(0.0004)	(0.0009)	(0.0011)	(0.0004)	(0.0006)	(0.0004)	(0.0007)
ΔY_{t-1}	0.1373***	–0.0895***	–0.1118***	0.1655***	0.1333***	–0.0848**	–0.2045***
	(0.0327)	(0.0331)	(0.0332)	(0.0330)	(0.0326)	(0.0330)	(0.0332)
ΔY_{t-2}	0.1739***	0.0545	0.0711**	0.1522***	0.1526***	–0.0494	–0.0243
	(0.0324)	(0.0335)	(0.0332)	(0.0328)	(0.0326)	(0.0330)	(0.0331)
Constant	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	910	910	910	910	910	910	910
Wald χ^2 (6)	83.95	22.21	27.81	71.81	60.97	10.94	41.42

Note: Service1 = Wholesale and retail trade, transport, accommodation, and food service activities. Service2 = Information and communication. Service3 = Financial and insurance activities. Service4 = Real estate activities. Service5 = Professional, scientific, and technical activities; administrative and support service activities. Service6 = Public administration, defense, education, human health, and social work activities. Service7 = Arts, entertainment, and recreation; other service activities; activities of household and extraterritorial organizations and bodies. Standard errors in parentheses and ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table 8. Effects of Monetary Policy on Main Industry Sectors (SR and LR restriction)

	(1) Total	**(2) Manufacturing**	**(3) Services**	**(4) Agriculture**	**(5) Construction**
MP_{t-1}	0.0004	–0.0001	0.0005	0.0029	0.0003
	(0.0005)	(0.0018)	(0.0003)	(0.0020)	(0.0009)
$\boldsymbol{MP_{t-2}}$	**–0.0012****	**–0.0029***	**–0.0007*****	**0.0004**	**0.0005**
	(0.0005)	**(0.0018)**	**(0.0003)**	**(0.0020)**	**(0.0009)**
MP_{t-3}	–0.0002	–0.0001	–0.0005*	–0.0004	–0.0014
	(0.0005)	(0.0018)	(0.0003)	(0.0020)	(0.0009)
MP_{t-4}	0.0006	0.0019	0.0006**	0.0009	0.0010
	(0.0005)	(0.0017)	(0.0003)	(0.0019)	(0.0008)
ΔY_{t-1}	–0.0450	–0.1675***	0.1907***	–0.0802**	0.1602***
	(0.0334)	(0.0332)	(0.0329)	(0.0333)	(0.0332)
ΔY_{t-2}	0.0888***	–0.0361	0.2137***	–0.0563*	0.1889***
	(0.0334)	(0.0332)	(0.0330)	(0.0334)	(0.0333)
Constant	Yes	Yes	Yes	Yes	Yes
Obs.	910	910	910	910	910
Wald χ^2 (6)	15.78	29.85	113.74	10.20	72.89

Note: Agriculture contains forestry and fishing. Standard errors in parentheses and $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

coefficient for the manufacturing industries is 4.14 times larger than the one for the service industries. The result that monetary policy is less effective in the service industries is consistent with the findings of Ganley and Salmon (1997).

Robustness Checks. Tables 9 and 10 show estimation results when three-month and one-year OIS rate changes before and after policy announcements are used as the monetary policy shocks. The qualitative interpretation of these results is that the service sector is still less sensitively affected by monetary policy than the manufacturing sector given the coefficient values on the manufacturing and service industries. However, the monetary policy shocks identified from the OIS rates affect the real economy with a one-quarter lag, while the shocks identified from the VAR model have a two-quarter lag.

It is also worth noting that the empirical analysis using the monetary policy shocks identified with asset prices is limited to qualitative rather than quantitative interpretation. This is because it is hard to interpret the size of the shocks since they capture not only changes in the base rate but also changes in the qualitative content of the statement. For example, in response to inflation during COVID-19, the ECB raised its key interest rate by 75 basis points (bp) on September 8 and October 27, 2022, but changes in the OIS three-month and one-year rates were 6.78 bp and 7.40 bp on September 8 and −0.10 bp and −12.82 bp on October 27, respectively. This discrepancy suggests that qualitative changes in the monetary policy stance play a crucial role.

3.3 Population Aging Effects on Impacts of Monetary Policy: Using Empirical Findings

This paper explores to what extent the effects of monetary policy change due to population aging, using the empirical findings of this paper. Then, I examine the difference in the effects of monetary policy between two country groups with a high and low share of the service sector.

Population Aging Effects on Impacts of Monetary Policy. Using the findings of Sections 2.3 and 3.2, I compute to what extent the changes in the industrial structures driven by the aging of the population reduce the effectiveness of monetary policy. First, this paper assumes the industrial structures of the euro area in 2023

Table 9. Effects of Monetary Policy on Main Industry Sectors (OIS 3M)

	(1) Total	(2) Manufacturing	(3) Services	(4) Agriculture	(5) Construction
$\boldsymbol{MP_{t-1}}$	**–0.0012*****	**–0.0014****	**–0.0009****	**0.0007**	**–0.0009**
	(0.0003)	**(0.0006)**	**(0.0004)**	**(0.0081)**	**(0.0008)**
MP_{t-2}	0.0000	–0.0009	0.0003	–0.0051	0.0018**
	(0.0003)	(0.0006)	(0.0004)	(0.0081)	(0.0008)
MP_{t-3}	0.0002	–0.0003	0.0003	0.0000	0.0003
	(0.0003)	(0.0006)	(0.0004)	(0.0084)	(0.0009)
MP_{t-4}	–0.0001	0.0006	–0.0001	–0.0075	–0.0006
	(0.0003)	(0.0006)	(0.0004)	(0.0083)	(0.0008)
ΔY_{t-1}	–0.6084***	–0.4343***	–0.7917***	–0.0983***	–0.4894***
	(0.0319)	(0.0326)	(0.0322)	(0.0326)	(0.0341)
ΔY_{t-2}	0.0691**	0.0397	0.0713**	–0.1942***	–0.2408***
	(0.0320)	(0.0326)	(0.0322)	(0.0326)	(0.0341)
Constant	Yes	Yes	Yes	Yes	Yes
Obs.	925	925	925	925	925
Wald χ^2 (6)	760.66	255.22	2,654.59	42.83	219.85

Note: Agriculture contains forestry and fishing. Standard errors in parentheses and $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 10. Effects of Monetary Policy on Main Industry Sectors (OIS 1Y)

	(1) Total	(2) Manufacturing	(3) Services	(4) Agriculture	(5) Construction
$\boldsymbol{MP_{t-1}}$	**–0.0014*****	**–0.0019****	**–0.0008**	**0.0048**	**–0.0018***
	(0.0003)	**(0.0007)**	**(0.0005)**	**(0.0105)**	**(0.0011)**
MP_{t-2}	0.0001	–0.0008	0.0011*	0.0022	0.0023**
	(0.0003)	(0.0008)	(0.0006)	(0.0110)	(0.0011)
MP_{t-3}	0.0004	–0.0003	0.0010*	0.0108	0.0000
	(0.0003)	(0.0008)	(0.0006)	(0.0110)	(0.0011)
MP_{t-4}	–0.0001	0.0006	0.0001	–0.0041	–0.0007
	(0.0003)	(0.0008)	(0.0005)	(0.0109)	(0.0011)
ΔY_{t-1}	–0.6032***	–0.4326***	–0.7935***	–0.0979***	0.4855***
	(0.0321)	(0.0327)	(0.0324)	(0.0327)	(0.0341)
ΔY_{t-2}	0.0680**	0.0369	0.0683**	–0.1941***	–0.2441***
	(0.0322)	(0.0326)	(0.0323)	(0.0327)	(0.0342)
Constant	Yes	Yes	Yes	Yes	Yes
Obs.	925	925	925	925	925
Wald χ^2 (6)	753.03	254.00	2,655.81	43.35	221.96

Note: Agriculture contains forestry and fishing. Standard errors in parentheses and $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 11. Decline Rate of Effects of Monetary Policy Due to 1 pp Increase in Old Population Share (empirical analysis)

Identification Method	VAR (Recursive)	VAR (SR & LR)
Decline Rate of Monetary Policy Effects	1.48%	1.96%

Note: The decline in the effectiveness of monetary policy is calculated based on the output response two quarters after the monetary policy shock occurs.

as a baseline, where the share of services, manufacturing, agriculture, and construction in the economy is 72.5 percent, 16.6 percent, 1.7 percent, and 5.6 percent, respectively. Then, when the proportion of the population aged 65 or over increases by 1 percentage point, the industrial structures are assumed to change according to the coefficients in Table 3. After that, with these changes in the industrial structures and the heterogeneous effects of monetary policy across industries in Tables 6, 8, 9, and 10 together, we get Table 11 that shows the decline rate of the effects of monetary policy due to a 1 percentage point increase in the old population share. Specifically, when the proportion of the population aged 65 or over increases by 1 percentage point, the service (manufacturing) sector share rises (declines) by 1.11 (0.96) percentage points, and the effects of monetary policy decline by 1.48 percent to 1.96 percent due to the cross-industry heterogeneity of the impacts of monetary policy. Here, the range is presented since the heterogeneous effects of monetary policy across industries are estimated differently depending on the shock identification method.

Heterogeneous Effects by Country Group. A revised dynamic panel model, Equation (4), is estimated to check the difference in the effects of monetary policy between the countries with a high and low share of the service sector:

$$\Delta Y_{i,t} = c + \sum_{k=1}^{p} \phi_k \Delta Y_{i,t-k} + \mathbb{1}_i \sum_{k=1}^{q} \gamma_k^{high} MP_{t-k} + (1 - \mathbb{1}_i) \sum_{k=1}^{q} \gamma_k^{low} MP_{t-k} + \psi_i + \mu_{i,t}, \tag{4}$$

where $\Delta Y_{i,t}$ is the growth rate of total industry output in a country i, and $\mathbb{1}_i$ is a dummy variable indicating whether a country i has a high share of the service sector or not. Specifically, a country is regarded to have a high share of the service sector if the historical average of the service sector share from the first quarter of 1995 to the fourth quarter of 2019 exceeds the sample median of 71.3 percent. I use the same data set as in the estimation above. In particular, MP_t is the identified shock using the recursive restriction. However, the number of countries under the analysis increases from 10 to 18.[6]

Table 12 provides the estimation results of Equation (4), i.e., the output response of the total industry in countries with a high or low share of the service sector to a 1 percentage point contractionary monetary policy shock. As expected, the output effects of monetary policy are more significant in the countries with a lower share of the service sector than in the opposite case.

4. Theoretical Model

This paper builds a TANK model in which two types of households, young (Y) and old (O) households, and two sectors, manufacturing (M) and service (S) sector, exist, using the frameworks of Barsky, House, and Kimball (2007) and Lee (2022). This model helps us to better understand the mechanisms behind the results in the empirical analysis. Also, with this model, I quantitatively estimate the decline rate of the effectiveness of monetary policy due to the aging of the population and structural changes to the service economy, and do some alternative parameterization experiments to study how the results would change in the different settings of the economy. The full set of the model equilibrium conditions is in the appendix.

4.1 Households

The TANK model consists of two types of households: young households, or workers, and old households, or retirees. The number

[6]Countries with a high proportion of service industries are Luxembourg, Malta, Cyprus, Greece, France, Belgium, Netherlands, Portugal, and Italy. Countries with a low proportion of service industries consist of Estonia, Latvia, Spain, Finland, Austria, Germany, Lithuania, Ireland, and Slovenia.

Table 12. Heterogeneous Effects of Monetary Policy by Country Group

		Total
Countries with Higher Service Sector Share	MP_{t-1}	–0.0678***
		(0.0251)
	$\boldsymbol{MP_{t-2}}$	**–0.1265*****
		(0.0318)
	MP_{t-3}	–0.1101***
		(0.0353)
	MP_{t-4}	0.0675
		(0.0460)
Countries with Lower Service Sector Share	MP_{t-1}	–0.1044**
		(0.0527)
	$\boldsymbol{MP_{t-2}}$	**–0.2839*****
		(0.0597)
	MP_{t-3}	–0.2036***
		(0.0605)
	MP_{t-4}	–0.0269
		(0.0663)
ΔY_{t-1}		0.0490
		(0.0833)
ΔY_{t-2}		0.2074***
		(0.0651)
Constant		Yes
Obs.		1,623
Wald χ^2 (6)		357.87

Note: Standard errors in parentheses and ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

of households is normalized to one, and in particular, the young accounts for ϕ. So, the remaining $1 - \phi$ are the old.

4.1.1 Young Households (Workers)

Young households, or workers, maximize the following expected lifetime utility:

$$E_t \sum_{t=s}^{\infty} \beta^{t-s} \left(\frac{{C_t^Y}^{1-\sigma}}{1-\sigma} - \frac{{N_t^Y}^{1+\mu}}{1+\mu} \right), \tag{5}$$

and young households' consumption C_t^Y is defined as

$$C_t^Y \equiv \left[\omega^Y C_{S,t}^{Y\,\frac{\eta-1}{\eta}} + (1-\omega^Y) D_t^{Y\,\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}, \tag{6}$$

where $C_{q,t}^Y \equiv \left[\int_{L_q} (\frac{1}{J_q})^{\frac{1}{\theta}} C_{q,t}^Y(i)^{\frac{\theta-1}{\theta}}\, di\right]^{\frac{\theta}{\theta-1}}$ for $q \in \{M, S\}$ is consumption of the sectoral good q. Here, $i \in L_M = [0, J_M)$, and $i \in L_S = [J_S, 1]$, where the parameters J_M and J_S measure the economic size of each sector. In the model, young and old households are assumed to have heterogeneous consumption baskets. Thus, the consumption of young households is defined with their own consumption weights on service and durable goods, ω^Y and $1-\omega^Y$, which have different values from old households' consumption weights ω^O and $1-\omega^O$. D_t^Y is the consumption of durable goods, and its law of motion is

$$D_t^Y = (1-\delta) D_{t-1}^Y + C_{M,t}^Y. \tag{7}$$

Also, young households have the following budget constraint:

$$\begin{aligned} &P_{S,t} C_{S,t}^Y + P_{M,t} C_{M,t}^Y + P_{M,t} A_{t+1}^Y \\ &\quad = P_{M,t} A_t^Y (1+i_t) + P_{M,t} W_t N_t^Y + P_{M,t} \frac{\Pi_t}{\phi}, \end{aligned} \tag{8}$$

where $P_{q,t} = \left[\int_{L_q} (\frac{1}{J_q})^{\frac{1}{\theta}} P_{q,t}(i)^{1-\theta}\, di\right]^{\frac{1}{1-\theta}}$ for $q \in \{M, S\}$ is the price in each sector q; in particular, $P_{M,t}$ is the numeraire, and A_t^Y is the assets that young households hold. In contrast to old households, young households supply labor $N_t^Y = N_{M,t}^Y + N_{S,t}^Y$, and they earn a wage W_t.[7] Since young households own firms, each of them receives $\frac{\Pi_t}{\phi}$ every period, where Π_t is the aggregate profit of firms.

4.1.2 Old Households (Retirees)

Old households, or retirees, maximize the following expected lifetime utility:

$$E_t \sum_{t=s}^{\infty} \beta^{t-s} \Big(\frac{C_t^{O\,1-\sigma}}{1-\sigma} \Big). \tag{9}$$

[7] This paper assumes perfect mobility and labor supplies are perfect substitutes.

Similar to young households, old households also have their own consumption baskets,

$$C_t^O \equiv \left[\omega^O C_{S,t}^{O\,\frac{\eta-1}{\eta}} + (1-\omega^O) D_t^{O\,\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \tag{10}$$

where $C_{q,t}^O \equiv \left[\int_{L_q} (\frac{1}{J_q})^{\frac{1}{\theta}} C_{q,t}^O(i)^{\frac{\theta-1}{\theta}} \, di \right]^{\frac{\theta}{\theta-1}}$ for $q \in \{M, S\}$ is old households' consumption of the sectoral good q. As mentioned above, ω^O and $1-\omega^O$ are the consumption weights of old households on service and durable goods, and they have different values from the young households' consumption weights ω^Y and $1-\omega^Y$. And D_t^O is consumption of durable goods and follows the law of motion below:

$$D_t^O = (1-\delta) D_{t-1}^O + C_{M,t}^O. \tag{11}$$

Also, old households have the following budget constraint:

$$P_{S,t} C_{S,t}^O + P_{M,t} C_{M,t}^O + P_{M,t} A_{t+1}^O = P_{M,t} A_t^O (1+i_t), \tag{12}$$

where A_t^O are the assets that old households hold. Since old households have already retired, they do not earn income from labor.

4.2 Firms

There are two types of firms, manufacturing and service firms, in the model, and only young households are endowed with the ability to produce differentiated goods when they are born. Firms take input prices, wages, and rental rates of capital, as given, and choose capital and labor to maximize profits.[8]

Production. Firm $i \in [0,1]$ in the sector $q \in \{M, S\}$ produces a differentiated good using labor (N) and capital (K).[9] Their production functions are

$$Y_{M,t}(i) = N_{M,t}(i)^{1-\alpha} K_{M,t-1}(i)^{\alpha} \tag{13}$$

[8]In particular, equilibrium wages, and rental rates of capital are determined by labor and capital supply and demand conditions. See the appendix.

[9]Although the model is based on Barsky, House, and Kimball (2007), capital is not fixed and is determined by production in the manufacturing sector. In this paper, the main difference between the manufacturing and service sectors is capital intensity, which leads to different investment behavior in response to monetary policy. To have this effect, capital should not be fixed.

$$Y_{S,t}(i) = N_{S,t}(i). \tag{14}$$

Since the service sector uses only labor to produce services as in Equation (14), α implies the difference in capital intensity between the manufacturing and service firms. This difference in capital intensity allows population aging to cause changes in the impacts of monetary policy by affecting the effectiveness of the cost of capital channel.

Sectoral output is defined with a constant elasticity of substitution (CES) aggregate of differentiated goods in the sector q, and sectoral labor employment is the summation of all firms' labor employment in each sector q:

$$\begin{aligned} Y_{q,t} &\equiv \left[\int_{L_q} \left(\frac{1}{J_q}\right)^{\frac{1}{\theta}} Y_{q,t}(i)^{\frac{\theta-1}{\theta}} \, di \, \right]^{\frac{\theta}{\theta-1}} \text{ and} \\ N_{q,t} &= \int_{L_q} N_{q,t}(i) \, di \quad \text{for} \quad q \in \{M, S\}. \end{aligned} \tag{15}$$

Here, $i \in L_M = [0, J_M)$ and $i \in L_S = [J_S, 1]$, where the parameters J_M and J_S measure the economic size of each sector.

Price Setting. Based on Calvo (1983), this paper assumes that firms in each sector q can set the prices of their products with the probability of $1-h_q$ every period while they keep their prices with the probability of h_q. Consequently, the aggregate price in each sector q is determined by the following equation:

$$P_{q,t} = \left[(1 - h_q) {P^*_{q,t}}^{1-\theta} + h_q {P_{q,t-1}}^{1-\theta} \right]^{\frac{1}{1-\theta}} \quad \text{for} \quad q \in \{M, S\}, \tag{16}$$

where $P^*_{q,t}$ is the price set in the sector q in the period t which maximizes firms' expected profits.

For the price setting of firms in the manufacturing and service sector, they adjust their prices $P^*_{q,t}$ to maximize the expected sum of discounted profit,

$$\begin{aligned} &\max_{P^*_{q,t}(i)} E_t \sum_{k=0}^{\infty} h_q^k \Lambda_{t,t+k} [P^*_{q,t}(i) Y_{q,t+k}(i) \\ &\quad - P_{q,t+k} mc_{q,t+k}(i) Y_{q,t+k}(i)] \quad \text{for} \quad q \in \{M, S\}, \end{aligned} \tag{17}$$

where $\Lambda_{t,t+1} = \beta \frac{C_{t+1}^{Y\,\frac{1}{\eta}-\sigma}}{C_t^{Y\,\frac{1}{\eta}-\sigma}} \frac{C_{S,t+1}^{Y\,-\frac{1}{\eta}}}{C_{S,t}^{Y\,-\frac{1}{\eta}}} \frac{\frac{P_{M,t+1}}{P_{S,t+1}}}{\frac{P_{M,t}}{P_{S,t}}}$ is the stochastic discount factor, which comes from the assumption that young households own firms.

Then, the first-order condition is

$$E_t \sum_{k=0}^{\infty} h_q^k \Lambda_{t,t+k} \left[P_{q,t}^*(i) - \frac{\theta}{\theta-1} P_{q,t+k} mc_{q,t+k}(i) \right] \times \frac{1}{J_q} \left(\frac{P_{q,t}^*(i)}{P_{q,t}} \right)^{-\theta} Y_{q,t+k} = 0 \quad \text{for} \quad q \in \{M, S\}. \tag{18}$$

All manufacturing and service firms adjusting their prices in the period t face the same optimization problem of each sector. Thus, this paper drops an individual index i. So, $P_{q,t}^*(i) = P_{q,t}^*$ and $mc_{q,t}(i) = mc_{q,t}$ for $q \in \{M, S\}$.

Profit. Π_t is the aggregate profit which is determined by the following equation:

$$\Pi_t = \int_{L_M} \left[\frac{P_{M,t}(i)}{P_{M,t}} - mc_{M,t} \right] Y_{M,t}(i)\, di + \int_{L_S} \left[\frac{P_{S,t}(i)}{P_{M,t}} - mc_{S,t} \right] Y_{S,t}(i)\, di. \tag{19}$$

To simplify Equation (19) further, this paper introduces price dispersion $\Delta_{q,t}$ in each sector q. Then, Equation (19) can be rearranged as

$$\Pi_t = \left(1 - \frac{mc_{M,t}\Delta_{M,t}}{J_M} \right) Y_{M,t} + \left(\frac{P_{S,t}}{P_{M,t}} - \frac{mc_{S,t}\Delta_{S,t}}{J_S} \right) Y_{S,t}, \tag{20}$$

where

$$\Delta_{q,t} = J_q(1-h_q) \left(\frac{P_{q,t}^*}{P_{q,t}} \right)^{-\theta} + h_q \left(\frac{P_{q,t-1}}{P_{q,t}} \right)^{-\theta} \Delta_{q,t-1} \quad \text{for} \quad q \in \{M, S\}.$$

4.3 Monetary Policy

The central bank sets the nominal interest rate. Specifically, monetary policy is characterized by the Tayler rule

$$\hat{i}_t = \phi_\pi (J_M \hat{\pi}_{M,t} + J_S \hat{\pi}_{S,t}) + \phi_Y (J_M \hat{Y}_{M,t} + J_S \hat{Y}_{S,t}) + \nu_t, \tag{21}$$

where $\pi_{q,t}$ is inflation in each sector $q \in \{M, S\}$ and $\hat{X}$ is log-deviations from the steady state of X variables. Also, ν_t is the monetary policy shock and follows an AR(1) process in the logarithm.

4.4 Market Clearing

Market clearing conditions are as follows.

Goods Market. Supply of M goods equals demand for M goods by households and M firms

$$Y_{M,t} = C_{M,t} + I_{M,t}, \tag{22}$$

where demand for M goods by households equals the sum of young and old households' demand for M goods

$$C_{M,t} = \phi C^{Y}_{M,t} + (1 - \phi) C^{O}_{M,t} \tag{23}$$

and investment is determined by the law of motion of capital

$$I_{M,t} = J_M[K_{M,t+1} - (1 - \delta)K_{M,t}]. \tag{24}$$

Supply of S goods equals demand for S goods only by households, which means only manufacturing goods can be used for capital investment,

$$Y_{S,t} = C_{S,t}, \tag{25}$$

where demand for S goods by households equals the sum of young and old households' demand for S goods

$$C_{S,t} = \phi C^{Y}_{S,t} + (1 - \phi) C^{O}_{S,t}. \tag{26}$$

Asset Market. Asset market equilibrium requires the following clearing conditions:

$$A_t = J_M K_{M,t}, \tag{27}$$

where total assets equal the sum of the assets that young and old households hold,

$$A_t = \phi A^{Y}_t + (1 - \phi) A^{O}_t. \tag{28}$$

Labor Market. Total labor that only young households provide equals labor used in the M and S sectors:

$$\phi N_t^Y = J_M N_{M,t} + J_S N_{S,t}. \tag{29}$$

National Account. Total production equals the sum of production in the M and S sectors:

$$Y_t = Y_{M,t} + Y_{S,t}. \tag{30}$$

5. Findings from Theoretical Model

This section discusses model parameter values and quantitatively estimates how much the effectiveness of monetary policy declines due to the aging of the population, and conducts some alternative parameterization experiments to explore how the results would change in the different settings of the economy.

5.1 Model Parameter Calibration

Table 13 provides the model parameter values. The time discount factor, β, is 0.995, and the depreciation rate, δ, is 0.05 based on Fraumeni (1997). The demographic parameter, ϕ, is chosen to match relevant data in Figure 1. However, in alternative parameterization experiments, I replace it to examine the population aging effects. The elasticity of substitution across goods in each sector, θ, is 11 but the elasticity of substitution between manufacturing goods and services, η, is assumed to be 1 following Barsky, House, and Kimball (2007).[10] The consumption weights on service goods of young and old households, ω^Y and ω^O, are calibrated to 0.47 and 0.62 based on relevant data and Cravino, Levchenko, and Rojas (2022), which finds that the service consumption share of the people aged 65 or over is 10–15 percentage points higher than that of the people under 65. Most importantly, the difference in the capital share between the manufacturing and service sectors, α, is 0.15 following Díez-Catalán (2018), which finds that the labor shares for service and

[10] Acemoglu (2002) states that two factors in the CES function are gross substitutes if the elasticity of substitution is greater than 1 and gross complements if the elasticity of substitution is less than 1.

Table 13. Model Parameter Calibration

Parameter	Value	Note for Calibration
A. Household		
σ	1	Standard Value (Log Utility)
β	0.995	Matches to Annual Discount Rate of 2 Percent
δ	0.05	Fraumeni (1997)
ϕ	0.78	Matches to Share of Under 65 Years of 78 Percent
θ	11	Standard Value
η	1	Barsky, House, and Kimball (2007)
ω^o	0.62	Matches to Service Consumption Share of 50 Percent and Cravino, Levchenko, and Rojas (2022)
ω^Y	0.47	
B. Firm		
α	0.15	Matches to the Difference in Capital Share between Service and Manufacturing Sectors of 15 pp, and Díez-Catalán (2018)
h_M	0.65	Bils and Klenow (2004) and Álvarez et al. (2005)
h_S	0.82	
J_M	0.275	Matches to Service Sector Share of 72.5 Percent
J_S	0.725	
C. Monetary Policy		
ϕ_π	1.5	Papadamou, Sidiropoulos, and Vidra (2018)
ϕ_Y	0.4	
ρ	0	Standard Value
σ^υ	0.01	Standard Value

nonservice industries in Europe in 2015 are 0.67 and 0.52 and those in the U.S. are 0.72 and 0.43. So, in an alternative parameterization experiment, I set $\alpha = 0.3$ to match the data in the U.S. For Calvo parameters, h_M and h_S, this paper captures the empirical evidence that manufacturing goods prices are adjusted more frequently than services prices (e.g., Bils and Klenow 2004). Calvo parameters also match the fact that the average duration of goods prices in the euro area is 13 months, which is the empirical findings of Alvarez et al.

(2005). The market shares of the manufacturing and service industries, J_M and J_S, are set to 0.275 and 0.725 based on the industrial structures in the euro area in 2023, and I adjust them according to the changes in the proportion of young households, ϕ. Specifically, $J'_S = J_S + \epsilon(\phi' - \phi)$, where ϵ captures how much the service industries share changes due to the demographic changes and is set to be 1.0 based on the findings in Section 2.3. Monetary policy rule parameters, ϕ_π and ϕ_Y, are chosen based on the literature about the Taylor rule in the euro area (Papadamou, Sidiropoulos, and Vidra 2018). The persistence of the monetary policy shock, ρ, is zero and the standard deviation of the monetary policy shocks, σ^ν, is 0.01.

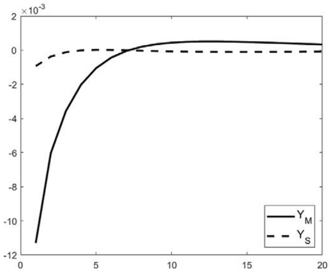
5.2 Population Aging Effects on Impacts of Monetary Policy: Using Theoretical Model

I examine the effects of the monetary policy shock on the dynamics of sectoral output in the model. In particular, I theoretically compute to what extent the aging of the population reduces the output effects of monetary policy by accelerating the transition to the service economy.

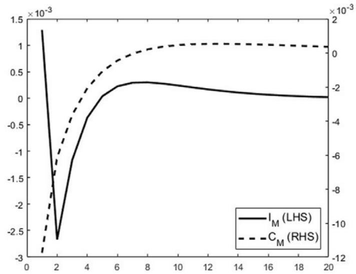
Results. Figure 4 indicates the impulse responses of sectoral output, capital investment and manufacturing goods consumption, and sectoral inflation to a 1 percentage point positive monetary policy shock. The major lesson is that, as shown in panel A, output in the manufacturing industries responds to the contractionary monetary policy shock more sensitively than that in the service industries, which is also the key takeaway of the empirical analysis in Section 3.2. This difference in monetary policy sensitivity across industries is attributed to the firm- and consumer-side cost of capital channel. As shown in panel B, capital investment and consumption of manufacturing goods are strongly responsive to monetary policy shocks. Lastly, as shown in panel C, the price volatility in response to monetary policy shocks is also higher in the manufacturing sector than in the service sector.

As in the empirical analysis conducted in Section 3.3, I estimate to what extent monetary policy becomes less effective as the elderly population grows. In the dynamic stochastic general equilibrium (DSGE) model, a 1 percentage point increase in the old population share, $1 - \phi$, is assumed to increase the service sector

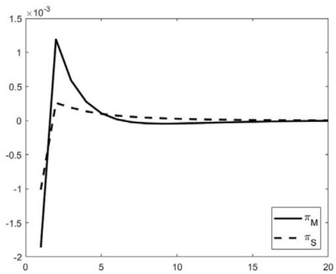
Figure 4. Impulse Responses to 1 Percentage Point Contractionary Monetary Policy Shock



A. Output in M and S sector



B. Investment and Consumption in M sector



C. Inflation in M and S sector

share, J_S, by 1 percentage point but decrease the manufacturing sector share, J_M, by 1 percentage point, which is based on the findings of Section 2.3. Here, the old population ratio is calibrated to match the share of the population aged 65 or over as the empirical analysis. Under these assumptions, the model shows that the effects of monetary policy decrease by 2.27 percent when the old population share increases by 1 percentage point. Table 14 provides this result.

Finally, both empirical and theoretical results reveal that the output effects of monetary policy can decrease by 1.48 to 2.27 percent when the share of the population 65 or over rises by 1 percentage point. Then, taking into account Eurostat's population projections and the findings of this paper together, the output effects of monetary policy in the euro area are expected to decrease, as shown in Figure 5. For example, by 2040, the decline rate of monetary policy effectiveness is expected to be -9.0 to -13.8 percent.

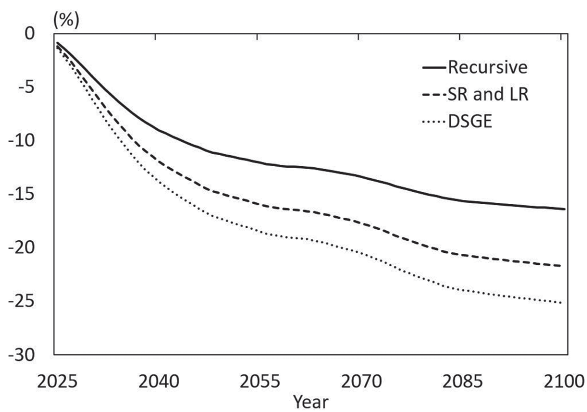
It should be pointed out that the theoretical results above are broadly consistent with the empirical results but differ in the extent

Table 14. Decline Rate of Effects of Monetary Policy Due to 1 pp Increase in Old Population Share (theoretical analysis)

	Baseline	**APE 1 (Capital Share)**	**APE 2 (Calvo Parameter)**
Parameter Values	$\alpha = 0.15$ $h_M = 0.65$ $h_S = 0.82$	$\alpha = 0.30$ $h_M = 0.65$ $h_S = 0.82$	$\alpha = 0.15$ $h_M = 0.77$ $h_S = 0.77$
Decline Rate of Monetary Policy Effects	2.27%	2.56%	2.36%

Note: The decline in the effectiveness of monetary policy is calculated based on the output response in the quarter in which the monetary policy shock occurs.

Figure 5. Decline Rate of Monetary Policy Effects from 2023 to Each Year Due to Population Aging in Euro Area



to which monetary policy becomes less effective as the population ages due to a combination of multiple factors. First, there may be measurement errors in the identification of monetary policy shocks. Even the results of the empirical analysis are quite different depending on the monetary policy identification method. Second, the results of the empirical analysis include some transmission channels of monetary policy that are excluded in the DSGE modeling. For example, consumption of services is nonessential. It therefore may be more responsive to interest rate changes than consumption of goods. Service firms are also generally small and medium-sized enterprises (SMEs), which may be more sensitive to interest rate changes due to their higher dependence on intermediated credit. However, since it is difficult to precisely decompose the impact of these measurement errors and miscellaneous monetary policy channels, this paper presents a range of estimates of the extent to which monetary policy effectiveness declines with population aging.

Alternative Parameterization Experiments. I also conduct two alternative parameterization experiments (APE), the results of which are shown in Table 14. First, this paper sets $\alpha = 0.3$ to reflect the case of the United States, where the difference in capital intensity between the manufacturing and service sector is higher than in the euro area. In this setting, the aging of the population further weakens the cost of capital channel by reducing the share of manufacturing, which is relatively more capital-intensive, i.e., the reduction in the monetary policy effects due to a 1 percentage point increase in the old population share is 12.8 percent $[= (\frac{-2.56}{-2.27} - 1) \times 100]$ larger than when $\alpha = 0.15$.

Second, although the increase in the share of the service sector decreases the effectiveness of monetary policy by reducing capital intensity, it also increases the monetary policy effectiveness by increasing price rigidity in the economy. To remove the latter effects, I assume that there is no difference in the price rigidity between the manufacturing and service sector, i.e., the Calvo parameters are set equal to $0.65 \times J_M + 0.82 \times J_S = 0.77$ for both sectors. In this case, an increase in the share of the service sector due to population aging reduces the output effects of monetary policy by 4.0 percent $[= (\frac{-2.36}{-2.27} - 1) \times 100]$ more than the baseline calibration. This is because the effects of improving the monetary policy effectiveness due to the rise in the share of the service sector with higher price rigidity disappear.

6. Conclusion

In recent years, the population has aged fast around the world, especially in developed countries such as the euro area, and so economists and politicians come to have more interest in the impacts of population aging on our economy and society. Accordingly, many studies have been conducted concerning the effects of population aging. Among them, the main contribution of this paper is to focus on the impacts of the transition to the service economy caused by population aging on the effectiveness of monetary policy, about which there have been a limited number of papers so far. This study reveals that population aging facilitates the shift toward a service-oriented economy, and due to the weak effects of monetary policy in the service sector, the aging population contributes to a reduction in the overall effectiveness of monetary policy.

The implications drawn from these findings suggest that while factors such as rising incomes and technological advancements drive the expansion of the service sector, the accelerated pace of population aging is anticipated to further augment the service sector's share, consequently leading to an additional decline in monetary policy effectiveness. In light of these circumstances, proactive interest rate adjustment policies by monetary authorities are required in an aging society. Also, fiscal policy can emerge as a viable alternative, capable of compensating for the limitations of less effective monetary policy. In particular, unlike monetary policy, fiscal policy can be precisely targeted, such as through industry-specific programs tailored to the service sector.

Appendix. Model Equilibrium Conditions

This appendix gives the full set of the model equilibrium conditions.

A.1 Households

Young Households:

$$C_t^Y \equiv \left[\omega^Y {C_{S,t}^Y}^{\frac{\eta-1}{\eta}} + (1-\omega^Y){D_t^Y}^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \tag{A.1}$$

$$D_t^Y = (1-\delta)D_{t-1}^Y + C_{M,t}^Y \tag{A.2}$$

$$\frac{P_{S,t}}{P_{M,t}}C_{S,t}^Y + C_{M,t}^Y + A_{t+1}^Y = A_t^Y(1+i_t) + W_t N_t^Y + \frac{\Pi_t}{\phi} \tag{A.3}$$

$$C_t^{Y\,\frac{1}{\eta}-\sigma}\big[\omega^Y C_{S,t}^{Y\;-\frac{1}{\eta}}\frac{P_{M,t}}{P_{S,t}}-(1-\omega^Y)D_t^{Y\,-\frac{1}{\eta}}\big]$$
$$=\beta\omega^Y(1-\delta)E_t\big[C_{t+1}^{Y\;\frac{1}{\eta}-\sigma}C_{S,t+1}^{Y\;-\frac{1}{\eta}}\frac{P_{M,t+1}}{P_{S,t+1}}\big] \tag{A.4}$$

$$C_t^{Y\,\frac{1}{\eta}-\sigma}C_{S,t}^{Y\;-\frac{1}{\eta}}\frac{P_{M,t}}{P_{S,t}}=\beta E_t\big[(1+i_{t+1})C_{t+1}^{Y\;\frac{1}{\eta}-\sigma}C_{S,t+1}^{Y\;-\frac{1}{\eta}}\frac{P_{M,t+1}}{P_{S,t+1}}\big] \tag{A.5}$$

$$N_t^{Y\,\mu}=\omega^Y C_t^{Y\,\frac{1}{\eta}-\sigma}C_{S,t}^{Y\;-\frac{1}{\eta}}\frac{P_{M,t}}{P_{S,t}}W_t \tag{A.6}$$

Old Households:

$$C_t^O\equiv\Big[\omega^O C_{S,t}^{O\;\frac{\eta-1}{\eta}}+(1-\omega^O)D_t^{O\;\frac{\eta-1}{\eta}}\Big]^{\frac{\eta}{\eta-1}} \tag{A.7}$$

$$D_t^O=(1-\delta)D_{t-1}^O+C_{M,t}^O \tag{A.8}$$

$$\frac{P_{S,t}}{P_{M,t}}C_{S,t}^O+C_{M,t}^O+A_{t+1}^O=A_t^O(1+i_t) \tag{A.9}$$

$$C_t^{O\,\frac{1}{\eta}-\sigma}\big[\omega^O C_{S,t}^{O\;-\frac{1}{\eta}}\frac{P_{M,t}}{P_{S,t}}-(1-\omega^O)D_t^{O\,-\frac{1}{\eta}}\big]$$
$$=\beta\omega^O(1-\delta)E_t\big[C_{t+1}^{O\;\frac{1}{\eta}-\sigma}C_{S,t+1}^{O\;-\frac{1}{\eta}}\frac{P_{M,t+1}}{P_{S,t+1}}\big] \tag{A.10}$$

$$C_t^{O\,\frac{1}{\eta}-\sigma}C_{S,t}^{O\;-\frac{1}{\eta}}\frac{P_{M,t}}{P_{S,t}}=\beta E_t\big[(1+i_{t+1})C_{t+1}^{O\;\frac{1}{\eta}-\sigma}C_{S,t+1}^{O\;-\frac{1}{\eta}}\frac{P_{M,t+1}}{P_{S,t+1}}\big] \tag{A.11}$$

A.2 Firms

Manufacturing Firms:

$$Y_{M,t}=J_M\frac{N_{M,t}^{1-\alpha}K_{M,t}^{\alpha}}{\Delta_{M,t}} \tag{A.12}$$

$$\Delta_{M,t}=J_M(1-h_M)\Big(\frac{P_{M,t}^*}{P_{M,t}}\Big)^{-\theta}+h_M\Big(\frac{P_{M,t-1}}{P_{M,t}}\Big)^{-\theta}\Delta_{M,t-1} \tag{A.13}$$

$$W_t=(1-\alpha)mc_{M,t}\frac{Y_{M,t}}{N_{M,t}} \tag{A.14}$$

$$r_t^k = \alpha mc_{M,t}\frac{Y_{M,t}}{K_{M,t}} \tag{A.15}$$

$$mc_{M,t} = \Big(\frac{W_t}{1-\alpha}\Big)^{1-\alpha}\Big(\frac{r_t^k}{\alpha}\Big)^{\alpha} \tag{A.16}$$

$$P^*_{M,t} = \frac{\theta}{\theta-1}\frac{X_{1M,t}}{X_{2M,t}} \tag{A.17}$$

$$X_{1M,t} = {C_t^Y}^{\frac{1}{\eta}-\sigma}{C_{S,t}^Y}^{-\frac{1}{\eta}}\frac{P_{M,t}}{P_{S,t}}P_{M,t}^{1+\theta}mc_{M,t}Y_{M,t} + h_M\beta E_t[X_{1M,t+1}] \tag{A.18}$$

$$X_{2M,t} = {C_t^Y}^{\frac{1}{\eta}-\sigma}{C_{S,t}^Y}^{-\frac{1}{\eta}}\frac{P_{M,t}}{P_{S,t}}P_{M,t}^{\theta}Y_{M,t} + h_M\beta E_t[X_{2M,t+1}] \tag{A.19}$$

$$P_{M,t} = [(1-h_M){P^*_{M,t}}^{1-\theta} + h_M{P_{M,t-1}}^{1-\theta}]^{\frac{1}{1-\theta}} \tag{A.20}$$

Service Firms:

$$Y_{S,t} = J_S\frac{N_{S,t}}{\Delta_{S,t}} \tag{A.21}$$

$$\Delta_{S,t} = J_S(1-h_S)\Big(\frac{P^*_{S,t}}{P_{S,t}}\Big)^{-\theta} + h_S\Big(\frac{P_{S,t-1}}{P_{S,t}}\Big)^{-\theta}\Delta_{S,t-1} \tag{A.22}$$

$$mc_{S,t} = W_t \tag{A.23}$$

$$P^*_{S,t} = \frac{\theta}{\theta-1}\frac{X_{1S,t}}{X_{2S,t}} \tag{A.24}$$

$$X_{1S,t} = {C_t^Y}^{\frac{1}{\eta}-\sigma}{C_{S,t}^Y}^{-\frac{1}{\eta}}\frac{P_{M,t}}{P_{S,t}}P_{S,t}^{1+\theta}mc_{S,t}Y_{S,t} + h_S\beta E_t[X_{1S,t+1}] \tag{A.25}$$

$$X_{2S,t} = {C_t^Y}^{\frac{1}{\eta}-\sigma}{C_{S,t}^Y}^{-\frac{1}{\eta}}\frac{P_{M,t}}{P_{S,t}}P_{S,t}^{\theta}Y_{S,t} + h_S\beta E_t[X_{2S,t+1}] \tag{A.26}$$

$$P_{S,t} = [(1-h_S){P^*_{S,t}}^{1-\theta} + h_S{P_{S,t-1}}^{1-\theta}]^{\frac{1}{1-\theta}} \tag{A.27}$$

Total Profit:

$$\Pi_t = \Big(1-\frac{mc_{M,t}\Delta_{M,t}}{J_M}\Big)Y_{M,t} + \Big(\frac{P_{S,t}}{P_{M,t}} - \frac{mc_{S,t}\Delta_{S,t}}{J_S}\Big)Y_{S,t} \tag{A.28}$$

A.3 Monetary Policy

Central Bank:

$$\hat{i}_t = \phi_\pi(J_M\hat{\pi}_{M,t} + J_S\hat{\pi}_{S,t}) + \phi_Y(J_M\hat{Y}_{M,t} + J_S\hat{Y}_{S,t}) + \nu_t \tag{A.29}$$

$$1 + \pi_{M,t} = \frac{P_{M,t}}{P_{M,t-1}} \tag{A.30}$$

$$1 + \pi_{S,t} = \frac{P_{S,t}}{P_{S,t-1}} \tag{A.31}$$

$$\log \nu_t = \rho \log \nu_{t-1} + \sigma^\nu \varepsilon_t \tag{A.32}$$

Fisher Equation:

$$i_t = r_t + E_t[J_M\pi_{M,t+1} + J_S\pi_{S,t+1}] \tag{A.33}$$

$$r_t = r_t^K - \delta \tag{A.34}$$

A.4 Market Clearings

$$Y_t = Y_{M,t} + Y_{S,t} \tag{A.35}$$

$$Y_{M,t} = C_{M,t} + I_{M,t} \tag{A.36}$$

$$C_{M,t} = \phi C^Y_{M,t} + (1-\phi)C^O_{M,t} \tag{A.37}$$

$$I_{M,t} = J_M[K_{M,t+1} - (1-\delta)K_{M,t}] \tag{A.38}$$

$$Y_{S,t} = C_{S,t} \tag{A.39}$$

$$C_{S,t} = \phi C^Y_{S,t} + (1-\phi)C^O_{S,t} \tag{A.40}$$

$$A_t = \phi A^Y_t + (1-\phi)A^O_t \tag{A.41}$$

$$A_t = J_M K_{M,t} \tag{A.42}$$

$$\phi N^Y_t = J_M N_{M,t} + J_S N_{S,t} \tag{A.43}$$

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