Demographic Transition, Aggregate Productivity Growth Slowdown, and Structural Change

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[Preliminary and incomplete.]

Abstract

We derive an OLG model to study the effect of demographic transition and aggregate productivity growth slowdown on structural changes in employment in agriculture in European countries. The demographic transition in the model is associated with a significant fall in mortality probabilities, especially in old age, a fall in population growth, and a fall in labor productivity. Overall, together with the productivity growth slowdown, it implies an increase in the savings rate and a fall in the interest rate. The higher savings and investments directly affect the employment share in agriculture because the agricultural sector has higher capital intensity and capital-labor substitutability than the rest of the economy. We show that the demographic transition alone can account for about 15 percent of the observed fall in agricultural employment in the 1970-2020 period. Together with the TFP growth slowdown, it can account for more than 30 percent of the observed fall in agricultural employment.

Keywords: Agricultural Sector; Demographic Change; Productivity Growth Slowdown; Structural Change; Interest Rate
JEL classification: J11; E44; O41

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1 Introduction

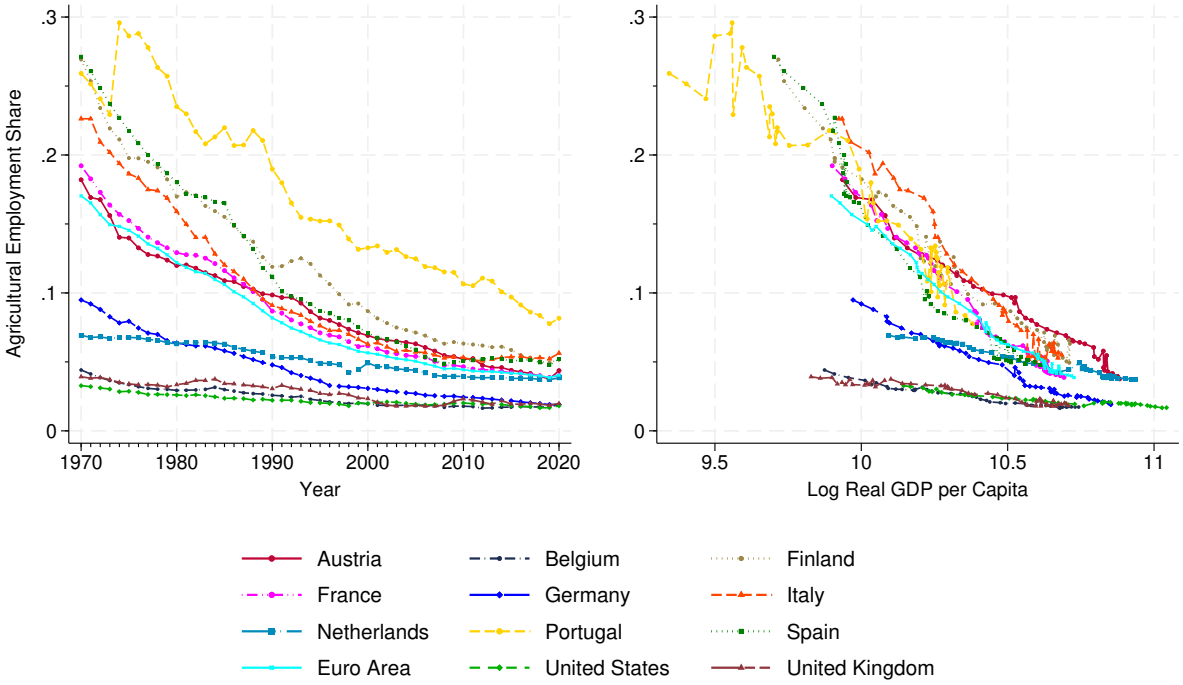
Many advanced economies have started undergoing major demographic changes such as the fall in fertility and mortality probabilities, especially in old age, a few decades ago. These changes are expected to continue in the foreseeable future. There is also evidence that the growth rate of aggregate productivity has slowed down in advanced economies (e.g., Philippon, 2022). Many studies have linked these trends with an increased capital accumulation and the observed fall in the real interest rate (e.g., Bielecki et al., 2020, Carvalho et al., 2016, Krueger and Ludwig, 2007). Over the same period, the advanced economies have experienced substantial sectoral reallocations of employment, that have resulted, for example, in a significant fall in the relative size of employment in the agricultural sector.

The fall in the real interest rate and the increased capital accumulation can be culprits of the observed reallocation of employment as posited by the frameworks developed by Acemoglu and Guerrieri (2008) and Ngai and Pissarides (2007). In this paper, we derive an OLG model to quantify the effect of demographic transition and aggregate productivity growth slowdown on the reallocation of employment from agricultural to non-agricultural sectors in the Euro Area countries. We focus on the agricultural sector because this sector has a higher capital intensity and capital-labor substitutability than the rest of the economy (e.g., Valentinyi and Herrendorf, 2008, Herrendorf et al., 2015). In turn, we focus on countries in the Euro Area because they have had a significant share of employment in agriculture in the 1970s and marked changes in old age mortality probabilities and fertility rates.

The model features cohorts of overlapping generations that have age-specific labor productivity and age- and time-varying mortality probability. They have to retire at a certain age and start receiving pensions upon retirement with a pay-as-you-go pension system. The agents accumulate assets through their savings and consume a basket of agricultural and non-agricultural goods. These two are gross complements. In the quantitative exercise, we impose on the model the observed age-specific labor productivity, government expenditures and debt levels, as well as the trends in fertility, age-specific mortality probabilities, and aggregate total factor productivity. We further calibrate the model to match the real interest rate and the aggregate share of employment and labor compensation share in agriculture in 1970 in the sample countries as well as the fall in employment share in agriculture in the 1970-2020 period.

The share of employment in agriculture falls from 17% in 1970 to 4.1% in 2020 in the data and almost as much in the benchmark simulation. According to the results, 15.3% of this fall can be attributed to demographic transition and further 16.3% can be attributed to the slowdown of aggregate productivity growth. The share of employment in agriculture

Figure 1: Share of Employment in Agriculture



Note: This figure illustrates the shares of hours of employment in agriculture out of total hours of employment in industries in Euro Area countries, the UK and the US. The data from the Penn World Tables 10.1 database, the March 2011 update of November 2009 version of the EU KLEMS database, and the 2022 and 2023 versions of the EUKLEMS database.

would be more than 8% and about twice higher in 2020 absent demographic transition and aggregate productivity growth slowdown. The demographic transition in the quantitative exercise implies much lower mortality rates and much more rectangular survival functions (as documented also by Cervellati and Sunde, 2013). It increases savings and capital and reduces the interest rate. The higher levels of capital increase the allocation of capital relative to labor in agriculture more than in the non-agricultural sector because of higher output-capital elasticity and capital-labor substitutability in agriculture. They lead to a fall in employment in agriculture because of this and the gross complementary between agricultural and non-agricultural goods. Savings and capital accumulation also increase because of the fall in aggregate productivity growth. The consumers expect lower growth in the future and compensate for that with higher savings and capital accumulation.

The pension scheme, as given by the benefit ratio and retirement age, matters for the results in this model because it affects consumption and savings decisions. For example, a pension scheme with a benefit ratio of 1 would imply a 7% lower fall in the employment

share in agriculture during the 1970-2020 period (the benefit ratio observed in the EU SILC database is 0.34). In turn, a retirement age 7 years higher than the retirement age used in the benchmark simulation, 64, would imply a 3% lower fall.

We assume that there is an agricultural sector-biased productivity growth able to match the entire fall in agricultural employment share in the 1920-2020 period. According to the simulations, agricultural employment share would be about 12% in 2020 absent this sector-biased productivity growth. Moreover, structural change in employment is non-monotonic and agricultural employment slightly rebounds after 2040 in the simulation with no agricultural sector-biased productivity growth. This is because savings and capital decline as the demographic transition and aggregate productivity growth slowdown end.

Economies experience substantial sectoral reallocations of employment as they grow richer, a phenomenon commonly referred to as structural change. These reallocations manifest, for example, in a gradual decline in the relative size of employment in the agricultural sector accompanied by a corresponding increase in of relative size of employment elsewhere. An extensive literature studies the mechanisms behind the observed patterns of structural change focusing on supply and/or demand. Supply-side theories consider differences across sectors in capital intensities and technological growth rates. These give rise to changes in the composition of employment because of price/substitution effects (Acemoglu and Guerrieri, 2008, Baumol, 1967, Ngai and Pissarides, 2007). In turn, demand-side theories underscore the significance of differences in income elasticities of demand across sectors, specifically the non-homotheticity in preferences (Kongsamut et al., 2001, Foellmi and Zweimüller, 2006). Several recent papers study the importance of these mechanisms in unison in the medium- as well as in the long-term (e.g., Comin et al., 2021, Boppart, 2014, Herrendorf et al., 2014, Święcki, 2017). In turn, Alvarez-Cuadrado et al. (2017) and Alvarez-Cuadrado et al. (2018) incorporate differences in factor substitutability across sectors in frameworks introduced by Acemoglu and Guerrieri (2008) and Ngai and Pissarides (2007) and show that these can be important for explaining structural change patterns in the US.[1] To our knowledge, this paper is one of the first to introduce a rich demographic structure in a two-sector framework featuring the mechanisms studied in detail by Acemoglu and Guerrieri (2008), Ngai and Pissarides (2007), and Alvarez-Cuadrado et al. (2017, 2018) and match the evolution of real interest rate together with the shares of employment and labor compensation in agriculture in European countries.

Within the growing body of literature studying structural change, a study is particularly closely related to this paper. Bar and Leukhina (2010) study the effect of changes in young-

[1] A few papers have also studied the importance of trade and specialization for structural transformation (e.g., Święcki, 2017, Teignier, 2018, Uy et al., 2013).

age mortality rates on employment in agricultural and non-agricultural sectors in the UK starting from the 17th century. They do that in a general equilibrium framework featuring endogenous fertility and show that changes in young-age mortality rates in the late 19th and early 20th centuries have significantly affected employment share in agriculture as well as fertility decisions. Bar and Leukhina (2010) also show that differences in sector-specific TFP growth rates over this period help to explain the remainder of the reallocation of labor.[2] There are a few important differences between this study and this paper. First, this paper focuses on a sample of continental European countries whereas Bar and Leukhina (2010) focus on the UK. The employment reallocation from the agricultural to the non-agricultural sector has happened at a much later stage in the sample countries than in the UK according to Figure 1. This difference translates to significant differences in methodologies and perspectives on changes in mortality rates. For example, young-age mortality rates have been rather stable in the period of the main analysis of this paper but there has been a significant fall in old-age mortality probability and thus old-age mortality rates. This study then focuses on the changes in the savings rate and the resulting dynamics of the interest rate and abstracts from endogenous fertility, treating fertility as an exogenous time-varying parameter. It evaluates the effects of pension scheme parameters on structural change. Moreover, it allows for a rich interaction between sectors and capital accumulation and sectoral labor shares assuming that sectoral outputs are gross complements and that agricultural and non-agricultural sectors differ in output-capital elasticity and capital-labor substitutability.[3]

This paper is also related to the literature that studies the effects of the demographic transition and aggregate productivity growth slowdown on the interest rate and the economy (e.g., Aksoy et al., 2019, Bielecki et al., 2020, Carvalho et al., 2016, Del Negro et al., 2019, Krueger and Ludwig, 2007). To our knowledge, it presents the first framework to study these effects in a multi-sector economy.

The rest of the paper is organized as follows. Section 2 offers the data. Section 3 describes the data and the calibration. Section 4 offers the results. Finally, section 6 concludes.

[2] Yin (2023) use a similar framework, albeit without physical capital, and conclude that sector-specific TFP growth differences primarily drove employment reallocation in China between 1940 and 2020.

[3] From a different angle, Cravino et al. (2022) document that older households spend a larger share of their income on services than younger households. They argue that changes in the age structure of the population account for a sizeable fraction of the growth in the US service sector.

2 The Model

The economy is populated by 81 cohorts of overlapping generations. We use the letter j to index their age and $L_{j,t}$ to denote the size of the cohort at time t. The youngest agent is 20 years old and is assigned an age index $j = 1$. The agents are subject to age- and time-dependent mortality risk $\delta_{j,t}$. They can live up to 100 years ($j \equiv J = 81$).

A representative household from the cohort at age j maximizes its expected lifetime utility that depends on consumption according to

$$U_{j,t} = \sum_{i=0}^{J-j} \left(\beta^i \frac{L_{j+i,t+i}}{L_{j,t}} \right) \frac{c_{j+i,t+i}^{\sigma} - 1}{\sigma - 1}, \tag{1}$$

where $\beta \in (0, 1)$ is the subjective discount factor, and the ratio

$$L_{j+i,t+i}/L_{j,t} = 1 \ - \delta_{L,j,t} \tag{2}$$

is the probability of survival for at least i more years.

The agents work till retirement at age 63 ($j \equiv JR = 44$). They receive gross pension benefits pen_t that are independent of their age during retirement. All workers pay social security contributions. These are levied together with other taxes on labor income at total rate τ_t and fund the pensions and government expenditures. In addition to pensions, the agents can trade assets, consisting of claims on domestic capital and domestic government debt, to smooth their consumption. These assets are perfect substitutes and pay real interest rate r_t. There can be borrowing and lending across different cohorts implying that asset holdings $a_{j,t}$ do not necessarily have to be positive at any age j. Most of the agents die before reaching their maximum age leaving unintentional bequests. The bequests are redistributed equally across all living agents in the form of lump-sum transfers beq_t. The agents also receive lump-sum and age-specific dividends $\pi_{j,t}$ from intermediate goods producers. An agent at age j faces the following budget constraint

$$\begin{aligned} c_{j,t} + a_{j+1,t+1} = (1 - \tau_t) \left[(1 - \mathbf{1}_{j \geq JR}) \times w_t z_j + \mathbf{1}_{j \geq JR} \times pen_t \right] \\ + \pi_{j,t} + beq_t + (1 + r_t)\, a_{j,t}, \end{aligned} \tag{3}$$

where $\mathbf{1}_{j \geq JR} = 1$ if the agent is retired and $\mathbf{1}_{j \geq JR} = 0$ otherwise, w_t is the gross real wage, and z_j is exogenous age-specific labor productivity.

The changes in mortality risk $\delta_{L,j,t}$ and the size of the cohorts of the youngest agents $l_{1,t+1} = L_{1,t+1}/L_{1,t} - 1$ govern the demographic transition processes in our model. Both

these changes are assumed to be exogenous.

The total number of agents L_t and the rate of population growth l_{t+1} are given by

$$L_t = \sum_{j=1}^{J} L_{j,t} \tag{4}$$

and

$$g_{L,t} = \frac{L_{t+1}}{L_t} - 1$$

where the number of agents in a cohort j evolves according to equation (2).

This structure implies that aggregate per-capita consumption, labor supply, asset holdings and bequests are given by

$$c_t = \sum_{j=1}^{J} \frac{L_{j,t}}{L_t} c_{j,t},$$

$$h_t = \sum_{j=1}^{J} \frac{L_{j,t}}{L_t} z_{j,t},$$

$$a_{t+1} = \sum_{j=1}^{J} \frac{L_{j,t}}{L_{t+1}} a_{j+1,t+1},$$

and

$$beq_t = \sum_{j=1}^{J} \frac{L_{j,t-1} - L_{j,t}}{L_t} (1 + r_t) a_{j,t}.$$

The demand for consumption goods is served by final goods producers. The final goods producers are perfectly competitive. They combine agricultural and non-agricultural goods, $y_{A,t}$ and $y_{NA,t}$ respectively, using a CES aggregator to produce y_t. The production function of the final goods is given by

$$y_t = x_{y,t} \left[\alpha \left(y_{A,t} - \bar{y}_A \right)^{\frac{\varepsilon-1}{\varepsilon}} + (1 - \alpha) \, y_{NA,t}^{\frac{\varepsilon-1}{\varepsilon}} \right]^{\frac{\varepsilon}{\varepsilon-1}}, \tag{5}$$

where $x_{y,t} \geq 0$ is exogenous productivity, $\alpha \in (0, 1)$, and $\varepsilon \geq 0$ is the elasticity of substitution between these goods.

The solution to the standard profit maximization problem for the final goods producers yields the following expression for the demand functions for agricultural and non-agricultural

goods

$$p_{A,t} = \frac{y_t}{y_{A,t} - \bar{y}_A} \frac{\alpha \left(y_{A,t} - \bar{y}_A\right)^{\frac{\varepsilon-1}{\varepsilon}}}{\alpha y_{A,t}^{\frac{\varepsilon-1}{\varepsilon}} + (1-\alpha) y_{NA,t}^{\frac{\varepsilon-1}{\varepsilon}}}, \tag{6}$$

$$p_{NA,t} = \frac{y_t}{y_{NA,t}} \frac{(1-\alpha) y_{NA,t}^{\frac{\varepsilon-1}{\varepsilon}}}{\alpha \left(y_{A,t} - \bar{y}_A\right)^{\frac{\varepsilon-1}{\varepsilon}} + (1-\alpha) y_{NA,t}^{\frac{\varepsilon-1}{\varepsilon}}}. \tag{7}$$

The agricultural and non-agricultural goods are CES aggregates of intermediate agricultural and non-agricultural goods,

$$y_{m,t} = \left[\int_0^1 \widetilde{y}_{m,t}^{\frac{\eta-1}{\eta}} (n) \, dn \right]^{\frac{\eta}{\eta-1}}, \tag{8}$$

where $\eta > 1$ is the elasticity of substitution between the intermediate goods in the agricultural and non-agricultural sectors.

The solution to the standard profit maximization problem for agricultural and non-agricultural goods producers yields the following expression for the demand functions for intermediate goods

$$\widetilde{y}_{m,t} (n) = \left(\frac{p_{m,t}}{\widetilde{p}_{m,t} (n)} \right)^{\eta} y_{m,t}, \tag{9}$$

where $p_{A,t}$ and $p_{NA,t}$ are the prices of agricultural and non-agricultural goods, $\widetilde{p}_{m,t} (n)$ is the price of intermediate good n in sector $m = A, NA$.

The production function of an intermediate goods producer n in sector $m = A, NA$ is given by

$$\widetilde{y}_{m,t} (n) = x_{m,t} \left\{ \alpha_m \left[u_{m,k,t} (n) \, x_{m,k,t} k_t \right]^{\frac{\varepsilon_m - 1}{\varepsilon_m}} + (1 - \alpha_m) \left[u_{m,h,t} (n) \, x_{m,h,t} h_t \right]^{\frac{\varepsilon_m - 1}{\varepsilon_m}} \right\}^{\frac{\varepsilon_m}{\varepsilon_m - 1}}, \tag{10}$$

where $x_{m,t} \geq 0$ is exogenous productivity in sector $m = A, NA$, $\alpha_m \in (0, 1)$, $u_{m,k,t} (n)$ and $u_{m,h,t} (n)$ are the shares of total capital k and labor h in firm n and sector m, $x_{m,k,t} > 0$ is exogenous factor-level productivity, and $\varepsilon_m \geq 0$ is the elasticity of substitution between factor inputs.

The producers of the intermediate goods are monopolistically competitive. There is mass one of each type of intermediate goods firm. The intermediate goods producers in each sector m select labor and capital inputs to maximize their profits taking into account the demand schedules given by equation (9). The per-period profit flows of an intermediate

goods producer n in sector m are given by

$$\pi_{m,t}(n) = \widetilde{p}_{m,t}(n)\,\widetilde{y}_{m,t}(n) - (1+\varphi_{m,h})\,w_t u_{m,h,t}(n)\,h_{m,t}(n) - i_{m,t}(n), \tag{11}$$

where $\varphi_{m,h} \geq 0 \ \geq 0$ is a wedge in labor input payments in sector $m = A, NA$, and $i_{m,t}(n)$ are investments in capital by firm n in sector m,

$$\begin{aligned} k_{m,t+1}(n) &= (1-\delta_K)\,k_{m,t}(n) + i_{m,t}(n), \\ k_{m,t}(n) &= u_{m,k,t}(n)\,k_t, \end{aligned} \tag{12}$$

where $\delta_K \in (0,1)$ is the rate of depreciation of physical capital.

The solution of the profit maximization problem for the intermediate goods producers yields the following expression for the demand for labor and the internal rate of return on capital

$$\begin{aligned} w_t =& \frac{1}{1+\varphi_{m,h}}\left(1-\frac{1}{\eta}\right)\tilde{p}_{m,t}(n)\,\widetilde{y}_{m,t}(n) \times \\ & \frac{(1-\alpha_m)\left[u_{m,h,t}x_{m,h,t}(n)\,h_t\right]^{\frac{\varepsilon_m-1}{\varepsilon_m}}}{\alpha_m\left[u_{m,k,t}(n)\,x_{m,k,t}k_t\right]^{\frac{\varepsilon_m-1}{\varepsilon_m}} + (1-\alpha_m)\left[u_{m,h,t}(n)\,x_{m,h,t}h_t\right]^{\frac{\varepsilon_m-1}{\varepsilon_m}}}\frac{1}{u_{m,h,t}(n)\,h_t}, \end{aligned} \tag{13}$$

$$\begin{aligned} r_t =& \left(1-\frac{1}{\eta}\right)\tilde{p}_{m,t}(n)\,\widetilde{y}_{m,t}(n) \times \\ & \frac{\alpha_m\left[u_{m,k,t}(n)\,x_{m,k,t}k_t\right]^{\frac{\varepsilon_m-1}{\varepsilon_m}}}{\alpha_m\left[u_{m,k,t}(n)\,x_{m,k,t}k_t\right]^{\frac{\varepsilon_m-1}{\varepsilon_m}} + (1-\alpha_m)\left[u_{m,h,t}(n)\,x_{m,h,t}h_t\right]^{\frac{\varepsilon_m-1}{\varepsilon_m}}}\frac{1}{u_{m,k,t}(n)\,k_t}. \end{aligned} \tag{14}$$

We assume that the per-period profits of all producers are transferred to the households. The transfers are proportional to their labor income.

Intermediate goods producers in each sector m are identical. They all charge the same price in equilibrium and $\tilde{p}_m(n) = \tilde{p}_m = p_m$ and produce the same amount of output $\widetilde{y}_m(n) = \widetilde{y}_m = y_m$. This leads to the following conditions for the allocations of labor and capital

$$\begin{aligned} u_{A,h,t} + u_{NA,h,t} &= 1, \\ u_{A,k,t} + u_{NA,k,t} &= 1. \end{aligned}$$

2.1 Government Budget

The government consumes $g_{y,t}$ per-capita quantity of final goods and manages the pension system. It finances its expenditures using taxes levied on labor income and by issuing per-

capita public debt $b_{y,t}$. The government's inter-temporal budget constraint is given by

$$\tau_t w_t \sum_{j=1}^{JR-1} \frac{L_{j,t}}{L_t} z_j + w_t \sum_{m=A,NA} \varphi_{m,h} u_{m,h,t} h_{m,t} + (1 + g_{L,t+1})\, b_{y,t+1} \tag{15}$$
$$= g_{y,t} + (1 - \tau_t)\, pen_t \sum_{j=JR}^{J} \frac{L_{j,t}}{L_t} + (1 + r_t)\, b_{y,t}.$$

The government sets pensions proportional to the average wage

$$pen_t = \rho_t w_t \sum_{j=1}^{JR-1} \left(L_{j,t} z_{j,t} / \sum_{j=1}^{JR-1} L_{j,t} \right), \tag{16}$$

where $\rho_t \in [0, 1]$ is the replacement rate.

We assume that $g_{y,t}, b_{y,t}$ and ρ_t are exogenously determined and the tax rate τ_t is such that the government budget constraint (15) is satisfied.

2.2 Market Clearing Conditions

The asset market clearing condition implies that

$$a_t = k_t + b_t,$$

where per-capita capital evolves according to

$$(1 + g_{L,t+1})\, k_{t+1} = i_t + (1 - \delta_K)\, k_t,$$

This together with the household and government budget constraints results in

$$y_t = i_t + c_t + g_t.$$

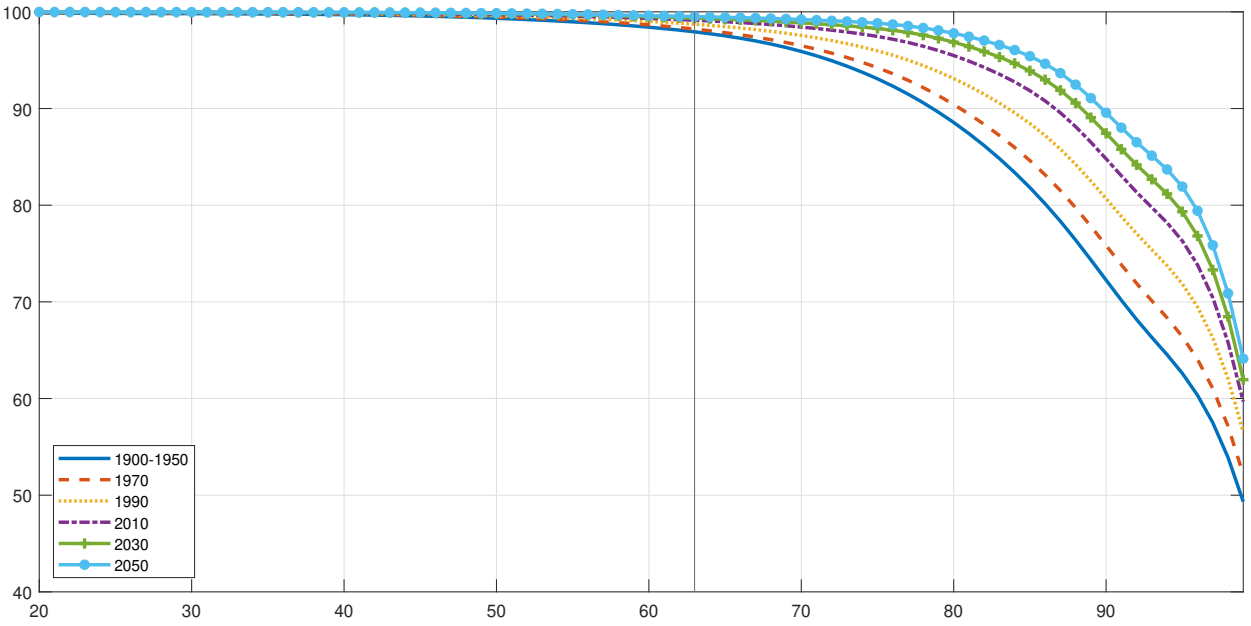
3 Exogenous Variables, Calibration, and Matched Data

We use data from multiple sources for this project. The data for age-specific mortality probabilities as well as the growth rate of the population of 20-year-old individuals (i.e., the fertility rate in the model) are from the 2022 version of the United Nations World Population Prospects covering years 1950–2021 (actual data) and 2022–2100 (projections). The data are for individual countries and we construct the series of age-specific time-varying probabilities

for the EA region using population-weighted averages.[4]

We assume that mortality probabilities were constant during 1900-1950 period. Figure 6 illustrates the computed survival probability by age for 1950, 1970, 1990, 2010, 2030, and 2050. Significant increases in the survival probability happen among older individuals, especially between ages 75 and 95. Figure 3 illustrates the implied discount factor of a 20-year-old individual averaged over its lifetime for every year. The discount factor increases (discount rate declines) as the probabilities of old-age survival increase.

Figure 2: Probability of Survival by Age



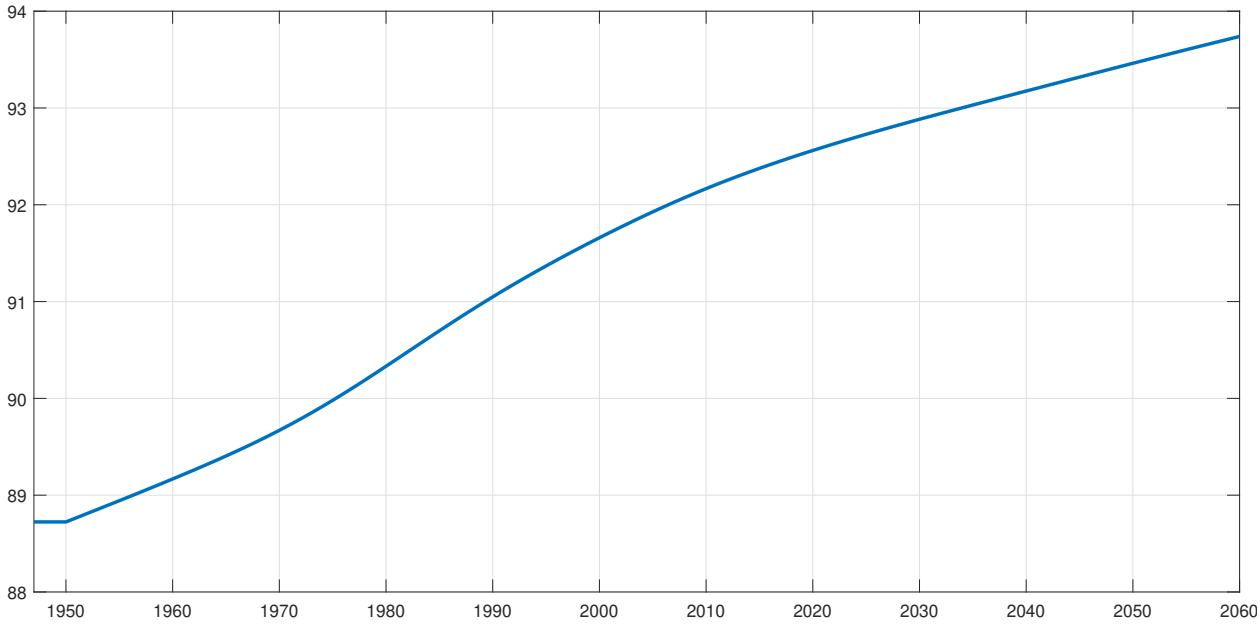
Source: United Nations World Population Prospects 2022.

Figure 5 offers the growth rate of the population of 20-year-old individuals. Together with the changes in mortality probabilities, it governs the main features of the demographic transition in this model. The growth in the number of 20-year-olds increases between 1960-1985 because of the baby boom generation.

We assume that labor productivity is age-specific. The demographic transition then has implications for aggregate labor productivity because it changes age composition in the labor market. We construct a measure of labor productivity using data from the EU-SILC database. The data cover the period 2004-2020. We compute inflation-adjusted individual-level hourly wage and self-employment income, regress it on 1-digit occupation, gender, full-

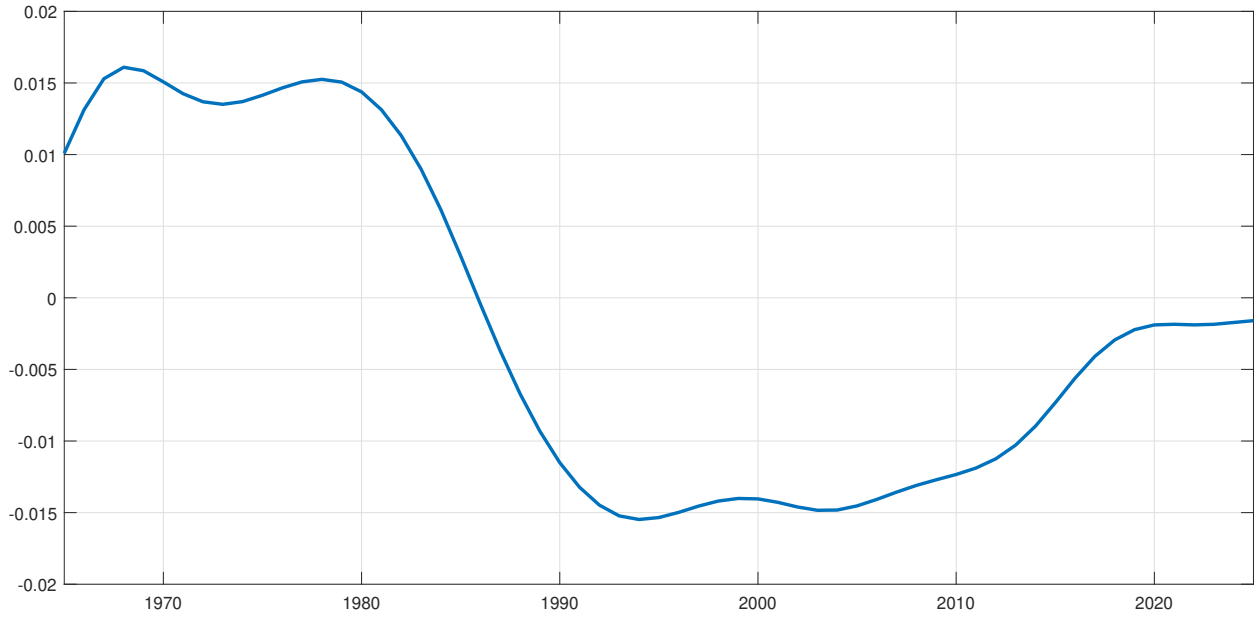
[4]We use the Hodrick-Prescott filter with a smoothing parameter of 100 to smooth the series that we feed into the model.

Figure 3: Average Life-Time Yearly Discount Rate



Note: $\beta = 1.01$.

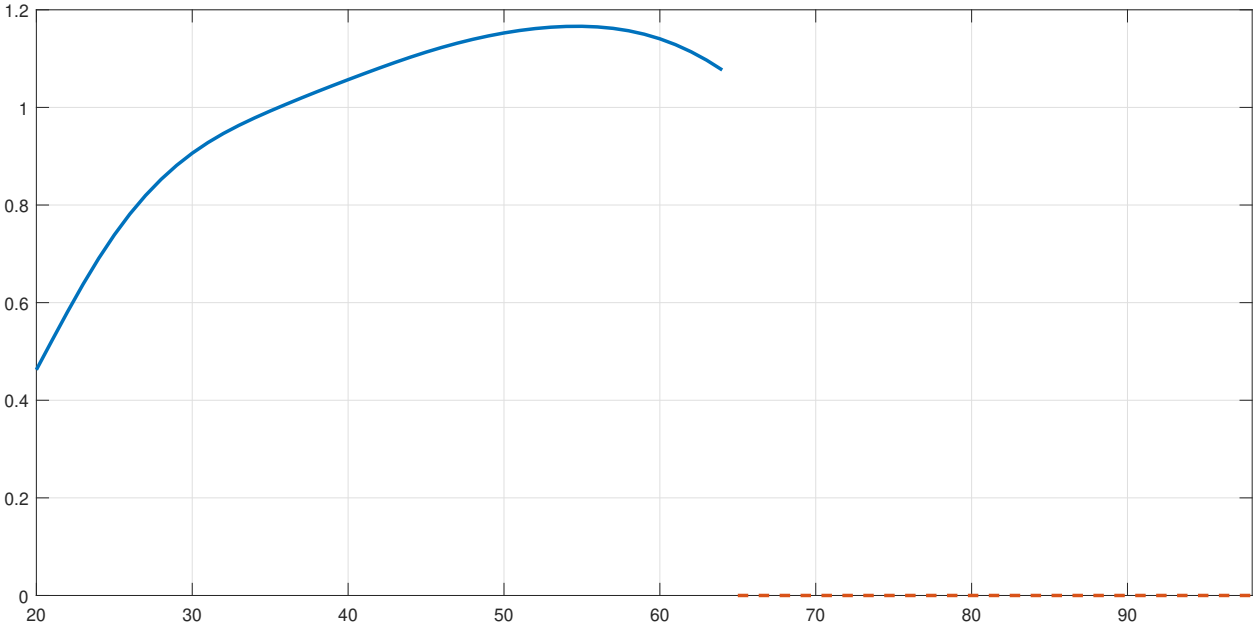
Figure 4: The Growth Rate of the Initial Population (Fertility Rate)



Source: Growth rate of the population of 20-year-old individuals. United Nations World Population Prospects 2022.

time/part-time, and country-year dummies, and take the average of the resulting residual using the sample weights and country-level total employment hours. We use this as the measure of labor productivity.

Figure 5: Labor Productivity

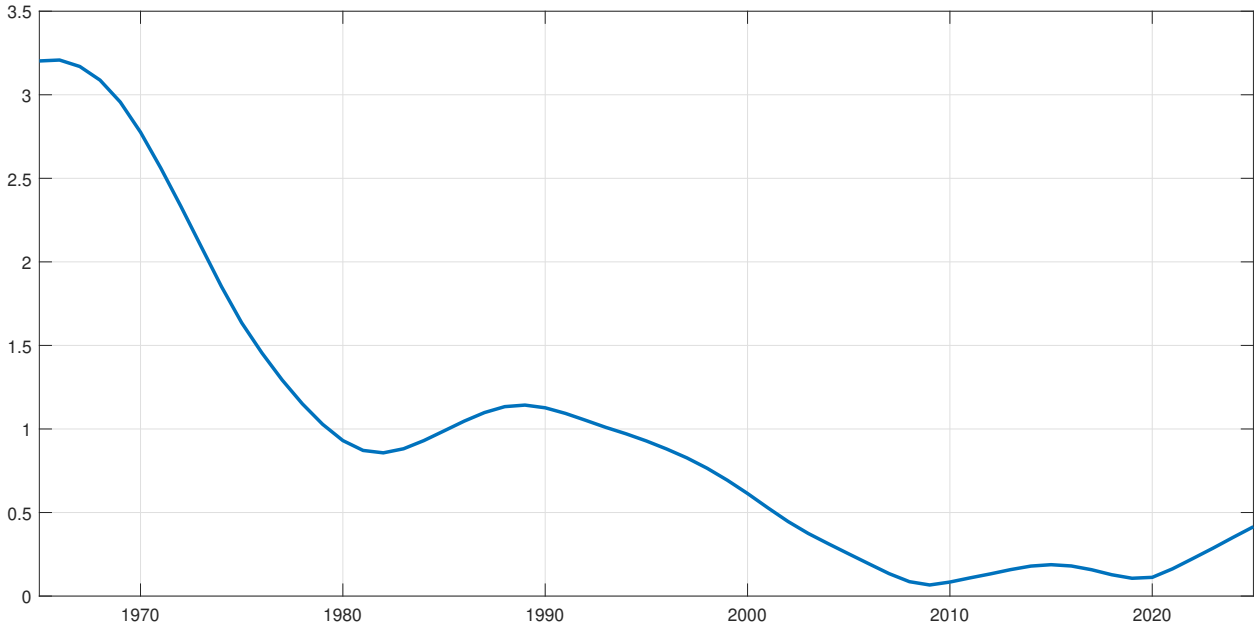


Source: The EU SILC database.

We use data for aggregate factor productivity growth from the European Commission's Annual Macroeconomic Database (AMECO) for the years 1960-2023 and aggregate productivity growth forecasts in the Euro Area from the Aging Working Group (AWG) for 2024-2070. We weight country-level observations with GDP levels to obtain the aggregate productivity growth rate in the sample countries. We use aggregate factor productivity growth data from Bergeaud et al. (2016) for the Euro Area countries in the years before 1960. We take the average of the growth rate of factor productivity in the period before 1960. Figure 5 illustrates these data. There is a visible aggregate factor productivity growth slowdown after the 1960s.

The data for general government gross and net debt are taken from the IMF WEO database, covering the years 1980–2027. We opt to feed the model with time series for net debt because a non-negligible part of the gross debt is held by the public sector (e.g., central banks) and is unavailable for households to trade. The levels of public debt before 1980 and after 2027 are fixed at the 1980 and 2027 levels, respectively. In turn, we fix the government expenditures to GDP ratio to its long-term average observed in the data, 0.2, given that it

Figure 6: The Growth Rate of the Aggregate Factor Productivity



Source: European Commission's Annual Macroeconomic Database (AMECO), the Aging Working Group (AWG), and Bergeaud et al. (2016).

varies very little in the main simulation period.

We compute the benefit ratio ρ as the ratio of the weighted average wages and pensions in the Euro Area countries using data from the EU SILC database and its sample individual weights. According to these data $\rho = 0.34$. We further set $\beta = 1.01$ and $\eta = 4.45$. These values imply an average lifetime discount rate of about 0.93 in the 2000s and a 22.5 percent mark-up. Together with $\rho = 0.34$ they allow us to match the weighted average level of real interest rate during the 1970-2020 period in the Euro Area countries.

We set the elasticity of intertemporal substitution $\sigma = 2$ following the estimates offered by Havranek et al. (2015) and the depreciation rate of capital $\delta_K = 0.05$, which is a usual value used in the literature. We use values $\varepsilon = 0.2$, $\varepsilon_A = 1.58$ and $\varepsilon_{NA} = 0.84$ for the elasticity of substitution between agricultural and non-agricultural outputs and the elasticities of substitution between labor and capital in these sectors following the estimates by Comin et al. (2021) and Herrendorf et al. (2015). We set $\alpha = 0.03$ and the values of α_A and α_{NA} to have an average of 67 percent labor income share. We also set $\varphi_{m,h} = -0.66$ to match the agricultural employment and labor income share in agriculture in the 1970s in the sample countries, 17% and 110% correspondingly. Table 1 summarizes the calibrated values of parameters.

Table 1: Calibration of Parameters

Parameter	Value	Comment
β	1.01	To match the level of r as observed in the EA over 1970–2023
ρ	0.34	Benefit ratio computed using data from the EU-SILC database
η	5	A 20% product markup
σ	2	Havranek et al. (2015)
δ_K	0.05	Depreciation rate of capital
ε	0.2	Comin et al. (2021)
ε_A	1.58	Herrendorf et al. (2015)
ε_{NA}	0.84	
α	0.03	Average aggregate labor income share ≈ 0.68 in 1970-2020
α_A	0.45	Share of agricultural employment ≈ 0.17 in 1970 and ≈ 0.04
α_{NA}	0.2	in 2020
		Labor income share in agriculture ≈ 1.1 in 1970
$\varphi_{A,h}$	-0.655	Agricultural subsidies in European countries, $\approx 55\%$ of the the Generalized Subsidy Equivalents
$x_{A,t}$	$0.688 \times e^{g_{x_A} t}$	Scale for agricultural sector and $g_{x_A} = 0.0189$ additional productivity growth in agriculture b/w 1900-2025
$\varphi_{m,\ell}$	0	No other subsidies than $\varphi_{A,h}$ ($m = A, NA$ and $\ell = k, h$)
$\bar{y}_A$	0	No income effect in the use of agricultural goods
$x_{m,\ell}$	1	No factor input biased tech. change ($m = A, NA$ and $\ell = k, h$)

3.1 Matched Data

We use as the primary source of data on employment share and labor compensation share in agriculture the November 2011 update of the 2009 version of the EU KLEMS database. It covers the period 1970-2007. We further use data from the 2023 version of the EU KLEMS database to extend the period to 2020. Figures 7 and 9 illustrate the share of employment and labor compensation in the agricultural sector. Both decline over time. Interestingly, the share of labor compensation in agriculture is above 1 in the 1970-1990 period. An explanation for this could be large subsidies in the agricultural sector, for example, within the frames of the Common Agricultural Policy.

In turn, we use data from the OECD database on long-term interest rates (interest rates paid on government bonds maturing in ten years) and inflation in each country to compute the real interest rate. We aggregate it to the Euro Area level using the real GDP of the countries as weights. Figure 8 illustrates it. The real interest rate has fallen about 6 percentage points during the sample period. Moreover, it was briefly negative in the period 2015-2021.

Agriculture is heavily subsidized in European countries. We obtain data on the level of agricultural subsidies (Generalized Subsidy Equivalents) in Euro Area countries relative to total value of agricultural production from the World Bank database (Anderson and Valenzuela, 2011). We rescale it to obtain subsidies relative to value added using the ratio of output and value added in agriculture from the EU KLEMS database. These subsidies include various forms of producer support, for example, in terms of subsidies to payments for inputs.

4 Results

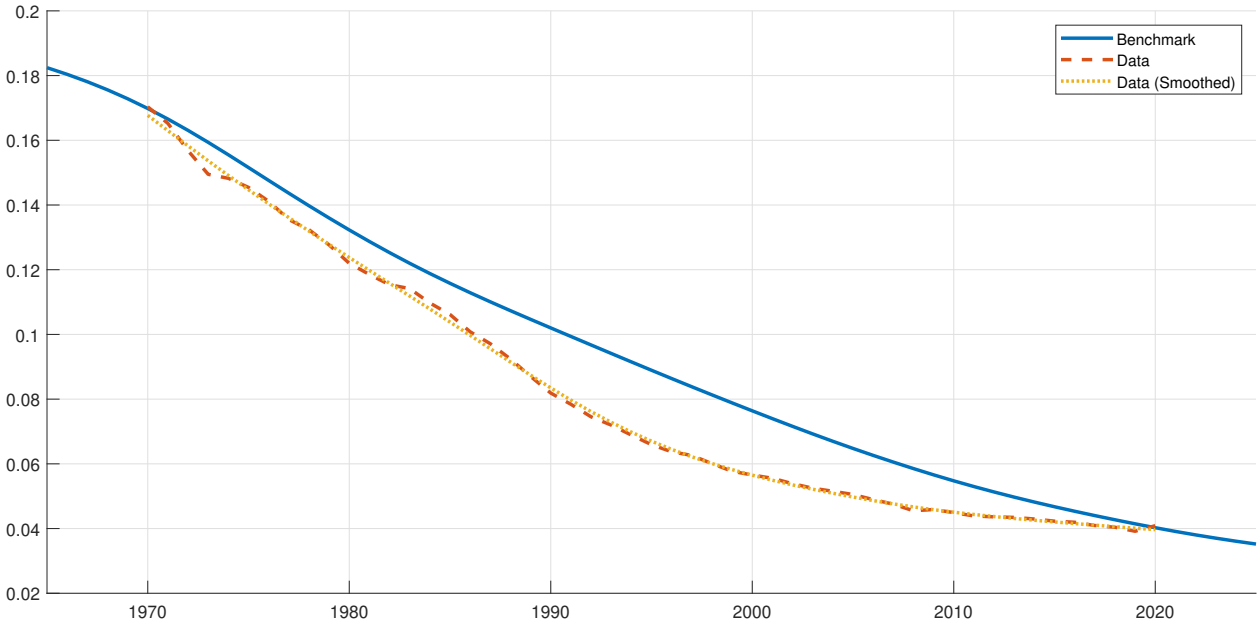
Our benchmark simulation uses parameter values from Table 1. We present the results in the first column of Table 2 and in figures 7, 8, and 9. The benchmark results match very well the evolution of the share of employment in agriculture in the period 1970-2020 in the data. They are also matching well the observed changes in real interest rate and the share of labor income in agriculture in 1970. The share of labor income in agriculture falls to 60% in the data by 2020. Labor income share also falls considerably in this period in the model albeit this is not a targeted moment.

Table 2: Benchmark Simulation Results

	Benchmark	Data	Data (Smoothed)
Employment Share in Agriculture in 1970	0.170	0.170	0.168
Employment Share in Agriculture in 2020	0.041	0.041	0.040
Real Interest Rate in 1970 ($100 \times r$)	5.261	5.314	5.198
Real Interest Rate in 2020 ($100 \times r$)	-0.526	1.169	-0.250
Labor Compensation Share in Agriculture in 1970	1.112	1.120	1.094
Labor Compensation Share in Agriculture in 2020	0.753	0.591	0.600

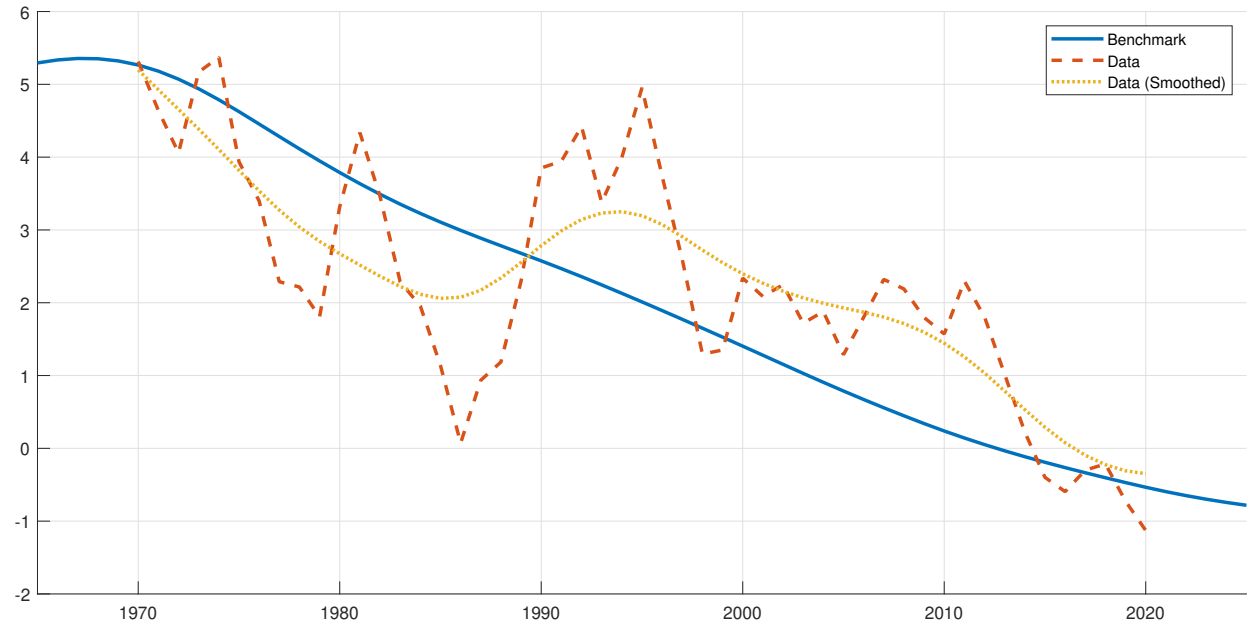
Note: The benchmark results use parameter values from Table 1. In the last column we offer the values observed in the data that we smooth using HP filter with parameter $\lambda = 100$.

Figure 7: Results for the Share of Employment in Agriculture



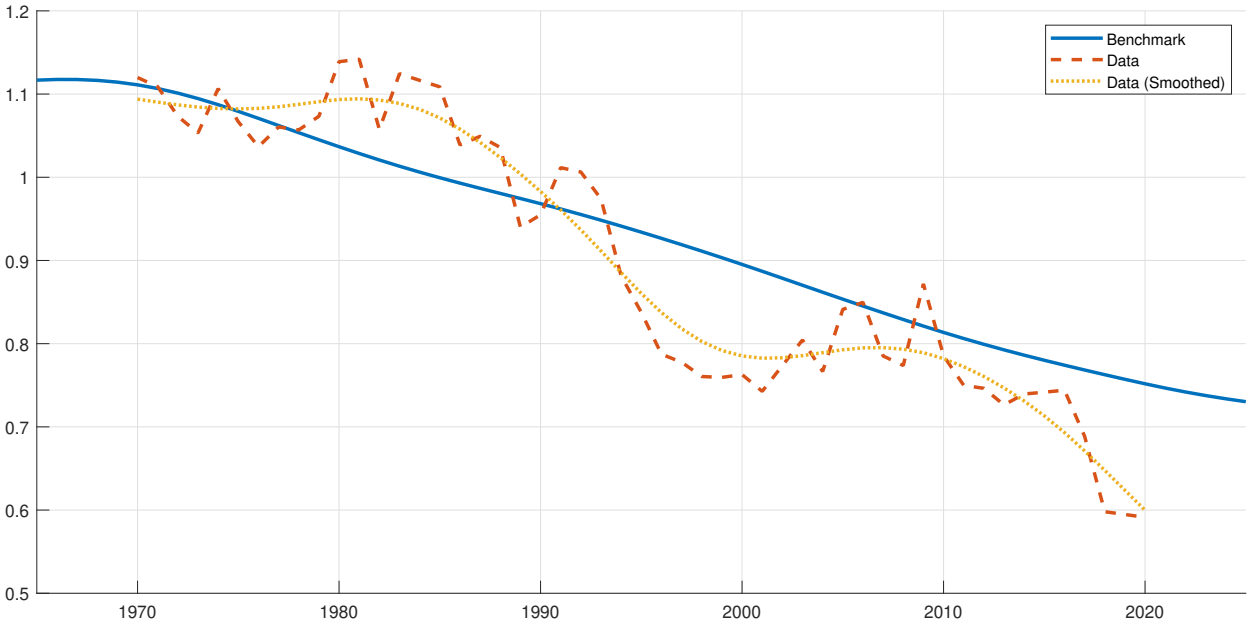
Note: This figure illustrates the share of hours of employment in agriculture out of total hours of employment in industries in Euro Area countries. The data are from the March 2011 update of the November 2009 version of the EU KLEMS database, and the 2022 and 2023 versions of the EU KLEMS database.

Figure 8: Results for Real Interest Rate



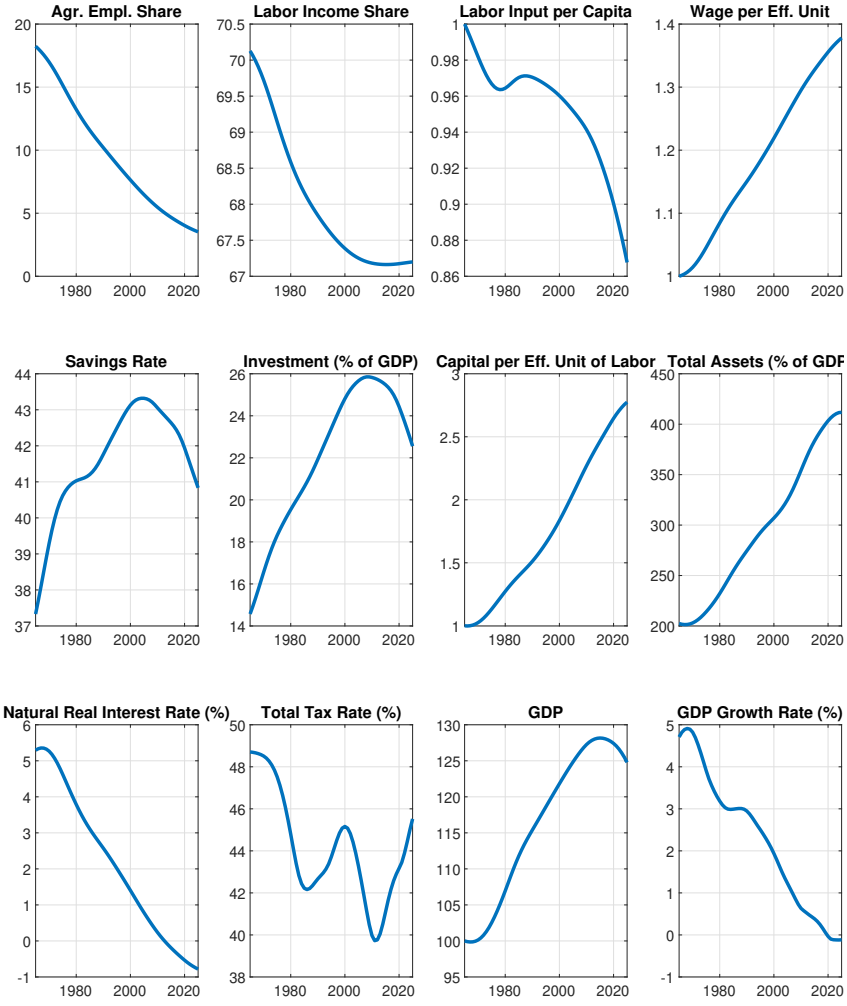
Note: This figure illustrates the real interest rate ($100 \times r$) in Euro Area countries. The data from the OECD database.

Figure 9: Results for Labor Income Share in Agriculture



Note: This figure illustrates the share of labor compensation in agriculture out of value added in Euro Area countries. The data from the March 2011 update of the November 2009 version of the EU KLEMS database, and the 2022 and 2023 versions of the EU KLEMS database.

4.1 Results from Counterfactual Simulation Exercises


Agr. Empl. Share
Labor Income Share
Labor Input per Capita
Wage per Eff. Unit
Savings Rate
Investment (% of GDP)
Capital per Eff. Unit of Labor
Total Assets (% of GDP
Natural Real Interest Rate (%)
Total Tax Rate (%)
GDP
GDP Growth Rate (%)

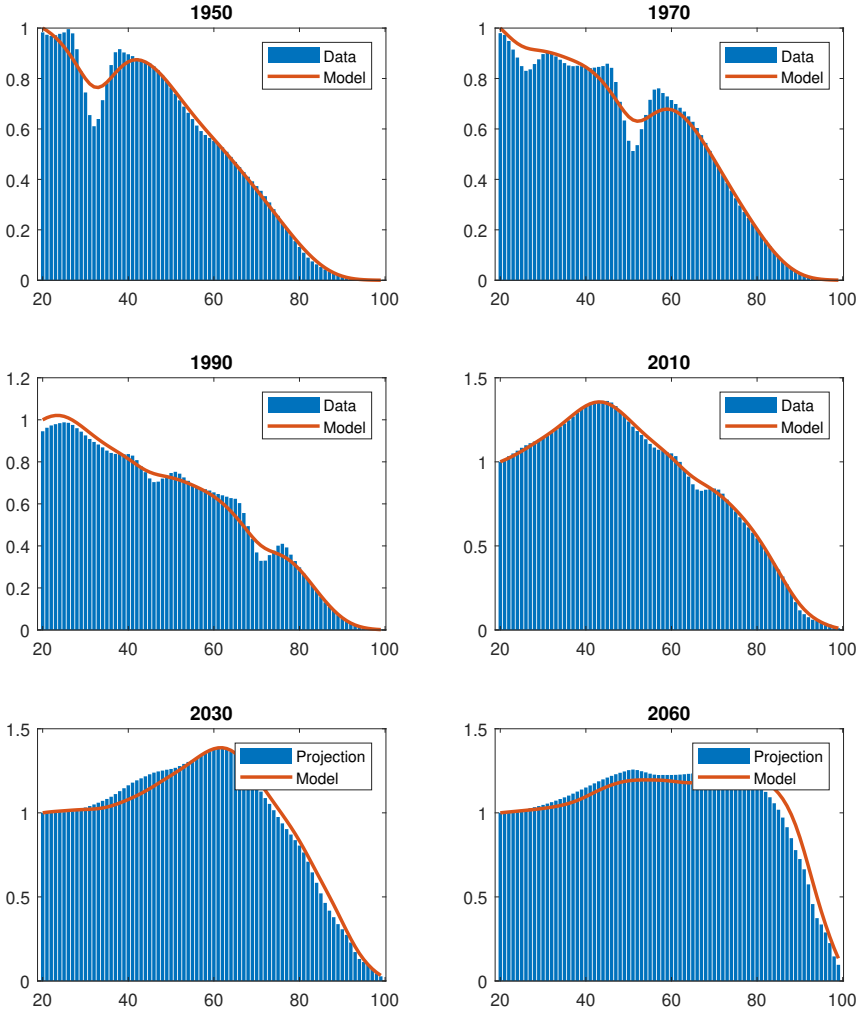
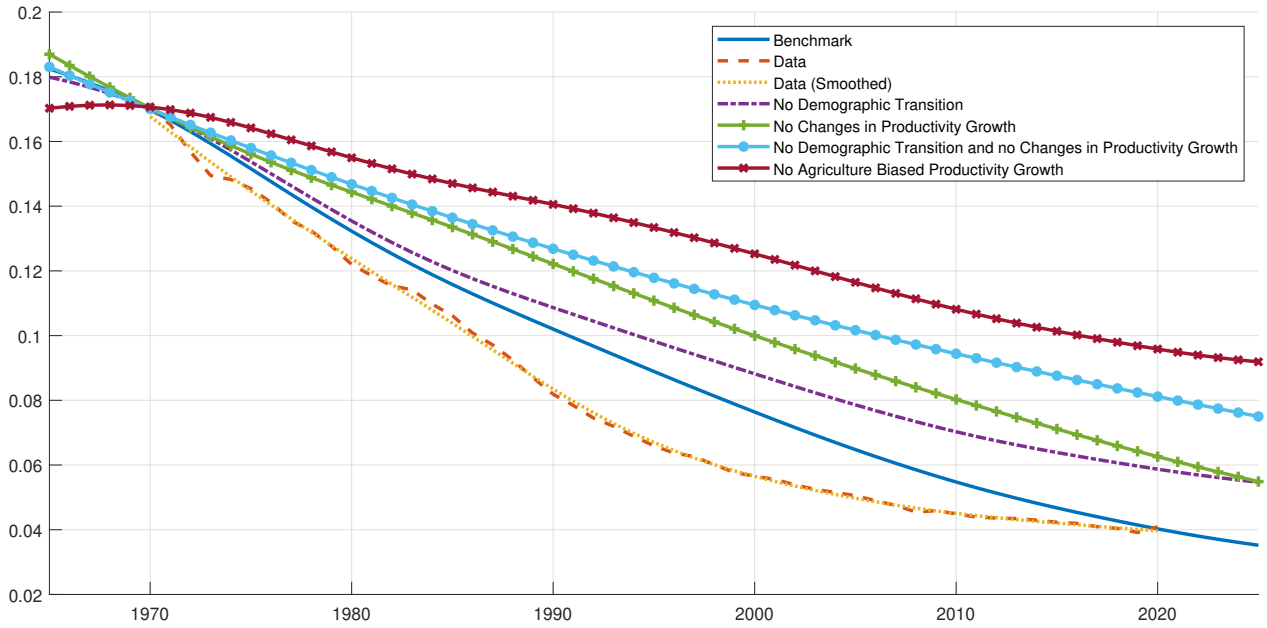

1950
Data
Model
1970
Data
Model
1990
Data
Model
2010
Data
Model
2030
Projection
Model
2060
Projection
Model

Table 3: Counterfactual Simulation Results - Employment Share in Agriculture

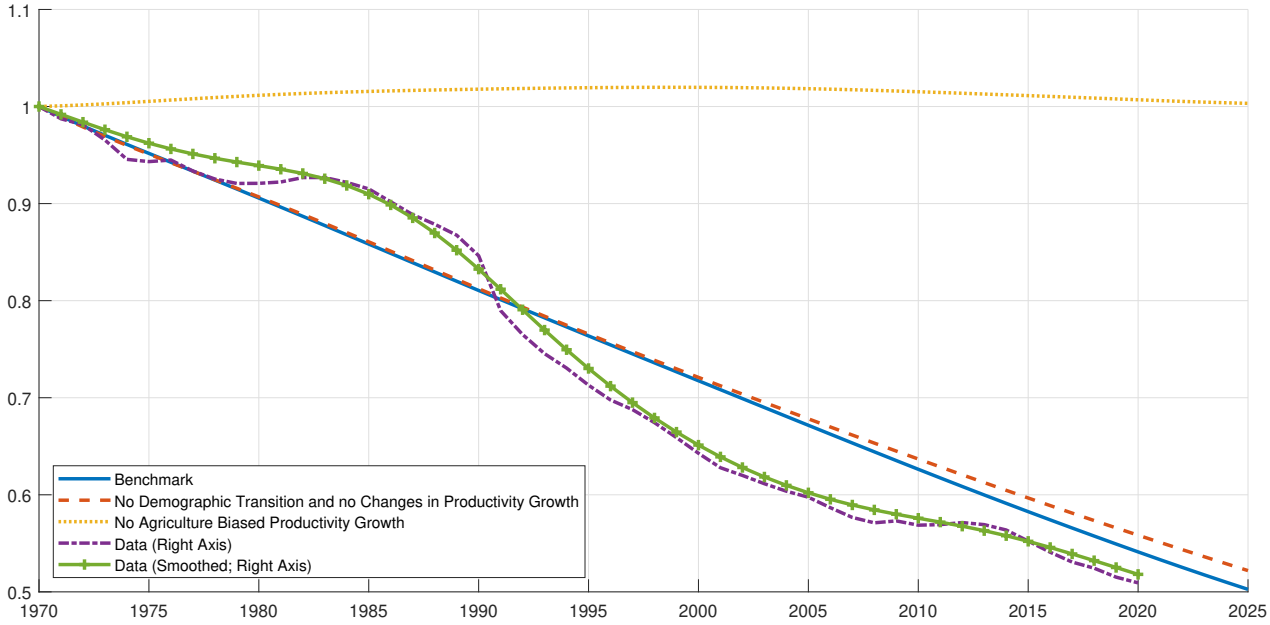
Counterfactual	$\frac{\Delta \text{Counterfactual}_{2020-1970}}{\Delta \text{Benchmark}_{2020-1970}} \times \frac{\text{Benchmark}_{1970}}{\text{Counterfactual}_{1970}}$	Share in 2020	Share in 2060
No Agricultural Sector Biased TFP Growth	0.386	0.120	0.124
No Changes in Demographics	0.853	0.060	0.063
No Changes in Fertility	0.955	0.047	0.047
No Changes in TFP Growth	0.830	0.063	0.059
No Changes in Demographics and TFP Growth	0.684	0.082	0.081
No Rebound in TFP Growth	1.014	0.040	0.032
Benefit Ratio $0.5 \times \rho$	1.035	0.037	0.034
Benefit Ratio $1.5 \times \rho$	0.977	0.044	0.046
Benefit Ratio $\rho = 1$	0.938	0.049	0.052
Retirement Age $= JR - 7$	1.033	0.037	0.040
Retirement Age $= JR + 7$	0.970	0.045	0.044
Subsidy $0.5 \times \varphi_{A,h}$	1.063	0.033	0.034
No Changes in Government Debt	1.009	0.040	0.040
Government Expenditures $\times 0.5$	1.011	0.040	0.040
Government Expenditures $\times 2$	0.968	0.045	0.044

Figure 10: Results for the Share of Employment in Agriculture and Rescaled Counterfactuals



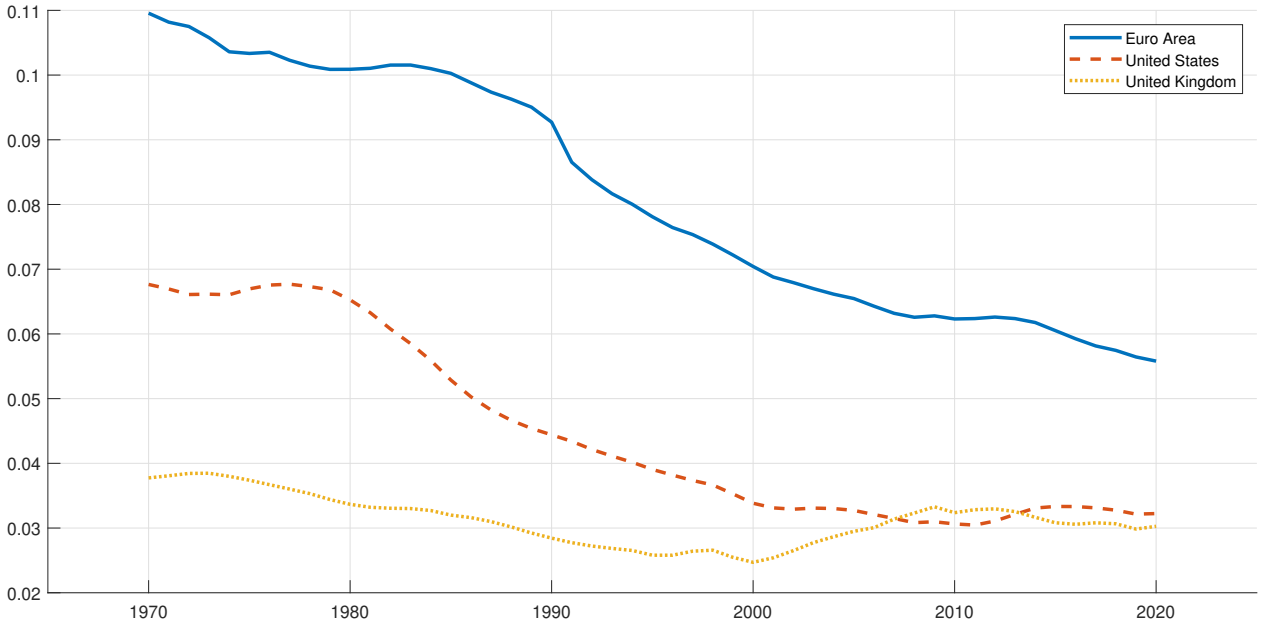
Note: This figure illustrates the share of hours of employment in agriculture out of total hours of employment in industries in Euro Area countries in benchmark as well as counterfactual simulations. We have adjusted the value of the constant multiplier of $x_{A,t}$ to have 17% employment share in agriculture in 1970. The data are from the March 2011 update of the November 2009 version of the EU KLEMS database, and the 2022 and 2023 versions of the EU KLEMS database.

Figure 11: The Share of Capital in Agriculture



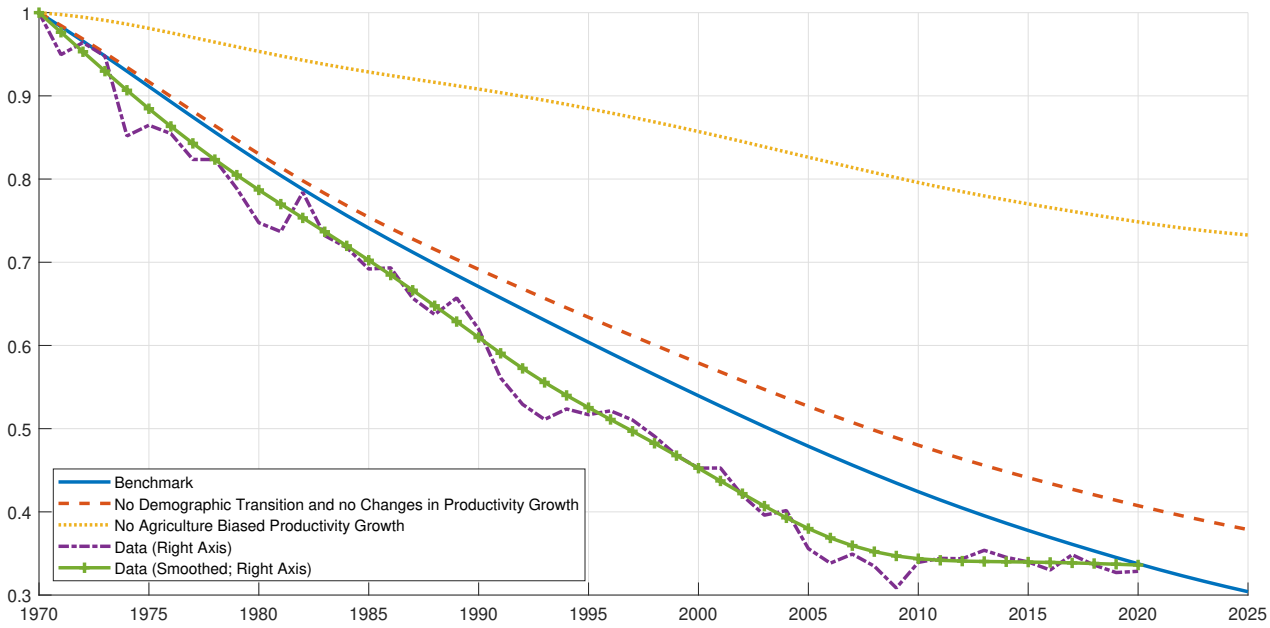
Note: This figure illustrates (the trend in) the share of capital in agriculture in the benchmark as well as in counterfactual simulations. It also illustrates (the trend in) the share of capital in agriculture out of the total market economy in the Euro Area countries. We have normalized the values of these shares to 1 in 1970. The data are from the March 2011 update of the November 2009 version of the EU KLEMS database, and the 2023 versions of the EU KLEMS database.

Figure 12: The Share of Capital in Agriculture in the Euro Area, the US, and the UK



Note: This figure illustrates the share of capital in agriculture out of the total market economy in the Euro Area countries, the United States, and the United Kingdom. The data are from the March 2011 update of the November 2009 version of the EU KLEMS database, and the 2023 versions of the EU KLEMS database.

Figure 13: The Share of Agricultural Value Added



Note: This figure illustrates (the trend in) the share of capital in agriculture in the benchmark as well as in counterfactual simulations. It also illustrates (the trend in) the share of capital in agriculture out of the total market economy in the Euro Area countries. We have normalized the values of these shares to 1 in 1970. The data are from the March 2011 update of the November 2009 version of the EU KLEMS database, and the 2023 versions of the EU KLEMS database.

5 Conclusions

We derive a general equilibrium model to quantify the effect of demographic transition and aggregate productivity growth slowdown on structural changes in employment in agricultural and non-agricultural sectors in the Euro Area countries. The model features cohorts of overlapping generations with age-specific labor productivity and age- and time-varying mortality probability. In the quantitative exercise, we impose on the model the observed age-specific labor productivity, government expenditures and debt levels, as well as the trends in fertility, mortality probabilities, and aggregate total factor productivity. We calibrate the model to match the levels of real interest rate and the share of employment and labor compensation share in agriculture in 1970, as well as the fall in employment share and in the real interest rate in the 1970-2020 period in sample countries.

The benchmark simulation effectively reproduces the matched moments. It also captures the decline in labor compensation share in agriculture by 2020, along with negative trends in both the share of capital in agriculture and agricultural value added, aligning closely with the observed data.

According to the simulation results, the demographic transition can account for about 15% of the observed fall in employment share in agriculture in the 1970-2020 period and aggregate productivity growth slowdown can account for about 17% of it. Together they account for more than 30% of the fall in employment share. Employment share in Agriculture would be twice higher and about 8% in 2020 in sample countries if there was no demographic transition and aggregate productivity growth slowdown. We also evaluate the effect of the pension scheme on the share of employment in agriculture and show that a benefit ratio of 1, instead of 0.34 as observed in the data, would imply a 6% lower fall in the employment share in agriculture. In turn, employment share in agriculture would fall by be 3% less if the retirement age was 71 instead of 64, the value used in the benchmark simulation.

In order to match the entire fall in the share of employment in agriculture, we assume that there is an agricultural sector-biased productivity growth. According to the simulations, agricultural employment share would fall about 60% less absent the agricultural sector-biased productivity growth. Moreover, structural change in employment is non-monotonic and agricultural employment slightly rebounds after 2040 in the simulation with no agricultural sector-biased productivity growth. This is because savings and capital decline as the demographic transition and aggregate productivity growth slowdown end.

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