Times of crisis and female labor force participation - Lessons from the Spanish flu

Timo Baas, Farzaneh Shamsfakhr

Department of Economics, University of Duisburg-Essen, Universitätsstraße 2, D-45117 Essen, Germany

Abstract

It is well known that macroeconomic shocks can have asymmetric impacts on the labor market participation of male and female workers. In the absence of universal social protection, a household may decide to temporarily increase female employment in order to compensate for a loss of income by the male counterpart. This phenomenon, usually analyzed during times of recession, is called the added worker effect. We go beyond this typical setting and attempt to identify and evaluate the added worker effect during times of a health shock. For this purpose, we develop and estimate a non-linear DSGE model using Bayesian methods and data from Sweden, covering the period 1915 - 1956. During this time, Sweden experienced the severe 1918 influenza pandemic outbreak, two massive economic recessions, and a period of pre-war preparedness, or Beredskapstiden. We find that females' participation in Swedish industry increased during the years related to the Spanish flu. In addition, the female labor supply responded to male labor supply fluctuations over the whole sample period.

Keywords: Gender, labor supply, Spanish flu, DSGE model, pruning
JEL: C51; E32; I15; J16

*Corresponding author
Email address: timo.baas@uni-due.de (Timo Baas)
URL: https://www.jpmakro.wiwi.uni-due.de (Timo Baas)

1. Introduction

Fluctuations in the size of the workforce have been observed in every major recession after the Second World War. Two opposing effects are discussed in connection with labor market participation: the added worker effect and the discouraged worker effect. The discouraged worker reacts to a deterioration in expected wages and a decrease in employment opportunities by becoming inactive or by being refraining from entering the workforce[1]. The added worker enters the labor force in times of crises. The most prominent explanation for this effect is that second-tier workers, who are most likely married females, become active if the first-tier wage earner drops out of the labor force. Most of the literature is concerned with the relative sizes of these two effects. In this paper, we focus on the added worker effect in times of health shocks, which have not been covered in previous studies.

Households change their labor market participation decisions based on economic conditions (Lundberg, 1985). If the first-tier worker becomes unemployed, a second-tier worker enters the labor force in order to compensate for the loss in household income (Woytinsky, 1953). A loss in income similar to that of being unemployed occurs if the first-tier worker falls ill. As in the previous case, the second-tier worker enters the labor market. However, the size of the added worker effect depends on households' insurance. Most developed countries have universal sick pay that covers all or part of a health-related loss in income. If the loss is compensated for, the incentive to enter the labor market diminishes. Between 1918 and 1959, Sweden lacked universal sick pay. Furthermore, the country was affected strongly by the Spanish flu[2], one of the most severe influenza-pandemics. Thus, Sweden provides an interesting case study for the added worker effect in times of a health-shock[3].

To address the added worker effect, we build and estimate a simple non-linear dynamic stochastic general equilibrium (DSGE) model. The model allows for asymmetries in participation decision by male and female workers, which means we can examine the added worker effect by gender[4]. Furthermore, we

[1]In a recession, not all potential added workers will find a job. In a recent study, Razzu and Singleton (2013) find that an outflow from inactivity to unemployment (employment) during a recession (boom) substantially increases the unemployment(employment) rate of females substantially. However, this pattern is not evident for males.

[2]Because the first report of the infection came from Spain, who did not take part in World War I, and apparently had an uncensored media, the epidemic was called the Spanish flu. Spanish flu was known as one of the deadliest pandemics in human history, and the largest of all pandemics during the 20th century.

[3]An additional reason for choosing Sweden is that the country remained neutral during the First World War. Because the Spanish flu affected employment, the overlap with the time of war makes it difficult to distinguish one effect from the other. Apart from being neutral, Sweden was heavily affected by the 1918 outbreak of the influenza epidemic. Almost 1 percent of the Swedish population (38,000 individuals) died from the Spanish flu.

[4]While prior studies focus on females, added workers could also be young males who enter the labor force by interrupting their education. In the case of Sweden Karlsson et al. (2014) find that minors entered the labor market.

distinguish between two types of unexpected health shocks both related to the outbreak of influenca. The first shock includes a change in the share of infected people, which affects the amount of labor supplied by a single worker, while the second shock on mortality covers changes in the size of population. Within this framework, female participation is expected to react to the pandemic in essentially two ways: a decrease in non-reported participation owing to the illness, and an increase in participation due to the added worker effect, which should predominantly affect married women. Using information of the number of people infected, the number of infected who subsequently died and the number of labor market participants, we examine household's labor supply decisions resulting from the illness-related loss in working time[5]. Furthermore, because the flu is a transitory shock, with nearly no impact on expected wages or on future employment opportunities, we address the added worker effect without having to be concerned about discouraged workers. The discouraged worker effect is thought to be important in the two recessions during our sample period. Thus, we also compare the effects of the recessions with those of the flu.

Our results indicate the existence of an added worker effect during the time of the Spanish flu. The pandemic increased females' participation in Swedish industry. However, this effect is not evident in subsequent waves of influenza infections, during which predominantly males entered the labor market. Females react to an increase in male participation by being absent from the labor market. We observe a similar pattern throughout the sample period. Females consider the labor supply decisions of males when deciding whether to enter the labor market, but the reverse does not hold. By comparing the participation effects during the Spanish flu with other periods, we find that during two recessions, the economic crises in the early 1920s and the depression in the early 1930s, females initially increased their participation as males retreat from the labor force. Then, in subsequent years, the male participation recovered and females left or stopped entering the labor market. Interestingly, during the period of military preparedness (Beredskapstiden), females also entered the labor force even though there was no significant decline in income to cause the added worker effect. With these findings, we contribute to the existing literature in at least three ways. First, we show that the added worker effect is a widespread phenomenon in economic and non-economic crises. Second, we demonstrate that participation decisions are not gender-neutral, and that females react on the participation decisions of males. Third, we provide insight into the absorption of shocks if essential instruments of social security, such as universal sick pay, are missing.

At first glance, finding a significant added worker effect in different crisis periods seems at odds with the findings of previous studies. Most empirical paper conclude that the discouraged worker effect is stronger than the added

[5]Infected workers remain employed in our time series data, because a flu infection is short if not accompanied by pneumonia. Therefore, being infected reduces working time rather than participation in the labor market.

worker effect. For instance Lundberg (1985) and Cain and Dooley (1976), using data after the Second World War, find a relatively small added worker effect that is overwhelmed by the discouraged worker effect. Only after the financial and economic crisis in 2009, the most severe economic crisis since the Great Depression, did studies begin to find a larger added workers effect. Bredtmann et al. (2014), employing a discrete choice model, find that married women whose husbands had lost their jobs had a higher participation rate than did women whose husbands were still employed. In the aftermath of the crisis in 2009, Riedl and Schoiswohl (2015), using macroeconomic time series derived from the European Labor Force Survey, find evidence of an increase in females' participation of 0.5 percentage points. Using less disaggregated data, Jonung and Roeger (2006) attribute a 0.2 percentage point increase in the employment of married women with children to the added worker effect. Therefore, the severity of a recession contributes to the size of the added worker effect, while social protection limits the effect. Thus, in low- and middle-income countries, the added worker effect should be higher than it is in high income countries (Karaoglan and Okten, 2015; Parker and Skoufias, 2004).

Furthermore, by finding that female workers react to the labor market participation decisions of males, we contribute to a series of recent publications on the labor supply of women within a household context. Nicoletti et al. (2016) find that females on unpaid maternity leave are sensitive to an employment shock that affects male household members. Blundell et al. (2016) see family labor supply decisions, outpacing other insurance mechanisms, as a major source of insurance against wage shocks. Cullen and Gruber (2000) find evidence that the generosity of unemployment insurance determines the spouses labor-supply, namely the labor market participation decision of second-tier or added workers. In addition to the findings of these studies, we find that females react less strongly to macroeconomic shocks than do their male counterparts. This implies that the observed high labor supply elasticities for females are essentially a reaction to male labor supply decisions. They are not restricted to a downswings in the economy or a reduction in wages.

Our paper is unique in that we are the first to address the added worker effect in times of a severe health shock. With regard to the mortality rate, the Spanish flu is considered one of the most severe diseases in Swedish history (Karlsson et al., 2014). Worldwide, the flu infected an estimated 500 million people, a third of the world's population at the time. By the end of 1920, between 50 and 100 million people had died as a result. Despite the enormity of this outcome, economic research on the consequences of such a pandemic is rather limited, even though the occurrence of something similar is quite imaginable, as the less severe Asian flu (1957 - 1958) and the Hong Kong flu (1968 - 1969) have shown. Seasonal influenza may pose a risk of the emergence of a new form of the flu virus. Given today's global mobility, such a virus may spread quickly around the world. In 2009, the world feared the so-called swine-flu, the second outbreak of a flu involving the H1N1 virus, after the 1918 pandemic. Fortunately, the modified virus turned out to be less lethal than its predecessor. The World Bank estimates that such a global influenza pandemic would cause a loss of 2 percent of the global GDP (Brahmbhatt, 2005). Given the differences in countries' levels of social protection, the impact might be much greater in developing countries. Thus, our results emphasize the importance of female vocational education, which would increase female labor force participation during crises, even if this does not translate immediately into higher non-crisis participation rates. The remainder of this paper is organized as follows. In the next section, we briefly outline the theoretical model. The data and estimation strategy for this model are described in section 3 and we discuss the empirical results in section 4. Lastly, section 5 concludes the paper.

2. The Model

Following the standard new Keynesian framework, as expounded for example in Clarida et al. (1999), Smets and Wouters (2003) and Christiano et al. (2005), we develop and estimate a non-linear DSGE model. The novel characteristics of our model are the presence of two kinds of labor, the imperfect substitutability of male and female workers, and the presence of epidemic shocks that affect aggregate labor.

2.1. Households

The economy is inhabited by a representative household that maximizes its lifetime utility as a function of consumption and labor supply. The utility function is separable in consumption c_{jt}, and hours worked by males $l_{j,m,t}$ and females $l_{j,f,t}$.

$$\max E_0 \sum_{t=0}^{\infty} \beta_t d_t \left\{ \ln c_t + \varphi_{m,t}\psi_m \frac{l_{j,m,t}}{1+\gamma_m} + \varphi_{f,t}\psi_f \frac{l_{j,f,t}}{1+\gamma_f} \right\}, \tag{1}$$

where E_0 is the conditional expectation operator, c_t is consumption, β is the discount factor, and $l_{m,t}$ and $l_{f,t}$ denote the labor provided by males or females, respectively. γ_m and γ_f are the inverse Frisch labor supply elasticities of males and females, respectively, d_t is an intertemporal preference shock, and $\varphi_{f,t}$ and $\varphi_{m,t}$ are gender specific labor disutility shocks affecting females and males, respectively.

In order to capture the aggregate risk, we assume that the household can trade the whole set of Arrow-Debreu securities. Securities $a_{j,t+1}$ pay one unit of consumption in event $\omega_{j,t+1}$ purchased by household j at time t at price $q_{j,t+1,t}$. Households also hold an amount of $b_{j,t}$ of government bonds, which pay a nominal gross interest rate R_t and physical capital, which is rewarded with r_t and is built-up according to the law of motion:

$$k_{j,t} = (1-\delta)k_{j,t-1} + x_{j,t}.$$

The utility maximization in Equation (1) is subject to a sequence of intertemporal budget constraints:

$$c_{j,t}+x_{j,t}+\frac{b_{j,t+1}}{p_t}+\int q_{t+1,t}a_{j,t+1}d\omega_{j,t+1,t} \tag{2}$$

$$=w_{m,t}l_{j,m,t}+w_{f,t}l_{j,f,t}+r_{j,t}k_{j,t-1}+R_{t-1}\frac{b_{j,t}}{p_t}+a_{j,t}+T_t+F_t,$$

where $w_{m,t}$ and $w_{f,t}$ are the gender specific wage rates paid to the labor, r_t is the rental rate of capital, T is a lump-sum transfer, and F_t is the firm's profit. We further assume that $a[1]=0$, a' and $a''>0$. The first order conditions for this problem are

$$d_t c_{j,t}^{-1}=\lambda_{j,t}, \tag{3}$$

$$\lambda_{j,t}=\beta E_t\left\{\lambda_{j,t,t+1}\right\}, \tag{4}$$

$$q_{j,t}=\beta E_t\left\{\frac{\lambda_{j,t+1}}{\lambda_{j,t}}\left(1-\delta\right)q_{j,t+1}+r_{t+1}\right\}, \tag{5}$$

$$w_{j,m,t}=d_t\varphi_{m,t}\psi_m l_{j,m,t}^{\gamma_m}\lambda_{j,t}^{-1}, \tag{6}$$

$$w_{j,f,t}=d_t\varphi_{f,t}\psi_f l_{j,f,t}^{\gamma_f}\lambda_{j,t}^{-1}. \tag{7}$$

2.2. Production of intermediate good firms

Intermediate goods producing firms use capital and labor for the production of a homogeneous good. Following Card and Lemieux (2001), we use a nested production function and assume that firms can choose to employ male and female labor. The aggregate technology to produce goods is given by a linear homogeneous production function:

$$y_t=\left[\alpha k_t^{\phi}+(1-\alpha)l_t^{\phi}\right]^{\frac{1}{\phi}}, \tag{8}$$

where y_t is output, k_t is capital, L_t is aggregate labor, and $\phi=1-\frac{1}{\sigma_{KL}}$ with σ_{KL} being the elasticity of substitution between capital and labor. In line with Borjas (2003), Ottaviano and Peri (2007), and Borjas et al. (2008), we assume that $\sigma_{KL}=1$, so that the CES function collapses to the Cobb-Douglas form combining capital k_t and aggregate labor l_t:

$$y_{d,t}=A_t k_t^{\alpha}l_t^{1-\alpha}. \tag{9}$$

The neutral technology process A_t is assumed to follow a random walk, with drift $A_t=A_{t-1}\exp\left(\triangle_A+z_{A,t}\right)$ where $\triangle_A$ is the long-run growth rate of technology and $z_{A,t}=\sigma_A\varepsilon_{A,t}$ involves a permanent shock to technology. However, to obtain a stationary equilibrium, we adjust the model variables with the gross growth rate of technology μ_t, defined as $\mu_t = \frac{A_t}{A_{t-1}}$, with $log\mu_t = logA_t - logA_{t-1} = \triangle_A + z_{A,t}$. [6]

In the lower nest, labor l_t is specified as a CES aggregate, containing male $l_{m,t}$ and female $l_{f,t}$ labor:

$$l_t = \left\{ \eta l_{m,t}^{\varrho} + (1-\eta) l_{f,t}^{\varrho} \right\}^{1/\varrho}, \tag{10}$$

where η can be referred to as a distribution parameter denoting the share of steady-state males and females, and $\varrho > 0$ is the elasticity of substitution between male and female labor. We can now derive the relation between male and female labor as a function of wages, the distribution parameter, and the elasticity of substitution:

$$\frac{l_{m,t}}{l_{f,t}} = \left(\frac{w_{f,t}}{w_{m,t}} \right)^{\varrho} \left(\frac{1-\eta}{\eta} \right)^{\varrho}, \tag{11}$$

with aggregate wages

$$w_t = \left(\eta^{\frac{1}{1-\varrho}} w_{m,t}^{-\frac{\varrho}{1-\varrho}} + (1-\eta)^{\frac{1}{1-\varrho}} \, w_{f,t}^{-\frac{\varrho}{1-\varrho}} \right)^{-\frac{1-\varrho}{\varrho}} \tag{12}$$

and the relation between labor and capital as a function of partial elasticities, aggregate wages, and interest on physical capital.

$$\frac{k_t}{l_t} = \left(\frac{w_t}{r_t} \right) \left(\frac{1-\alpha}{\alpha} \right). \tag{13}$$

As it can be easily seen, the gender employed in the intermediate good sector is determined by the wage differential between males and females, where the cost of labor depends on the preferences of households providing either of those two factors. The firm is a price taker in the labor market and the wage is determined by the labor supply equation of households and reflects the disutility of labor.

Therefore, the profits of the firm are:

$$F_t = y_t - l_t w_t \frac{1}{1-\alpha}.$$

2.3. Retail firms

There is a continuum of monopolistically competitive retailers on the unit interval, indexed by i. Each retailer purchases goods from the intermediate goods-producing firms and transforms them into a differentiated retail good using a linear technology, which is then resold to the households. During each period $t = 0, 1, 2, \dots$ each retailer i sells $Y_t(i)$ units of the retail good at the

[6] In line with zero steady-state growth rate in our model, HP-filtered data are used for the estimation .

nominal price $P_t(i)$. Let Y_t denote the composite of individual retail goods which is described by the CES aggregator of Dixit and Stiglitz (1977):

$$Y_t = \left[\int_0^1 Y_t(i)^{(\epsilon-1)/\epsilon} di\right]^{\epsilon/(\epsilon-1)}, \tag{14}$$

where $\epsilon > 1$ is the elasticity of substitution across the differentiated retail goods. Then, the demand curve facing each retailer i is given by

$$Y_t(i) = \left[\frac{P_t(i)}{P_t}\right]^{-\epsilon} Y_t, \tag{15}$$

and P_t is the aggregate price index

$$P_t = \left[\int_0^1 P_t(i)^{1-\epsilon} di\right]^{1/(1-\epsilon)}, \tag{16}$$

for all $t = 0, 1, 2, \ldots$. As in Calvo (1983), only a random and independent fraction $1 - \nu$ of the firms in the retail sector is allowed to set their prices optimally, whereas the remaining fraction ν index their prices to the previous period's inflation by parameter $\chi \in [0, 1]$. Hence, a retail firm i that can choose its price in period t, chooses price $P_t^*(i)$ to maximize

$$E_t \sum_{j=0}^{\infty} (\beta\nu)^j \beta_{t,t+j} \lambda_{t+j} \left[\left(P_{t-1}^{\chi} \frac{P_t^*(i)}{P_{t+j}}\right)^{-\epsilon} Y_{t+j} \left(P_{t-1}^{\chi} \frac{P_t^*(i)}{P_{t+j}} - \varsigma_{t+j}\right)\right], \tag{17}$$

where β_{t+j} is the discount factor used by the firms and ς_t is the real marginal costs:

$$\varsigma_t = \left(\frac{1}{1-\alpha}\right)^{1-\alpha} \left(\frac{1}{\alpha}\right)^{\alpha} w_t^{1-\alpha} r_t^{\alpha}. \tag{18}$$

The first-order condition for this problem is

$$P_t^*(i) = \frac{\epsilon}{(\epsilon-1)} \frac{E_t \sum_{j=0}^{\infty} (\beta\nu)^j \beta_{t,t+j} (\lambda_{t+j} P_{t+j}^{\epsilon} Y_{t+j} \varsigma_{t+j})}{E_t \sum_{j=0}^{\infty} (\beta\nu)^j \beta_{t,t+j} (\lambda_{t+j} P_{t+j}^{\epsilon-1} Y_{t+j})}. \tag{19}$$

We follow Fernández-Villaverde (2010) solving this equation recursively defining

$$g_{1,t} \equiv \beta\nu E_t \sum_{j=0}^{\infty} \left(\frac{P_{t+j}^{\chi}}{P_{t+j+1}}\right)^{-\epsilon} + (\lambda_{t+j} Y_{t+j} \varsigma_{t+j})$$

and

$$g_{2,t} \equiv \beta \nu E_t \sum_{j=0}^{\infty} \left(\frac{P^{\chi}_{t+j}}{P_{t+j+1}} \right)^{1-\epsilon} \left(\frac{P^*_{t+j}}{P^*_{t+j+1}} \right) g_{2,t+1} + (\lambda_{t+j} P^*_{t+j} Y_{t+j}),$$

which implies that $\epsilon g_{1,t} = (\epsilon - 1) g_{2,t}$. For $g_{1,t}, g_{2,t}$ to be well defined and stationary, we need $(\beta\nu)^j \beta_{t,t+j}$ to go to zero fast in relation to the rate of inflation. In this case we can write $g_{1,t}, g_{2,t}$. As we assume Calvo's price setting, the price index evolves according to

$$1 = \nu \left(\frac{p^{\chi}_{t-1}}{p_t} \right)^{1-\epsilon} + (1-\nu) {p^*_t}^{1-\epsilon}$$

.

2.4. The central bank

The central bank conducts monetary policy using a modified Taylor (1993) rule:

$$R_t / R = (R_{t-1}/R)^{\Gamma_R} \left(\left(\frac{Y_t / Y_{t-1}}{\triangle_A} \right)^{\Gamma_y} (\pi_t / \pi)^{\Gamma_\pi} \right)^{1-\Gamma_R}, \tag{20}$$

where R, Y, and π are the steady-state values of the gross nominal interest rate, output, and gross inflation rate. The degree of interest rate smoothing Γ_R and the reaction coefficients to inflation and output, Γ_π and Γ_y, are assumed to be positive.

The state deficit is assumed to be zero. Therefore, transfers follow the rule:

$$T_t = \frac{\int_0^1 m_{j,t} dj}{p_t} - \frac{\int_0^1 m_{j,t-1} dj}{p_t} + \frac{\int_0^1 b_{j,t+1} dj}{p_t} - R_{t-1} \frac{\int_0^1 b_{j,t} dj}{p_t}. \tag{21}$$

The central bank in our model is able to control the target level of the inflation rate only. The nominal interest rate R_t is beyond its control as it is equal to the steady-state real gross returns of capital plus the target level of inflation. If we apply the definition of transfers to the budget constraint we get:

$$c_t + x_t = w_{m,t} l_{m,t} + w_{f,t} l_{f,t} + r_t k_{t-1} + F_t. \tag{22}$$

2.5. Aggregation

External shocks that affect the population $s_{h,t}$ (i.e., mortality shocks) can change the number of households and in turn the supply of labor. Likewise, if the members of the household fall ill, they provide less labor or no labor at all. If all household members die, the household ceases to exist. Therefore, both mortality and morbidity shocks have similar but not identical consequences. A negative morbidity shock that affects the provision of labor reduces consumption to a lesser extent than the death of a household does. By normalizing the number of households to one, we get the following conditions for aggregates:

$$c_t = s_{h,t} c_{j,t}, \tag{23}$$

$$x_t = s_{h,t} x_{j,t}, \tag{24}$$

$$l_{d,t} = s_{h,t} si_t^{-1} l_{j,t}, \tag{25}$$

$$y_t = s_{h,t} y_{j,t}. \tag{26}$$

The share parameters, $s_{h,t}$, affecting the number of households, and $s_{l,t}$, affecting the provision of labor are 1 in the steady-state and are subject to stochastic shocks.

We can derive the good market equilibrium by equalizing the demand for intermediate good producers with the supply of each firm:

$$A_t k_{i,t-1}^{\alpha} l_{i,t}^{1-\alpha} = (c_t + x_t) \left(\frac{p_{i,t}}{p_t} \right)^{-\epsilon}. \tag{27}$$

If we use the capital-labor ratio, which is equal among firms, and by integrating out, we can use the Calvo price index to get:

$$c_t + x_t = \frac{A_t k_{t-1}^{\alpha} l_t^{1-\alpha}}{v_t^p} \tag{28}$$

with $v_t^p = \theta_p \frac{\pi_{t-1}^*}{\pi_t} v_{t-1}^p + (1-\theta_p) \pi_t^{*-\epsilon}$ as price distortion term.

2.6. Shocks

We formulate a set of random shocks including gender specific labor disutility shocks, shock to the household preferences and population. The production function is also assumed to be subject to a neutral technology shock. Finally, the Spanish flu is postulated as a stochastic morbidity shock.

$$\varphi_{m,t} = \rho_\omega \varphi_{m,t-1} + \sigma_{m,\omega} \varepsilon_{m,\omega,t} \ \varepsilon_{m,\omega,t} \sim N(0,1) \tag{29}$$

$$\varphi_{f,t} = \rho_\omega \varphi_{f,t-1} + \sigma_{f,\omega} \varepsilon_{f,\omega,t} \ \varepsilon_{f,\omega,t} \sim N(0,1) \tag{30}$$

$$d_t = \rho_d d_{t-1} + \sigma_d \varepsilon_{d,t} \ \varepsilon_{d,t} \sim N(0,1) \tag{31}$$

$$sh_t = \rho_{sh} sh_{t-1} + \sigma_{sh} \varepsilon_{sh,t} \ \varepsilon_{sh,t} \sim N(0,1) \tag{32}$$

$$\mu_t = \Delta_A + \sigma_A \varepsilon_{A,t} \ \varepsilon_{A,t} \sim N(0,1) \tag{33}$$

$$si_t = \rho_{si} si_{t-1} + \sigma_{si} \varepsilon_{si,t} \ \varepsilon_{si,t} \sim N(0,1), \tag{34}$$

All shocks follow an autoregressive process of order 1 with a time constant standard deviation σ and a time-varying component ε, representing the volatility of the shock (Fernández-Villaverde and Rubio-Ramirez, 2007a).

3. Estimation

In this section, we discuss the estimation of our DSGE model, the data we used, the estimation strategy applied, and the selection of priors. Because we want to cover the time of the Spanish flu in Sweden, between 1918 and 1920, we have to rely on historical time-series data that are available at low frequency only. In order to obtain greater precision in the estimation process, we decided to estimate a non-linear model using pruning, based on second-order Taylor approximations. We follow the literature in choosing priors to reflect the Swedish economy during our sample period, specify them within their theoretical boundaries, and discuss the results of the estimated posteriors.

3.1. Data

The annual time series we use to estimate our model start in 1915, three years before the outbreak of the Spanish flu, and end in 1956, 35 years after the complete departure of the flu shock. Using annual time-series has at least two drawbacks. First, we observe a heap in mortality in the second half of 1918 and at the beginning of 1919 (Figure 1), not in the whole year. This mutes the impact of the shock because workers infected by the flu worked for several months and, thus, are counted as employees. Second, setting up DSGE models using annual frequency is unusual, because these models lose precision by deviating from the steady state. By employing a second-order Taylor approximation, we can reduce this effect.

Figure 1 on page 27 about here

The number of infected individuals treated by a doctor is used to estimate the reduction in labor supply attributed to the flu. The data are extracted from Sweden's public health statistics for each year[7]. In Figure (2) we show the structural trend of the time series of infected and treated people (in log form), extracted using a one-sided HP filter. As expected, we identify a peak in the infection rate in 1918. It is also evident that the number of people infected develops dramatically during three years, 1918 to 1920. In the other years, the number of flu infections fluctuate around a significant lower mean. An exception is the time of the Second World War, when flu-driven doctoral visitations were low. Furthermore, in the same figure, we contrast the development of flu-driven doctoral consultations with the HP-filtered structural trends of female and male employment, and note some correlation among the three time series.

Figure 2 on page 28 about here

[7] Sveriges officiella statistic- Allmän hälso- och sjukvård 1913-1956

In summary, six time series are used in the estimation: the aforementioned series of infected people and treated people, GDP, population, per-capita consumption, and male and female employment (normalized by population) that approximates gender specific labor supply. To capture the mortality aspect of the Spanish flu in the labor force, we include population data. The Swedish labor statistics in the industrial sector are used as the source of male and female employment. These data are taken from the Historical Labor Database (HILD), provided by the University of Gothenburg. We rely on employment data from the industrial sector, because division by gender is unavailable for the other sectors. Therefore, our description of the added worker effect is rather broad. It includes transitions of female workers who are attracted by the decrease in the employment of male employees. These female workers can be inactive, unemployed, or from the agricultural/service sectors. The latter effect, however, seems to be quite small. Bansak et al. (2012) examine the impact of economic downturns on gender-related occupational segmentation in the United States between 1966 and 2010. They find that during recessionary phases, gender-related occupational segmentation and gender dissimilarity increase. Thus, at least during recessions, transitions from the agriculture and services sectors to the industrial sector are not a significant concern. On the other hand, the advantage of restricting our analyses to the industrial sector is that we rule out effects related to the structure of occupations. Dissimilarities in gender labor market outcomes during recessions are usually traced back to gender-related occupational choices (Goodman et al., 1993; Engemann and Wall, 2010). In this sense, men are predominantly employed in sectors that are heavily affected by economic crises, whereas females are usually placed in occupations that are less cyclical, and subsequently, are more resistant to recessionary effects (Rubery and Rafferty, 2013; Périvier, 2014; Wood, 2014). The remaining time series are obtained from the portal for historical data on Sweden (historia.se).

3.2. Estimation strategy

We simulate and estimate a non-linear DSGE model. The model solution is computed using the perturbation technique and pruning, based on the second-order Taylor approximation. More precisely, using perturbation methods, a local approximation of the model's solution is constructed by incorporating a parameter scaling the variance of the exogenous shocks. For this purpose, we apply an algorithm developed by Kim et al. (2008). The subsequent estimation of the model is conducted using a Bayesian approach in which the likelihood is evaluated with the non-linear particle filter[8] (a sequential Monte Carlo method), based on a second-order approximation of the model. We employ Bayesian techniques because they have been implemented in a large and growing body of empirical literature, owning to their important advantages in dealing with model misspecification and identification problems (An et al., 2007). Our estimation is

[8]For a detailed technical discussion, see the Appendix.

executed based on 3 parallel Markov chains of 100,000 draws and using a Monte-Carlo based optimization routine. The scale factor for the jumping distribution's covariance matrix in the Metropolis-Hasting algorithm is adjusted in order to capture a reasonable acceptance rate of roughly 30 percent.
The use of the particle filter relies on the requirements for the estimation of non-linear models. The likelihood function of our non-linear model with non-Gaussian shocks, a form of shocks subject to time-varying volatility, cannot be computed using the traditional Kalman filtering methods, which are frequently used to estimate models with Gaussian shocks[9]. Non-linear approximations of DSGE models have several advantages over linear approximations of such models. They allow us to capture the effects of uncertainty on economic decisions and to study asymmetries of business cycles. In particular, the time-varying volatility of the data, which is a fundamental issue in macroeconomics, cannot be attained under the Gaussanity assumption of linearized models (Schmitt-Grohe and Uribe, 2004; Fernández-Villaverde, 2010; Ruge-Murcia, 2012). In addition, estimating non-linear DSGE models delivers higher accuracy and substantially improves the fit of the model to real-world data (Andreasen et al., 2013; Fernández-Villaverde and Rubio-Ramírez, 2005).
We specify a series of observable equations in order to match the model variables with our detrended time series. The detrended series are obtained from a one-sided HP filter, applied to the logs of the six time-series used to estimate our model. The one-sided HP filter is a regular filter based on a two-sided moving average (Stock and Watson, 1999). To avoid stochastic singularity, six shocks are included in the model to match the number of time series used in the estimation: a technology shock, a preference shock, male and female labor disutility shocks, a shock to population that covers the mortality of those infected by the flu, and a flu morbidity shock. Each shock is specified as an AR(1) process.

3.3. Priors and posteriors

Using the above-mentioned time series, we are able to estimate 15 parameters and, in line with the literature, calibrate a further six parameters. The depreciation rate δ, labor disutility parameters of φ_m (for male worker) and φ_f (for female worker) are calibrated and chosen in such a way as to match the averages of the annual data on the investment to capital ratio, and the average share of hours spent on work, respectively. The male worker share parameter of the CES aggregate labor function $\eta = 0.8$ is inferred from the data on Swedish male and female employment, and the fixed cost parameter Φ is assumed to be zero. Moreover, following (Fernández-Villaverde, 2010), the elasticity of substitution between goods varieties ϵ that is assumed to be invariant across countries and time is set to 10. All other parameters can be identified and estimated. We initialize the prior means of the discount factor β and the capital share α to

[9]The Kalman filter assumes that the posterior density at every time step is Gaussian. Therefore, it can not describe a non-Gaussian density. In this case, the particle filter yields great accuracy and efficiency (Fernández-Villaverde and Rubio-Ramírez, 2007b)

match the average of the annual data on the long-term real interest rate and the capital share of income, respectively. The prior mean for the Frisch elasticity is acquired from a study by Jäntti et al. (2015) who analyze the labor supply elasticity of the Swedish labor market. The prior means of the Taylor rule are taken from the estimation conducted for the Riksbank, Sweden's central bank (Chappell and McGregor, 2014). In principle, using Taylor rules for determining monetary policy in a time that is called the beginning of central banking is tricky as the central banks during that time are not conducting monetary policy in a modern sense (Friedman and Schwartz, 1963). Nevertheless, we follow Orphanides (2003) who states that monetary policies during this time "appear to be consistent with the key aspects of Taylor's framework for interest-rate-based policy analysis".

Furthermore, we assume that 50 percent of firms readjust their nominal prices in every period, which identifies the Calvo parameters prior mean ν to be 0.5. In line with Smets and Wouters (2003), the remaining firms partially index their prices to the lagged inflation using the indexation factor prior mean χ, set to 0.5. Lastly, the substitution elasticity of the prior mean of male and female workers ϱ is set to 1.8, because we assume these two groups of workers are gross substitutes. Along with the parameters, we estimate the autoregressive parameters and the standard deviations of the shocks. 1summarizes the choice of priors and the posterior distribution of the estimated parameters, standard deviations, means and the 90% credible interval. Following common practice, we set the selected priors within their theoretical boundaries. Accordingly, the non-negative parameters, such as the standard deviations of the shocks, are assumed to have an inverse gamma distribution, and variables such as the persistence parameters and the Calvo parameter, are bounded between 0 and 1, and are supposed to follow a beta distribution. The remaining parameters, which are unbounded, are presumed to be normally distributed. The β parameter is given a gamma distribution. The standard deviations of the technology and labor disutility shocks are set to have a mean 0.05 and standard deviation 1.0. The standard deviations of the flu shock and the population shock are determined to have a lower value. In addition, because we are using a New Keynesian model, we follow Fernández-Villaverde (2010) in assigning a relatively large preference shock.

The estimates of the posteriors are in line with those reported in the empirical literature. In addition, comparing the prior and estimated posterior means and the standard deviations of structural parameters indicates that our priors are strongly identified and that, in general, our data is quite informative. As expected, there is little information in the data for some parameters, such as the Taylor rule coefficients for inflation and output. Furthermore, the share of capital is estimated at a higher value compared to the prior. Compared to our priors, the stochastic shocks all appear to be less volatile. Furthermore, the estimated preference shock and the shock to the population seem to be more persistent. The estimated mean volatility of the male and female labor disutility shocks deliver much higher values than those we assigned to the corresponding priors, yet their autoregressive coefficients are estimated at lower means. The estimates also yield a lower mean volatility and persistence of the flu morbidity shock.

Table 1 on page 25 about here

---

4. Results

In this section, we discuss the impact of the shocks on male and female participation decisions, as well as on other key macroeconomic variables. Accordingly, we first measure the contributions of the shocks to the fluctuations of the models variables using the variance decomposition for 1918. Second, we use the estimated Bayesian impulse-response functions to discuss the model's behavior in response to health shocks. Next, to disentangle and study the historical contribution of health shocks to the variance of the macroeconomic variables, we present the historical decomposition.

4.1. Variance decomposition

We derive the conditional variance decomposition of the posterior mean for the year 1918. Table 2 shows that the mortality shock contributes to nearly 20 percent of the variation in output, and that the morbidity shock contributes nearly 19 percent. Both shocks explain over 90 percent of the variations in aggregate employment. However, consumption is only slightly affected by the flu shocks, contributing 2.5 percent to the variations in consumption, while a preference shock, indicating a change in the time preference of households, account for 89 percent. This implies that households de-save in order to keep consumption stable. Similarly, the flu has only a slight effect on the labor supply of households. The shock contributes 20 percent to the male labor supply and 14 percent to the female labor supply, while the labor disutility shock of males accounts for 34 percent and that of females for 51 percent. Households seem to adjust labor supply in order to cope with the flu shocks. This hints at the existence of an added worker effect. However, it is surprising that, the male labor supply is able to adjust by this amount. Karlsson et al. (2014) explains this as an increase in the work of children and young adults.

Table 2 on page 26 about here

4.2. Impulse response functions

Figure (3) shows the median response of the model to one standard deviation of the estimated flu morbidity shock, plotted with the highest posterior density interval. The impulse response functions are calculated from a posterior sample of 100,000 draws. The flu shock directly affects aggregate employment by reducing the amount of work supplied by workers. Infected workers are still counted as employed but provide less work. The reduction would have been higher if additional workers did not enter the labor market. Male participation increases by 0.25 percent and female participation by 0.2 percent. Thus, aggregate employment is reduced by 1.2 percent. This translates into a decline in output by 0.4 percent. Surprisingly, consumption is reduced by only 0.08 percent, which implies that households limit their savings in order to keep consumption at a high level.

Figure 3 on page 29 about here

Similar to the flu shock, an economic crises increases female and male labor market participation (Figure 4). The reason for such a strong “added worker effect” is the specific circumstances of the severe depression in Sweden between 1920 and 1923, when the country lost more than 37 percent of per capita GDP and only reached the pre-crisis level again in 1939. Without generous social protection, workers had to work to make a living. If we treat the economy with a negative total factor productivity shock of one standard deviation, we see a drop in GDP of 6 percent. Males increase their labor market participation by 0.5 percent and females by 0.4 percent. Consumption during this time increases, revealing that deflationary tendencies did primarily affect savings and investment, causing a drop in GDP.

Figure 4 on page 30 about here

A time preference shock (Figure 5) mainly affects consumption. Households give a higher preference to consumption today rather than that of the future. Following a positive preference shock, consumption increases by 5 percent. A decrease in investment overcompensates for the increase in consumption and has a depressing impact on GDP, reducing it by 0.4 percent instantly, and by up to 0.8 percent over the next three years. In contrast to the shock to total factor productivity, households decrease their labor supply. This decrease is stronger for males (1 percent) than it is for woman (0.7 percent).

Figure 5 on page 31 about here

Moreover, a positive labor disutility shock (Figure 6) decreases labor supplied by male household members. A shock of one standard deviation decreases participation by more than 6 percent. This translates into a decrease in aggregate employment by less than 6 percent. The 0.5 percentage point difference between male labor supply and aggregate employment is attributed to a more than 2 percent increase in female labor supply. The decrease in aggregate employment reduces GDP by 2 percent and per-capita consumption by around 0.4 percent. This also shows the weak reaction of consumption to changes in GDP.

Figure 6 on page 32 about here

If we shock female disutility by one standard deviation (Figure 7), we see a decrease in female labor supply by slightly less than 6 percent. As in the case of a male disutility shock, added workers step in. However, the increase in male labor supply by 0.1 percent is very weak. Aggregate Employment decreases by 0.2 percent and reduces GDP by 0.06 percent. Consumption shrinks by 0.015 percent.

Figure 7 on page 33 about here

4.3. Historical decomposition

The Figures (8),(9),(10) and (11) show the variations of the model variables with respect to each of the six shocks in our model. These shocks are represented as colored lines in the graphs. The black dashed line in every graph indicates the deviation of the smoothed variable from its steady state.

Figure 8 on page 34 about here

The historical decomposition of GDP (Figure 8) shows the depressing impact of the Spanish flu in 1918. The flu shock reduces GDP, while an increase in labor supply mitigates this effect. Additionally, total factor productivity declines, worsening the impact of the flu. Furthermore, we see that, starting with the flu year, households shift consumption to the present. This effect exists even in the two years where the GDP is recovering. In 1920 - 1921, the time preference shock has a strong negative impact on GDP until it abates in 1928. Between 1920 and 1923, Sweden experiences a severe downturn. GDP per capita decreases by 37 percent, and needs nearly twenty years before it reaches the pre-crisis level again. In the first two years of the recession, the discouraged worker effect dominated. The discouraged worker effect increases the disutility of workers and, therefore, labor market participation. This effect accelerates the decrease in GDP. However, in later years, the discouraged worker effect diminishes, and the male added worker effect contributes to a recovery of GDP. Nevertheless, the road to recovery is long. Then, in 1930 - 1931 another recession contracts the GDP in Sweden, though to a lesser extent than the previous downturn. All Nordic countries including Sweden were hit by the Great Depression to a lesser extent than other industrialized countries.

Figure 9 on page 35 about here

The historical decomposition of male labor supply (Figure 9) indicates a negative impact of the Spanish flu on male labor provision. We see a harsh drop during the initial shock phase in 1918 and 1919. In 1920, the male labor provision increases and compensates for the loss of labor provision during the epidemic. However, in 1921, a recession hits the Swedish economy, decreasing the labor supply of males. We attribute the increase in disutility during this period to a dominating discouraged worker effect. In the years after 1923, this disutility decreases, and males provide more work. In addition, between 1932 and 1934 (the next recession), we see a negative impact of a drop in GDP on male labor provision and a recovery between 1934 and 1936. From 1937 onward, the male labor supply decreases. This period can be explained by the upcoming World War II and the Beredskapstiden, a military service that trained feasible soldiers to secure the borders and protect Sweden from invasion. After 1942, there is a slight recovery in labor participation, which lasts till 1948. During this time, the labor supply returns to its steady state level. After the war in 1945, we see an increase in the labor supply, but between1948 and 1951, the labor participation of males strongly decreases. The beginning of the 1950s is characterized by a recovery.

Figure 10 on page 36 about here

In contrast to the male labor supply, after an initial decrease in the female labor supply[10] owing to the flu outburst in 1918, we observe an increase in the female labor supply from 1918 to 1919 (Figure 10). However, in the years of the economic depression, similar to male employment, female employment decreases in reaction to a shrinkage of production and labor demand. During this period, we also see that, similar to the time of the pandemic, the female labor supply increases in reaction to a drop in the participation of males. Similar responses can be seen over the whole sample period.

Similarly, subsequent to a decrease in the men labor force participation in the time of pre-war preparations (Beredskapstiden) in 1936, we observe an increase in female labor supply. During the war, from 1939 to 1945, we see a considerable reduction in women's participation, a time in which male labor supply remains constant. This pattern may be explained by the enactment of a law in Sweden in 1939, under which employed women could not be dismissed by reason of pregnancy, childbirth, engagement, or marriage (Ruggie, 2014). Similarly, following the introduction of paid leave in 1955, both male (though to a lesser degree) and female labor supply decreased (Mason, ed, 1995).

[10] This mortality effect is somewhat stronger for women than for men. The gender distribution of death by influenza in Sweden shows that from 1918 to 1920, more females in the working population died from the flu than did males.

Figure 11 on page 37 about here

Both males and females are affected by the flu outbreak in 1918 and reduce their working hours (Figure 11). This leads to a negative impact of the health shock on aggregate employment. It can be seen, that aggregate employment decreases after the Spanish flu outbreak and that the reduction in aggregate labor is mainly stirred by a male labor disutility shock. This is because the share of males in the workforce is more than 80 percent. However, part of the reduction in the male labor force during 1918 - 1919, the beginning of the recession in 1923 - 1927, and in the Great Depression (1936 - 1938) is compensated by an increase in participation of women which alleviates the downward push to aggregate employment. In this sense, female added workers enter the labor force in times when discouraged male workers are absent. In those times, we see an increase in disutility that affects male workers and reduces male labor supply. We interpret this shock as the male discouraged worker effect dominating the male added worker effect.

4.4. Business cycle properties

To assess the fit of the model to the data, we compare the theoretical moments of the time series generated from a simulated benchmark DSGE model to the empirical moments (Table 3). The variables and the data are expressed in percentage deviations from the steady state. As shown, the model is able to truly replicate the characteristics documented in the Swedish data. However, the model generates slightly higher standard deviations and contemporaneous correlations with GDP for variables of population and aggregate employment than those observed in the data.

Table 3 on page 26 about here

4.5. Sensitivity analysis

As a robustness-check, we evaluate the sensitivity of our results to an alternative specification of the Spanish flu shock. Accordingly, our model is estimated using solely the number of people infected by influenza who subsequently died. According to the available data, during the period 1911-1951[11], on average, roughly 2 percent of infected people from influenza in Sweden died each year. This value increased to nearly 6 percent during the 1918 − 1919 influenza pandemic. The estimation results are summarized in Table (4) and the historical decomposition of shocks in Figure (27), (28) and (29) of the Appendix. As

[11]The model is also estimated for the period 1911-1951

shown, our results are quite robust across variants of the flu shock specification. However, the added worker effect for males and females in times of a flu shock is quite small. This implies that added worker primarily react on the illness of the household head rather than on the relatively small number of deaths.

5. Conclusion

We estimate a non-linear DSGE model to analyze the impact of times of crises on the labor market participation decisions of male and female household members in Sweden during the period 1915 - 1956. In this time, female workers react less to shocks than male workers do. Females react to male labor supply decisions, while the corresponding male reaction to labor supply decisions of females is nearly non-existent.

A decrease in the supply of male labor, caused by the Spanish flu, was followed by an increase in female participation. Our results show that in the aftermath of the Spanish flu outburst in 1918 and 1919, female labor supply upsurges, while male labor supply declines. These results imply that succeeding a severe shock, there is an inflow of inactive females to the labor market to substitute for the absence or deficiency of males. In the literature, this phenomenon is called the added worker effect. The entry of these women during the pandemic relieved the downward push on the Swedish labor force triggered by a shortage of male workers. Moreover, the response of females to a decline in male labor supply was also observed at the beginning of two recessions, as well as shortly before the Second World War, as Sweden prepared for an occupation and conscripted young males. Depending on the size of the female participation on the one hand, and the capacity of the economy to accommodate the new arrivals on the other hand, the inflow of inactive women to the labor market increases the capability of the economy to absorb different kinds of shocks and smooths macroeconomic fluctuations. These findings not only reconcile with prior research on the impact of health shocks and gender business cycles, but also add to the literature on the added worker effect by bridging the existing gap between these areas of research.

References

An, Sungbae, Frank Schorfheide, Malin Adolfson, Jesper Lindé, Mattias Villani, Fabio Canova, John Geweke, and Tao Zha, "Bayesian Analysis of DSGE Models: Rejoinder," *Econometric reviews*, 2007, *26* (2), 211–219.

Andreasen, Martin M., Marcelo Ferman, and Pawel Zabczyk, "The Business Cycle Implications of Banks Maturity Transformation," *Review of Economic Dynamics*, 2013, *16* (4), 581–600.

Bansak, Cynthia, Mary E. Graham, and Allan Zebedee, "Business Cycles and Gender Diversification: An Analysis of Establishment-Level Gender Dissimilarity," 2012.

Blundell, Richard W., Luigi Pistaferri, and Itay Saporta-Eksten, "Consumption inequality and family labor supply," *The American Economic Review*, 2016, *106* (2), 387–435.

Borjas, George J., "The Labor Demand Curve Is Downward Sloping: Reexamining the Impact of Immigration on the Labor Market," *Quarterly Journal of Economics*, 2003, *118* (4), 1335–1374.

Borjas, George, Jeffrey Grogger, and Gordon Hanson, *Imperfect Substitution between Immigrants and Natives: A Reappraisal*, Cambridge, MA: National Bureau of Economic Research, 2008.

Brahmbhatt, Milan, *Avian Influenza: Economic and Social Impacts*, Washington, D.C: The World Bank, 2005.

Bredtmann, Julia, Sebastian Otten, and Christian Rulff, "Husband's Unemployment and Wife's Labor Supply–The Added Worker Effect across Europe," *Ruhr Economic Papers*, 2014, (484).

Cain, Glen G. and Martin D. Dooley, "Estimation of a Model of Labor Supply, Fertility, and Wages of Married Women," *Journal of Political Economy*, 1976, *84* (4), S179–99.

Calvo, Guillermo A., "Staggered Prices in a Utility-Maximizing Framework," *Journal of Monetary Economics*, 1983, *12* (3), 383–398.

Card, David and Thomas Lemieux, "Can Falling Supply Explain the Rising Return to College for Younger Men? A Cohort-Based Analysis," *Quarterly Journal of Economics*, 2001, *116* (2), 705–746.

Chappell, Henry W. and Rob Roy McGregor, "Taylor Rules for Sweden's Riksbank," *SSRN Working Paper*, 2014, (2417245).

Christiano, Lawrence J., Martin Eichenbaum, and Charles L. Evans, "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy," *The journal of political economy*, 2005, *113* (1), 1–45.

Clarida, Richard, Jordi Galí, and Mark Gertler, *The science of monetary policy: A new Keynesian perspective*, Vol. 99,13 of *Economic research reports / C. V. Starr Center for Applied Economics, New York University, Faculty of Arts and Science, Department of Economics* 1999.

Cullen, Julie Berry and Jonathan Gruber, "Does unemployment insurance crowd out spousal labor supply?," *Journal of Labor Economics*, 2000, *18* (3), 546–572.

Dixit, Avinash and Joseph Stiglitz, "Monopolistic Competition and Optimum Product Diversity," *The American Economic Review*, 1977, *67* (3), 297–308.

Engemann, Kristie and Howard Wall, "The Effects of Recessions Across Demographic Groups," 2010.

Fernández-Villaverde, Jesús, "The Econometrics of DSGE Models," *SERIEs*, 2010, *1* (1-2), 3–49.

_ **and Juan F. Rubio-Ramírez**, "Estimating Dynamic Equilibrium Economies: Linear Versus Nonlinear Likelihood," *Journal of Applied Econometrics*, 2005, *20* (7), 891–910.

_ **and Juan F. Rubio-Ramirez**, "Estimating Macroeconomic Models: A Likelihood Approach," *Review of Economic Studies*, 2007, *74* (4), 1059–1087.

_ **and Juan F. Rubio-Ramírez**, *How Structural Are Structural Parameters?*, Cambridge, MA: National Bureau of Economic Research, 2007.

Friedman, Milton and Anna Jacobson Schwartz, *A monetary history of the United States: 1867-1960*, 4. printing ed., Vol. 12 of *Studies in business cycles*, Princeton: Princeton Univ. Press, 1963.

Goodman, William, Stephen Antczak, and Laura Freeman, "Women and Jobs in Recessions: 1969-92," 1993.

Jäntti, Markus, Jukka Pirttilä, and Håkan Selin, "Estimating Labour Supply Elasticities Based on Cross-Country Micro Data: A Bridge Between Micro and Macro Estimates?," *Journal of Public Economics*, 2015, *127*, 87–99.

Jonung, Lars and Werner Roeger, "The Macroeconomic Effects of a Pandemic in Europe - A Model-Based Assessment," *European Economy*, 2006, (251).

Karaoglan, Deniz and Cagla Okten, "Labor-Force Participation of Married Women in Turkey: A Study of the Added-Worker Effect and the Discouraged-Worker Effect," *Emerging Markets Finance and Trade*, 2015, *51* (1), 274–290.

Karlsson, Martin, Therese Nilsson, and Stefan Pichler, "The Impact of the 1918 Spanish Flu Epidemic on Economic Performance in Sweden: An Investigation into the Consequences of an Extraordinary Mortality Shock," *Journal of health economics*, 2014, *36*, 1–19.

Kim, Jinill, Sunghyun Kim, Ernst Schaumburg, and Christopher A. Sims, "Calculating and Using Second-Order Accurate Solutions of Discrete Time Dynamic Equilibrium Models," *Journal of Economic Dynamics and Control*, 2008, *32* (11), 3397–3414.

Lundberg, Shelly, "The Added Worker Effect," *Journal of Labor Economics*, 1985, *3* (1), 11–37.

Mason, Karen Oppenheim, ed., *Gender and family change in industrialized countries* International studies in demography, Oxford: Clarendon Press, 1995.

Nicoletti, Cheti, Kjell G. Salvanes, and Emma Tominey, "The family peer effect on mothers' labour supply," *IZA Discussion Papers*, 2016, (9927).

Orphanides, Anthanasios, "Historical monetary policy analysis and the Taylor rule," *Journal of Monetary Economics*, 2003, *50* (5), 983–1022.

Ottaviano, Gianmarco I. P. and Giovanni Peri, "The Effects of Immigration on US Wages and Rents: A General Equilibrium Approach," *C.E.P.R. Discussion Papers*, 2007, (6551).

Parker, Susan W. and Emmanuel Skoufias, "The Added Worker Effect over the Business Cycle: Evidence from Urban Mexico," *Applied Economics Letters*, 2004, *11* (10), 625–630.

Périvier, Hélène, "Men and Women During the Economic Crisis," *Revue de L'OFCE*, 2014, *133* (2), 41.

Razzu, Giovanni and Carl Singleton, "Are Business Cycles Gender Neutral?," 2013.

Riedl, Aleksandra and Florian Schoiswohl, "Is There an Added Worker Effect?–European Labor Supply during the Crisis," *Focus on European Economic Integration*, 2015, pp. 71–88.

Rubery, Jill and Anthony Rafferty, "Women and Recession Revisited," *Work, Employment & Society*, 2013, *27* (3), 414–432.

Ruge-Murcia, Francisco, "Estimating Nonlinear DSGE Models by the Simulated Method of Moments: With an Application to Business Cycles," *Journal of Economic Dynamics and Control*, 2012, *36* (6), 914–938.

Ruggie, Mary, *The State and Working Women: A Comparative Study of Britain and Sweden* Princeton Legacy Library, Princeton: Princeton University Press, 2014.

Schmitt-Grohe, Stephanie and Martin Uribe, "Solving Dynamic General Equilibrium Models Using a Second-Order Approximation to the Policy Function," *Journal of Economic Dynamics and Control*, 2004, *28* (4), 755–775.

Smets, Frank and Raf Wouters, "An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area," *Journal of the European Economic Association*, 2003, *1* (5), 1123–1175.

Stephen P. Brooks and Andrew Gelman, "General Methods for Monitoring Convergence of Iterative Simulations," *Journal of Computational and Graphical Statistics*, 1998, *7* (4), 434–455.

Stock, James H. and Mark W. Watson, "Forecasting Inflation," *Journal of Monetary Economics*, 1999, *44* (2), 293–335.

Taylor, John B., "Discretion versus Policy Rules in Practice," *Carnegie-Rochester Conference Series on Public Policy*, 1993, *39*, 195–214.

Wood, Catherine, "The Rise in Women's Share of Nonfarm Employment During the 2007-2009 Recession: A Historical Perspective," 2014.

Woytinsky, Wladimir, *Employment and Wages in the United States*, Twentieth Century Fund, New York, 1953.

6. Tables and Figures

Table 1: Prior and posterior distributions of the estimated parameters

Description		Prior distribution			Posterior distribution			
	Parameter	Density	Mean	Std. dev.	Mean	Std. dev.	10%	90%
Discount factor	β	Gamma	0.98	0.5e-2	0.98	2.4e-5	0.97	0.99
Capital share	α	Normal	0.30	0.10	0.66	0.003	0.59	0.72
Calvo parameter	ν	Beta	0.50	0.10	0.48	0.01	0.36	0.60
Male inverse Frisch elast.	γ_m	Normal	3.47	0.10	3.45	0.01	3.32	3.58
Female inverse Frisch elast.	γ_f	Normal	4.29	0.10	4.31	0.002	4.25	4.37
Male-female substitution elast.	ϱ	Normal	1.80	0.10	1.64	0.10	1.52	1.76
Taylor rule output	Γ_y	Normal	0.06	0.01	0.06	9.4e-5	0.05	0.07
Taylor rule inflation	Γ_Π	Normal	0.25	0.05	0.25	0.002	0.19	0.31
Taylor rule interest rate	Γ_R	Normal	1.10	0.25	1.31	0.03	1.11	1.53
Autorregressive coefficients of shocks								
Technology	Λ_μ	Beta	0.002	0.001	0.002	9.6e-09	0.002	0.002
Preference	ρ_d	Beta	0.50	0.10	0.59	0.005	0.49	0.68
Male labor disutility	ρ_φ	Beta	0.50	0.10	0.39	0.007	0.28	0.50
Female labor disutility	$\rho_{\varphi f}$	Beta	0.50	0.10	0.46	0.007	0.35	0.56
Flu morbidity	ρ_{si}	Beta	0.50	0.10	0.38	0.007	0.27	0.49
Population	ρ_{sh}	Beta	0.50	0.10	0.55	0.009	0.42	0.67
Standard deviations of shocks								
Technology	$exp(\sigma_\mu)$	Inv gamma	0.05	1.0	0.06	6.3e-05	0.05	0.07
Preference	$exp(\sigma_d)$	Inv gamma	0.10	2.0	0.06	6.4e-05	0.06	0.08
Male labor disutility	$exp(\sigma_\varphi)$	Inv gamma	0.05	1.0	0.26	9.0e-04	0.23	0.30
Female labor disutility	$exp(\sigma_{\varphi f})$	Inv gamma	0.05	1.0	0.22	6.0e-04	0.19	0.25
Flu morbidity	$exp(\sigma_{si})$	Inv gamma	0.05	0.5	0.01	2.2e-06	0.01	0.02
Population	$exp(\sigma_{sh})$	Inv gamma	0.05	0.5	0.01	3.8e-07	0.006	0.008

Table 2: Variance decomposition

Observable variable	Pref. shock	Male disutility shock	Female disutility shock	Tech. shock	Population	Flu morb. shock
Output	13.5	1.4	0.0	47.5	19.3	18.4
Consumption per-capita	89.0	0.2	0.0	8.3	0.4	2.1
Male labor supply	45.8	33.7	0.0	1.0	2.2	17.3
Female labor supply	29.7	6.4	50.6	0.6	1.4	11.2
Aggregate employment	4.6	3.1	0.0	0.1	52.4	39.8

Table 3: Unconditional moments

Observable variable	Std. dev.		Corr. with output	
	Data	Model	Data	Model
Output	0.10	0.10	1.000	1.000
Consumption per capita	0.12	0.13	0.82	0.70
Population	0.004	0.07	0.20	0.40
Male labor supply	0.06	0.03	-0.31	-0.14
Female labor supply	0.04	0.03	-0.09	-0.08
Aggregate employment	0.06	0.09	0.32	0.57

Figure 1: Influenza mortality 1918-1920

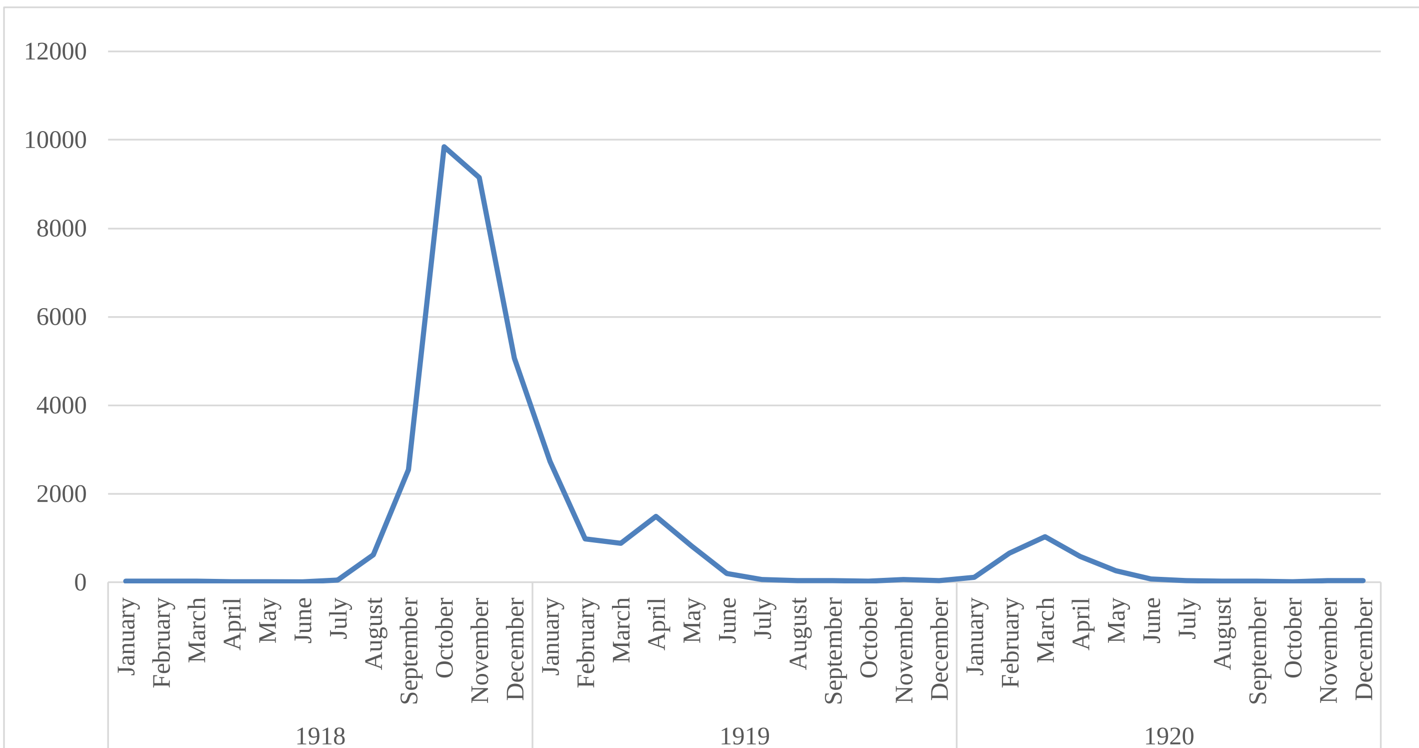


Figure 2: Periodicity of influenza, male and female employment- Sweden 1915-1956

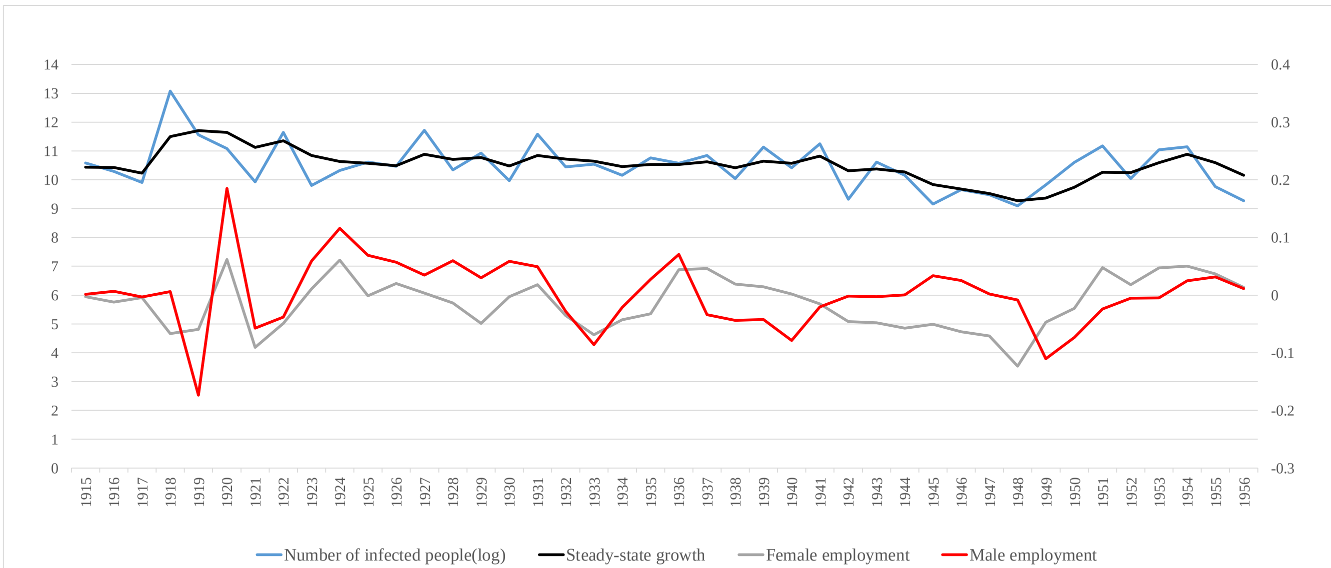


Figure 3: Flu morbidity shock

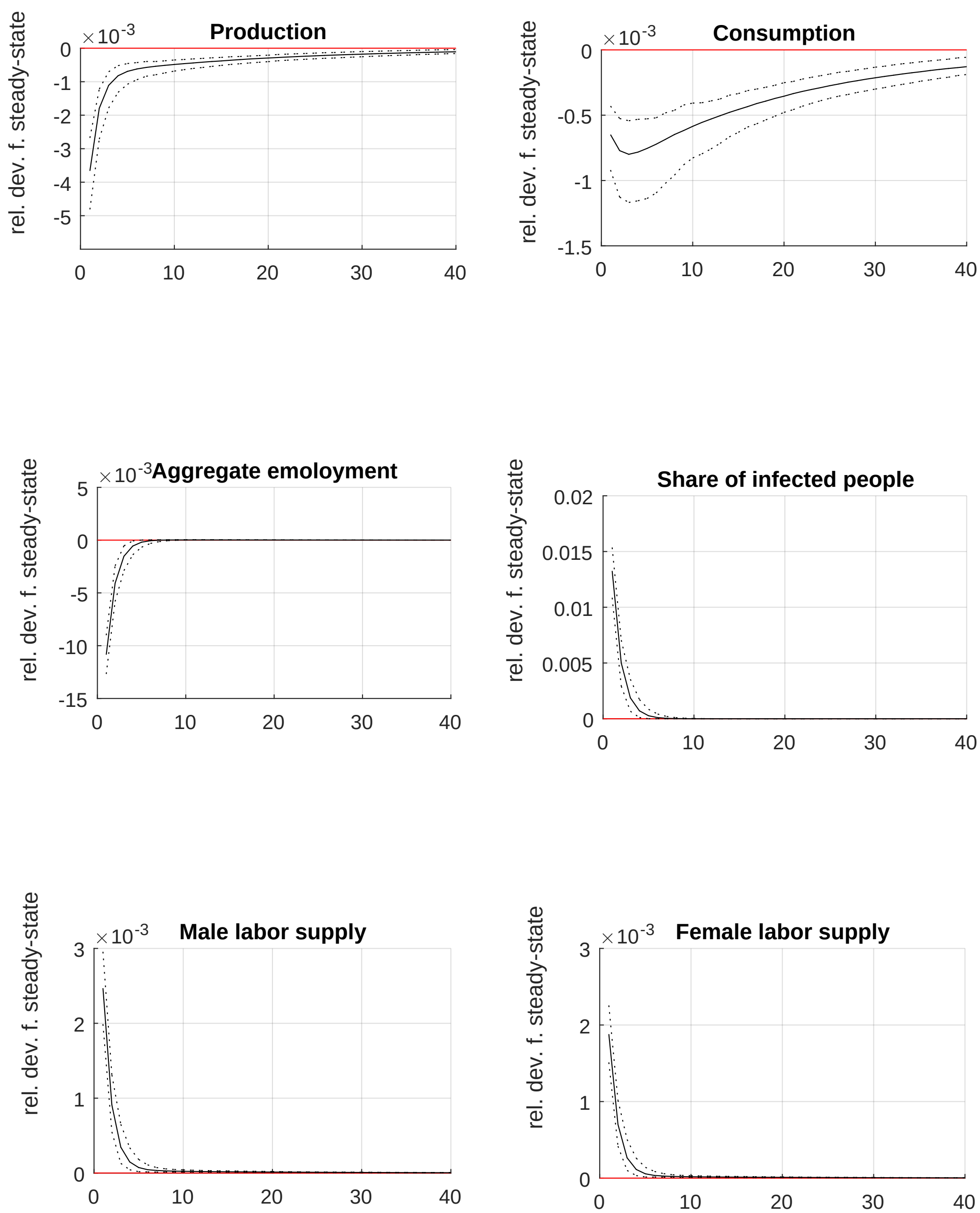


Figure 4: Negative neutral technology shock

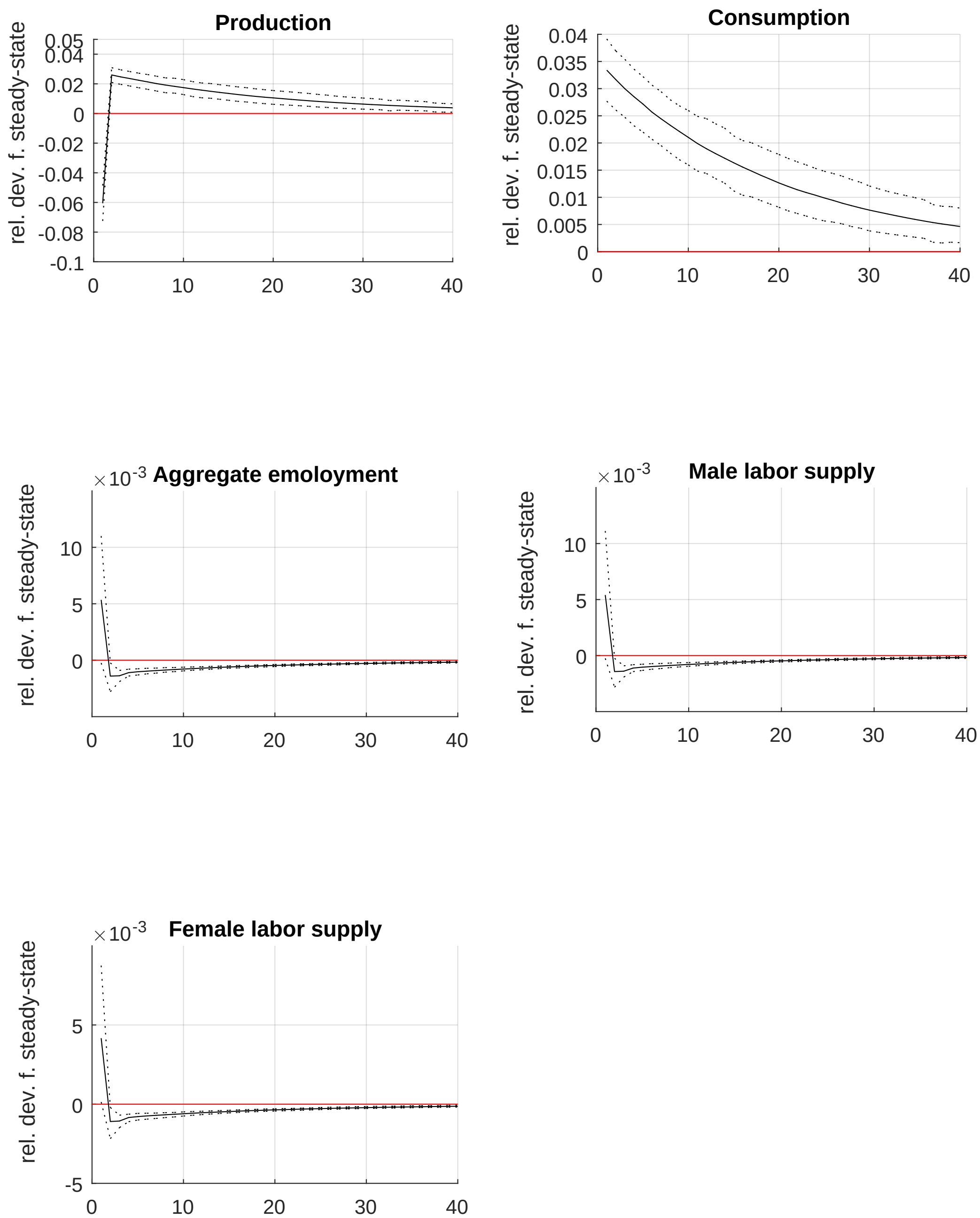


Figure 5: Preference shock

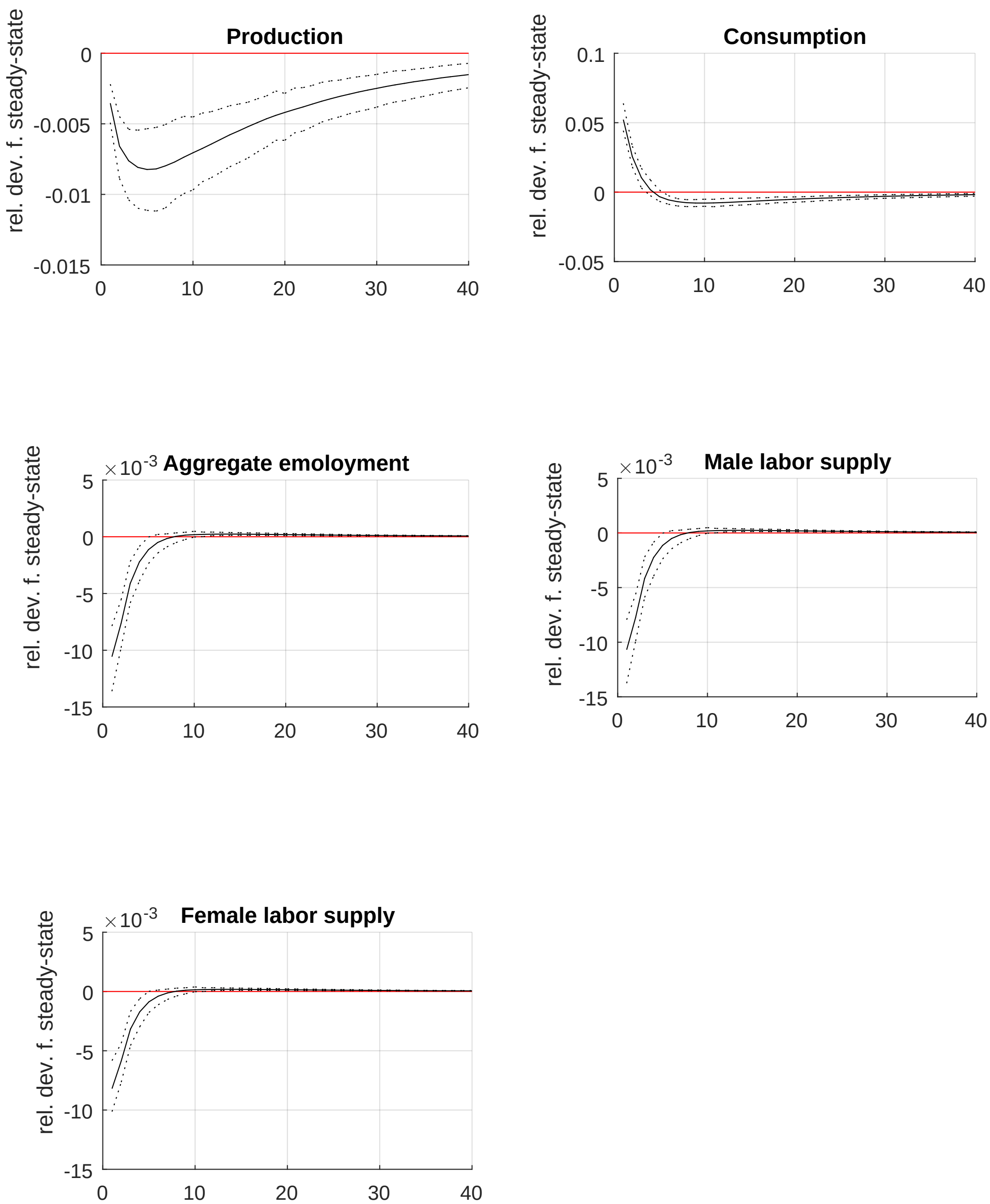


Figure 6: Male labor disutility shock

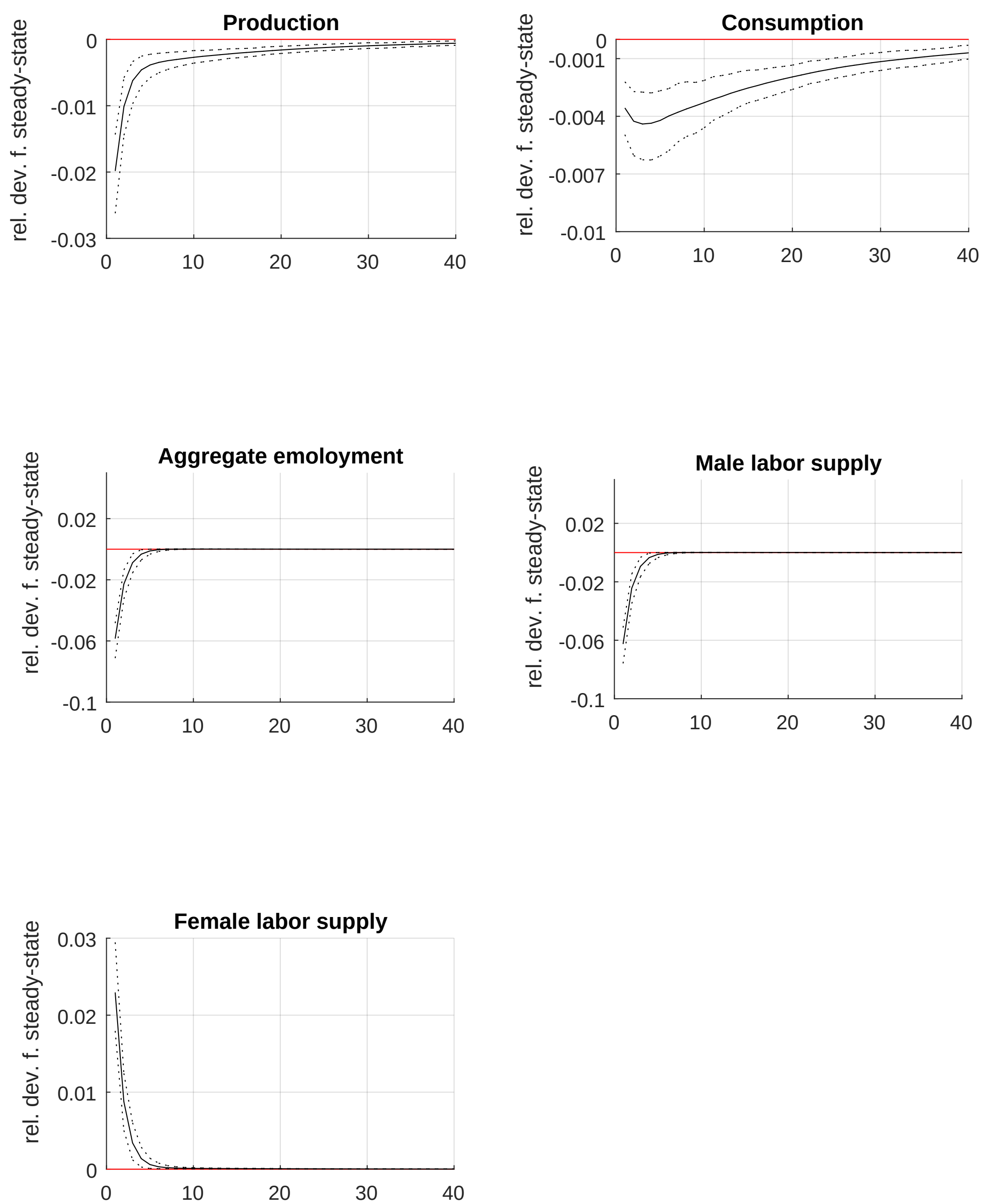


Figure 7: Female labor disutility shock

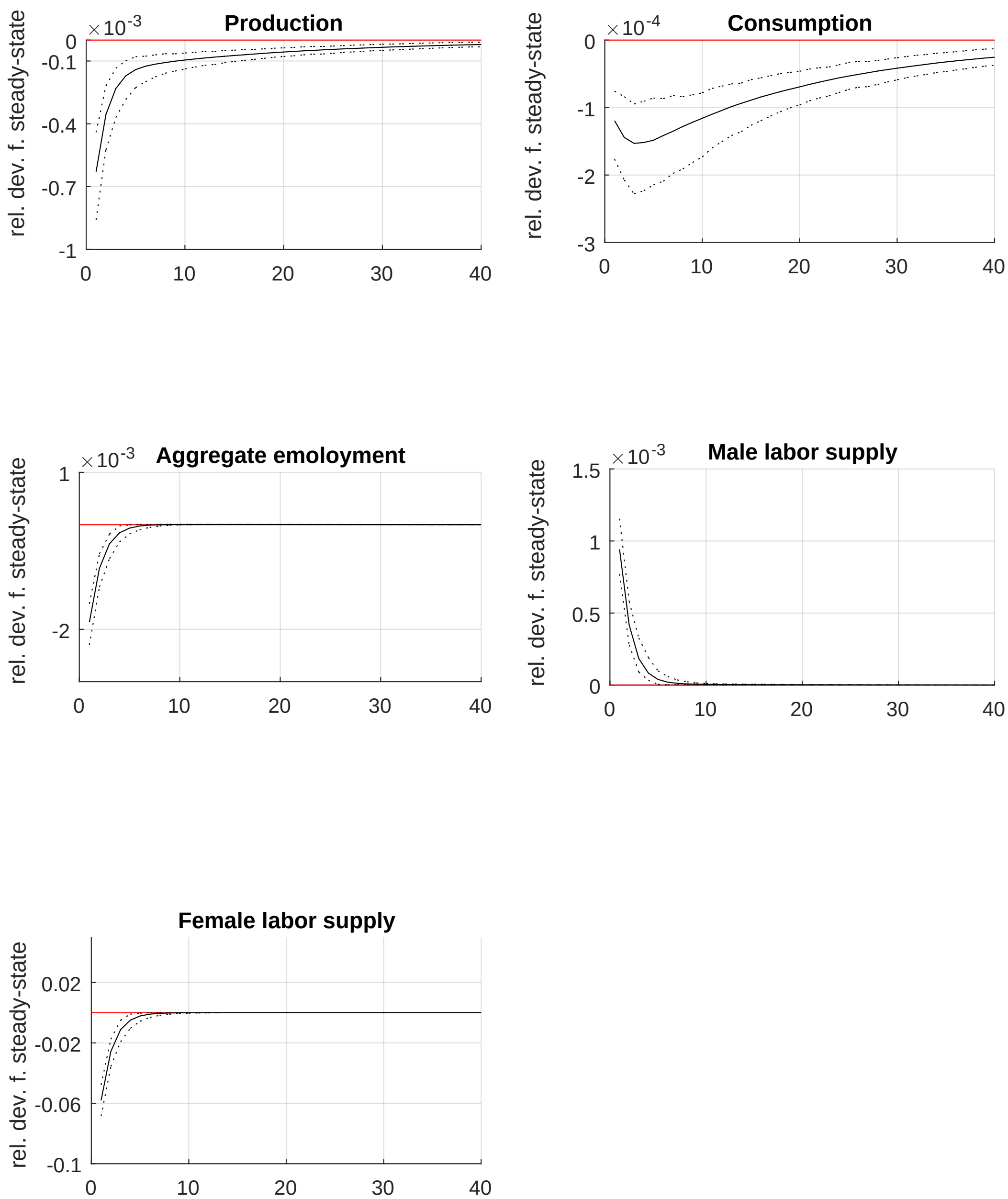


Figure 8: Historical decomposition of output

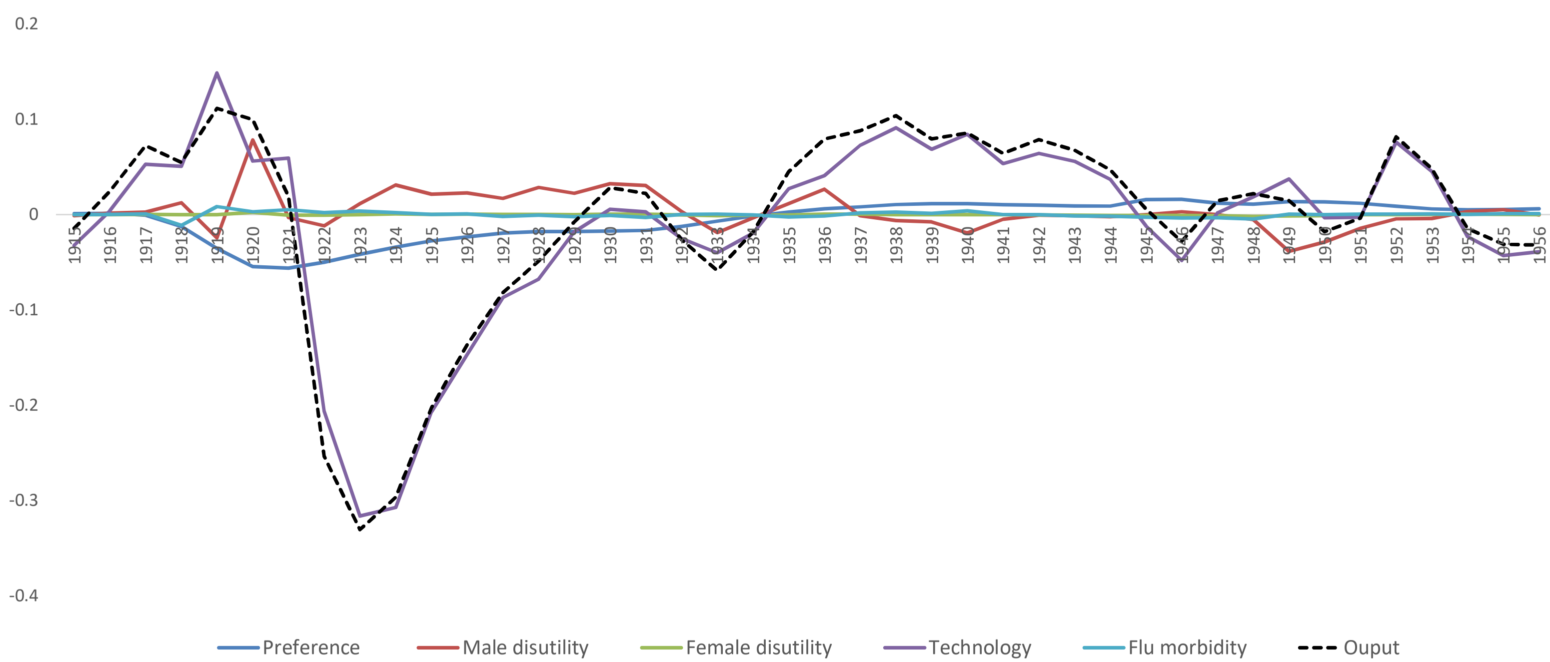


Figure 9: Historical decomposition of male labor supply

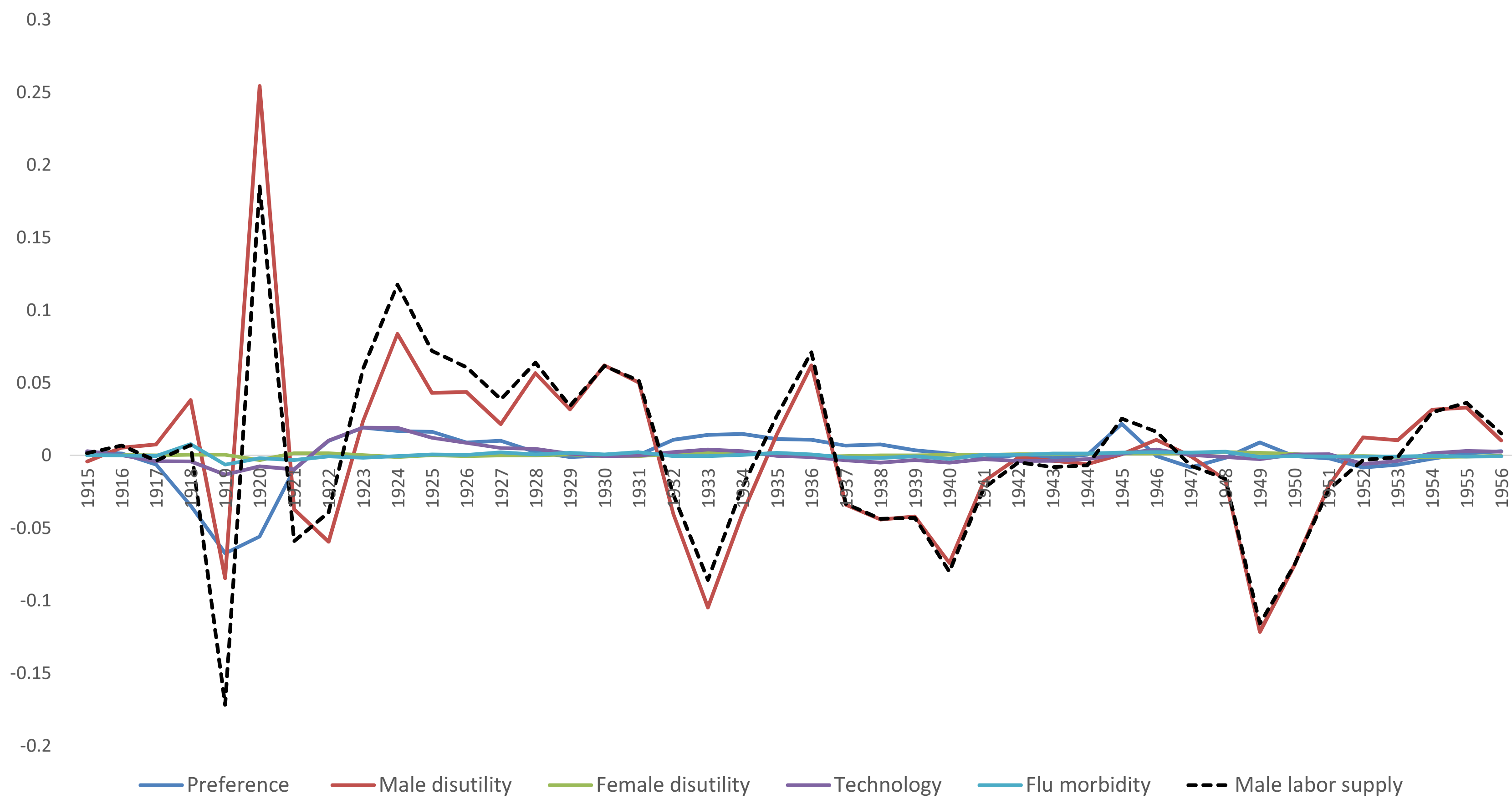


Figure 10: Historical decomposition of female labor supply

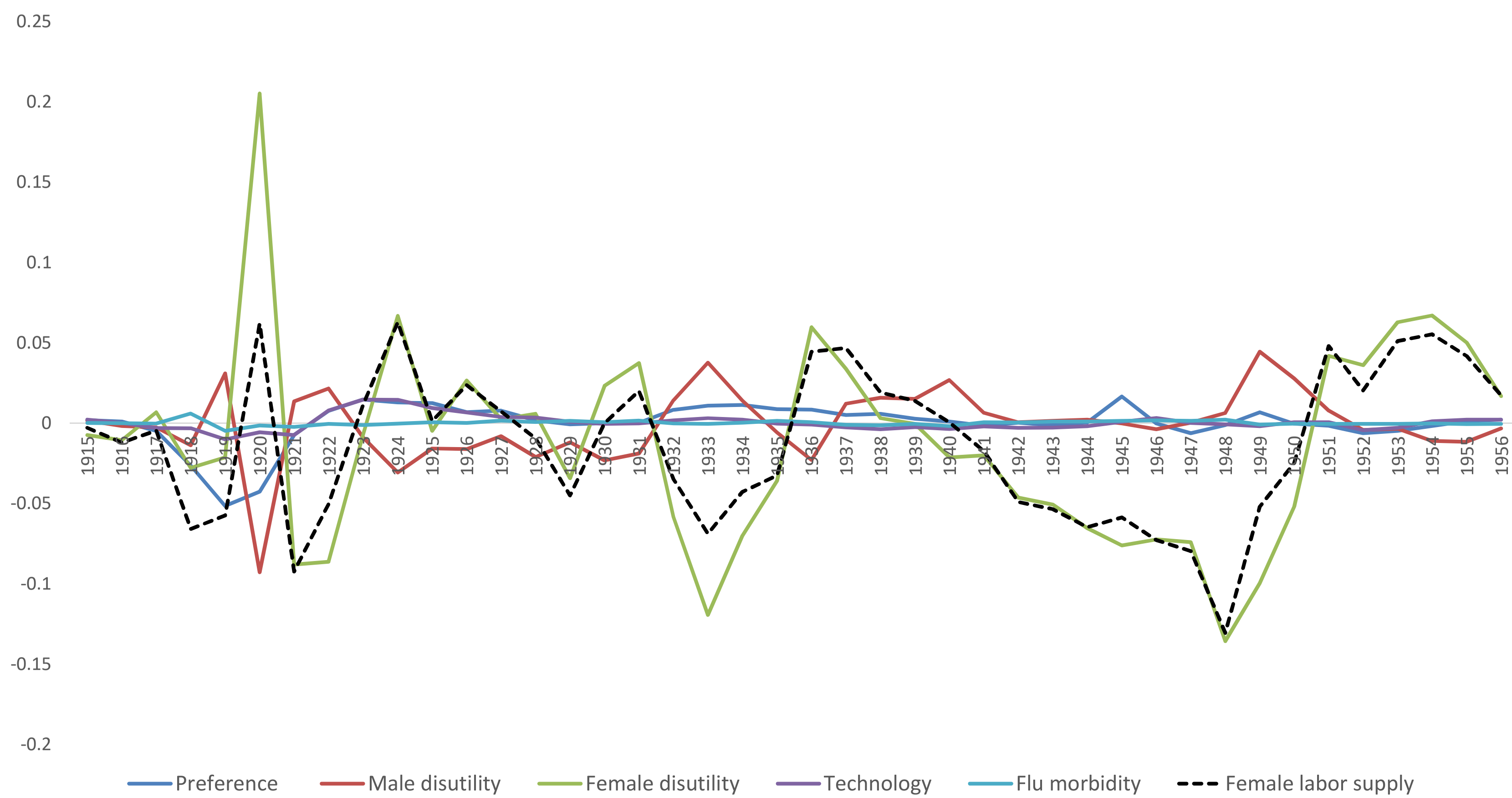
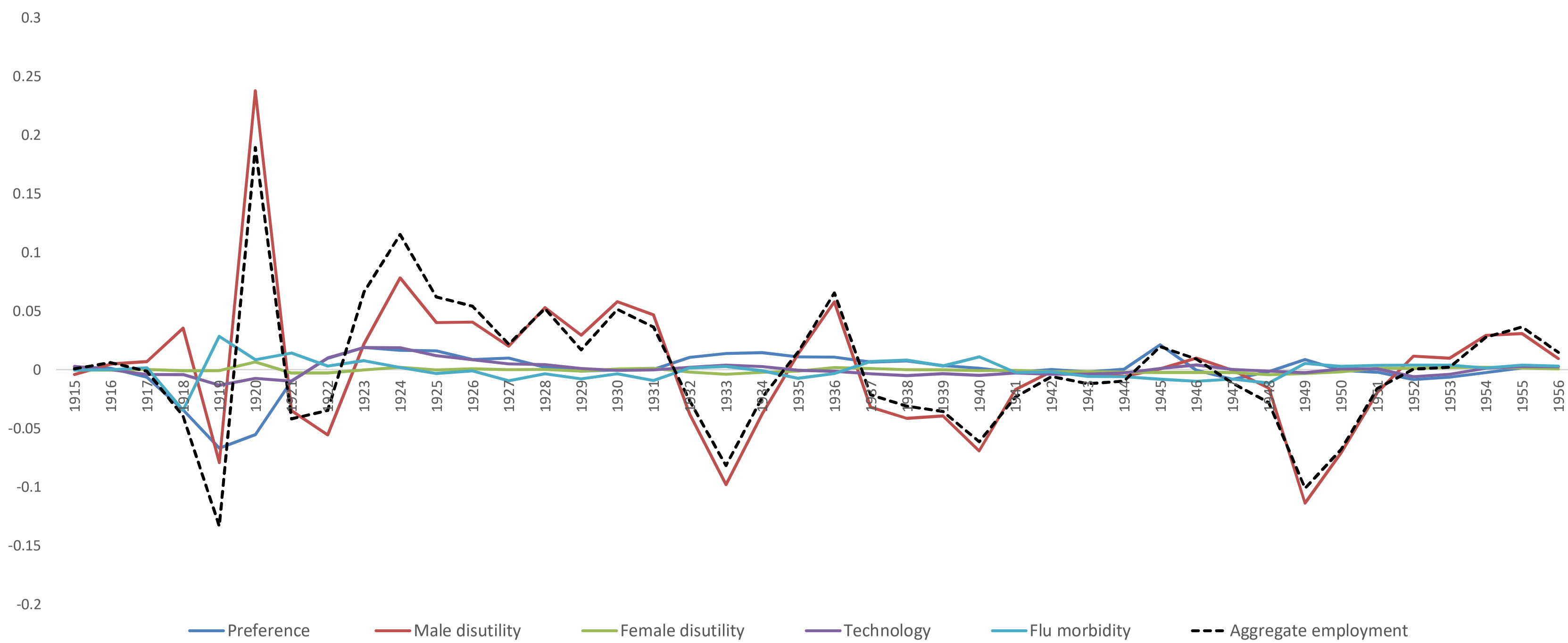


Figure 11: Historical decomposition of aggregate employment



7. Appendix

In this section we present the estimated posteriors shapes, the Stephen P. Brooks and Andrew Gelman (1998) convergence statistics for our Markov Chain Monte Carlo (MCMC) procedure as well as the results of our sensitivity analysis that we did not present in the main part of this paper for the sake of brevity. Additionally, more in-depth information is given on Bayesian estimation and pruning.

7.1. Posterior distributions

The estimated posterior distributions plotted along with the posterior mode and prior distributions of the structural parameters are displayed in Figure 12, 25 and 26. Distinct priors and posteriors indicate that the data is fairly informative (except for Taylor rule parameters that cannot be predicted through our data). It is also observed that the posterior distributions (solid black line) display a normal form. In addition, they are not unreasonably different from prior distributions (gray solid line). Moreover, the posterior modes correspond to the peak of the posterior distributions (green dashed line).

7.2. Monte Carlo Markov Chain (MCMC) convergence

MCMC univariate and multivariate convergence diagnostics (proposed by Stephen P. Brooks and Andrew Gelman, 1998), which are commonly applied as diagnostic tools for assessing the convergence of the posterior distribution, are plotted in the Figures 15 to 25and in Figure 26. Through this procedure, we compute and compare the between-chain and within-chain variance of the sample mean, and a fraction within a certain confidence interval of the simulated draws for each parameter (univariate convergence diagnostics). Then, we do the same for all the parameters together (multivariate convergence diagnostics) over all generated MCMC sequences/chains. Upon the convergence of the Markov chains, these two calculated inferences are supposed to be equal. Accordingly, the figures below clearly suggest that all three measures of the parameters' moments (including the 80 percent interval, and the second and third moments) are horizontally stable and converging within (represented by the red line) and between (represented by the blue line) the chains. As also shown, the multivariate convergence is attained after less than 10,000 iterations. In general, the results confirm the validity of our estimates.

7.3. Sensitivity analysis

To test the sensitivity of our model with regard to the flu shock, we replaced the morbidity and mortality shocks with a single mortality shock. In the regular run, the morbidity shock clearly outpaces the mortality shock, as only a minority of infected eventually die. We see that the death of infected clearly reduces aggregate employment (Figure 29) but has only a minor impact on the labor supply of males (Figure 27) and females (Figure 28). The sensitivity analyses, therefore, seems to confirm that the added worker effect is foremost a reaction on the illness related decline in labor provision of the partner.

7.4. Bayesian estimation

In the Bayesian approach, the posterior distribution of the model's parameters is characterized based on the priors and the data. According to Bayes' theorem, the posterior distribution of the structural parameters is computed as:

$$p(\theta \mid y) = \frac{L(y \mid \theta)p(\theta)}{\int L(y \mid \theta)p(\theta)d\theta} \propto L(y \mid \theta)p(\theta),$$

where $p(\theta)$ is the prior density of the parameter vector θ, and $\int L(y \mid \theta)p(\theta)d\theta$ is the marginal likelihood of y .

A Markov Chain Monte Carlo (MCMC) Metropolis-Hastings (MH) algorithm is employed to draw random chains of parameters θ_i from the posterior distribution under the assumption of normality:

$$\theta_i = N(\theta_{i-1}, \sigma\Omega),$$

where Ω is the inverse of the Hessian of the posterior kernel, computed at the posterior mode, and σ is a scaling parameter denoting the variance of the jumps within the MCMC chains.

As we apply a non-linear model, the likelihood function $L(y \mid \theta)$ is evaluated by the sequential Monte Carlo filter (Particle filter) proposed by Fernández-Villaverde and Rubio-Ramírez (2005).

7.5. Pruning

In the following, an algorithm developed by Kim et al. (2008) for generating the second order approximation to the solution to a DSGE model using the perturbation method and pruning is briefly described.[12]

The model is assumed to take the general form as:

$$K_{n\times 1}(w_{tn\times 1}, w_{t-1n\times 1}, \sigma\varepsilon_{tm\times 1}) + \Pi\sigma\eta_{tp\times 1} = 0, \tag{35}$$

where $E_t\eta_{t+1} = 0$ and $E_t\varepsilon_{t+1} = 0$, w_t is a vector of variables of the model, including control and predetermined state variables, ε_t is exogenous innovations, and η_t is a function of ε_t at the solution of the model, provided that the solution exists and is unique. σ is the scale factor or perturbation parameter that scales the square root of the covariance matrix Ω for ε_t.

The second-order Taylor expansion of the model around the steady-state $\bar{w}$ reads as follows:

$$\begin{aligned} K_{1ij}dw_{jt} = &-K_{2ij}dw_{j,t-1} - K_{3ij}\sigma\varepsilon_{jt} + \Pi_{ij}\eta_{jt}, \\ &-\frac{1}{2}(K_{11ijk}dw_{jt}dw_{kt} + 2K_{12ijk}dw_{jt}dw_{k,t-1} + 2K_{13ijk}dw_{jt}\sigma\varepsilon_{kt} \\ &+ K_{22ijk}dw_{j,t-1}dw_{k,t-1} + 2K_{23ijk}dw_{j,t-1}\sigma\varepsilon_{kt} + K_{33ijk}\sigma^2\varepsilon_{jt}\varepsilon_{kt}), \end{aligned} \tag{36}$$

where array K_{mij} refers to the first derivatives and array K_{mnijk} refers to the second derivatives.

The equation can be transformed to the following equations:

[12] All equations drawn from Kim et al. (2008)

$$\begin{aligned} dy_{it} = & G_{1ij} dx_{jt} + G_{2ijd} v_{j,t-1} + G_{3ij} \sigma \varepsilon_{jt} \\ & + \frac{1}{2}(G_{11ijk} dv_{jt} dv_{kt} + 2G_{12ijk} dv_{jt} dv_{k,t-1} + 2G_{13ijk} dv_{jt} \sigma \varepsilon_{kt} \\ & + G_{22ijk} dv_{j,t-1} dv_{k,t-1} + 2G_{23ijk} dv_{j,t-1} \sigma \varepsilon_{kt} + G_{33ijk} \sigma^2 \varepsilon_{jt} \varepsilon_{kt}), \end{aligned} \tag{37}$$

$$\begin{aligned} J_{1ij} dx_{jt} = & J_{2ij} dx_{j,t-1} + J_{3ij} \sigma \varepsilon_{jt} + \Pi * \eta_t \\ & + \frac{1}{2}(J_{11ijk} dv_{jt} dv_{kt} + 2J_{12ijk} dv_{jt} dv_{k,t-1} + 2J_{13ijk} dv_{jt} \sigma \varepsilon_{kt} \\ & + J_{22ijk} dv_{j,t-1} dv_{k,t-1} + 2J_{23ijk} dv_{j,t-1} \sigma \varepsilon_{kt} + J_{33ijk} \sigma^2 \varepsilon_{jt} \varepsilon_{kt}), \end{aligned} \tag{38}$$

where $dv = [dy, dx]$.
The solution to the model is subsequently given by:

$$y_t = F(y_{t-1}, x_{t-1}, \sigma\varepsilon_t, \sigma) \tag{39}$$

$$x_t = h(y_t, s), \tag{40}$$

for the state variables y_t and the control variables x_t.
The second-order expansion of the solution is written as:

$$dy_{it} = F_{1ij} dv_{j,t-1} + F_{2ij} \sigma \varepsilon_{jt} + F_{3i} \sigma^2 \tag{41}$$

$$+ \frac{1}{2} F_{11ijk} dv_{j,t-1} dv_{k,t-1} + 2F_{12ijk} dv_{j,t-1} \sigma \varepsilon_{kt} + F_{22ijk} \sigma^2 \varepsilon_{jt} \varepsilon_{kt} \tag{42}$$

$$dx_{it} = \frac{1}{2} M_{11ijk} dy_{jt} dy_{kt} + M_2 \sigma^2. \tag{43}$$

From Equation 42 we see that dy_t is quadratic in dy_{t-1}, so dy_{t+1} is quadratic in dy_t and so forth, which successively leads to explosive time paths. However, a stable solution can be captured using the pruning method, in which the terms in the solution that have higher-order effects than the approximation order are left out (pruned). In this method, the second order terms are computed based on a first-order expansion. As a result of this adjustment, for all s, $d\hat{y}_{t+s}$ is quadratic in dy_t:

$$\begin{aligned} dy^{(2)}_{t+s} \doteq & F_{1j} dy^{(2)}_{j,t+s-1} + F_3 \sigma^2 \\ & + \frac{1}{2} F_{11jk} (dy^{(1)}_{j,t+s-1} dy^{(1)}_{k,t+s-1} + \hat{\Sigma}_{k-1,jk}) + \frac{\sigma^2}{2} F_{22jk} \Omega_{jk} \end{aligned} \tag{44}$$

$$dx^{(2)}_{t+s} \doteq \frac{1}{2} M_{11jk} (dy^{(1)}_{j,t+s} dy^{(1)}_{k,t+s} + \hat{\Sigma}_{s,jk}) + M_2 \sigma^2 \tag{45}$$

$$dy^{(1)}_{t+s} \doteq F_{1j} dy^{(1)}_{j,t+s-1} \tag{46}$$

$$\hat{\Sigma}_{ij,s} = \sigma^2 F_{2ik} \Omega_{kl} F_{2jl} + F_{1ik} \hat{\Sigma}_{kl,s-1} F_{1jl}, \tag{47}$$

where (1) and (2) in the powers respectively denote the first and second order accurate solutions.

Table 4: Prior and posterior distributions of the estimated parameters (sensitivity check)

Description		Prior Distribution			Posterior Distribution			
	Parameter	Density	Mean	Std. Dev.	Mean	Std. Dev.	10%	90%
Discount factor	β	Gamma	0.98	0.5e-2	0.98	2.4e-5	0.97	0.99
Capital share	α	Normal	0.30	0.10	0.66	0.003	0.59	0.72
Calvo parameter	ν	Beta	0.50	0.10	0.49	0.01	0.36	0.60
Males inverse Frisch elast.	γ_m	Normal	3.47	0.10	3.44	0.01	3.32	3.58
Females inverse Frisch elast.	γ_f	Normal	4.29	0.10	4.31	0.002	4.25	4.37
Male-female substitution elast.	ϱ	Normal	1.80	0.10	1.64	0.10	1.52	1.76
Taylor rule output	Γ_y	Normal	0.06	0.01	0.06	9.4e-5	0.05	0.07
Taylor rule inflation	Γ_{Π}	Normal	0.25	0.05	0.25	0.002	0.19	0.31
Taylor rule interest rate	Γ_R	Normal	1.10	0.25	1.31	0.03	1.11	1.53
Autorregressive coefficients of shocks								
Technology	Λ_μ	Beta	0.002	0.001	0.002	9.6e-09	0.002	0.002
Preference	ρ_d	Beta	0.50	0.10	0.59	0.005	0.49	0.68
Male labor disutility	ρ_φ	Beta	0.50	0.10	0.39	0.007	0.28	0.50
Female labor disutility	$\rho_{\varphi f}$	Beta	0.50	0.10	0.45	0.007	0.35	0.56
Flu mortality	ρ_{si}	Beta	0.50	0.10	0.49	0.007	0.27	0.49
Population	ρ_{sh}	Beta	0.50	0.10	0.54	0.009	0.42	0.67
Standard deviations of shocks								
Technology	$exp(\sigma_\mu)$	Inv gamma	0.05	1.0	0.07	6.3e-05	0.05	0.07
Preference	$exp(\sigma_d)$	Inv gamma	0.10	2.0	0.07	6.4e-05	0.06	0.08
Male labor disutility	$exp(\sigma_\varphi)$	Inv gamma	0.05	1.0	0.28	9.0e-04	0.23	0.30
Female labor disutility	$exp(\sigma_{\varphi f})$	Inv gamma	0.05	1.0	0.23	6.0e-04	0.19	0.25
Flu mortality	$exp(\sigma_{si})$	Inv gamma	0.05	0.5	0.01	2.2e-06	0.01	0.02
Population	$exp(\sigma_{sh})$	Inv gamma	0.05	0.5	0.01	3.8e-07	0.006	0.008

7.6. Tables and figures

Figure 12: Prior and posterior distributions

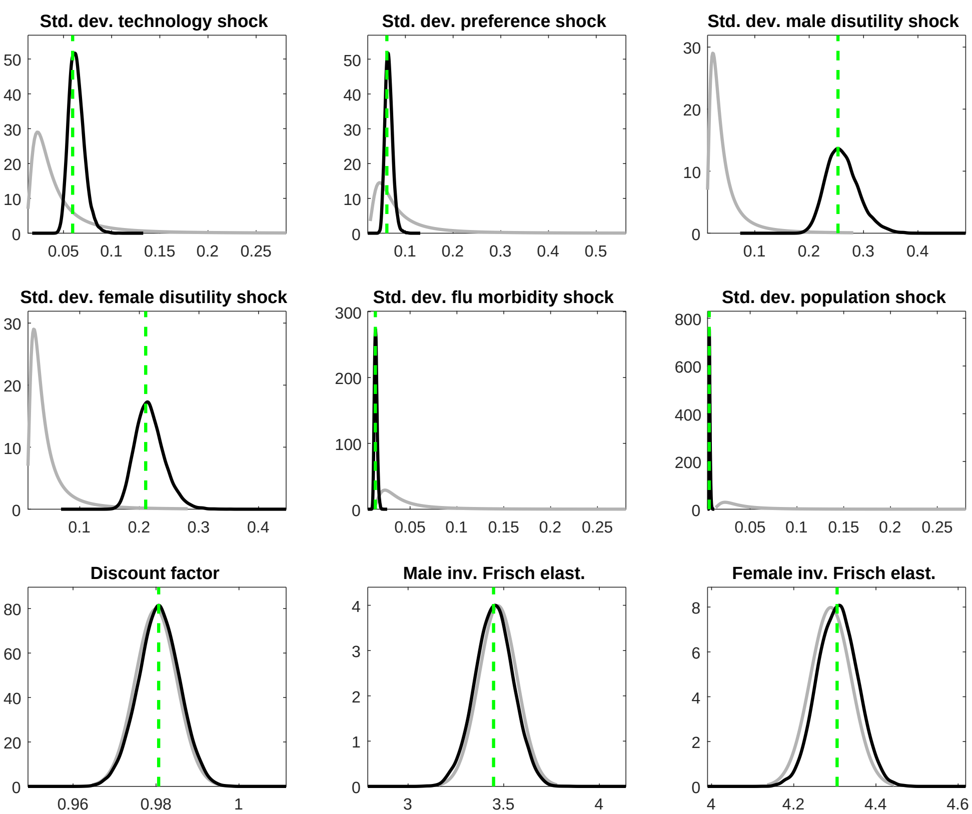


Figure 13: Prior and posterior distributions

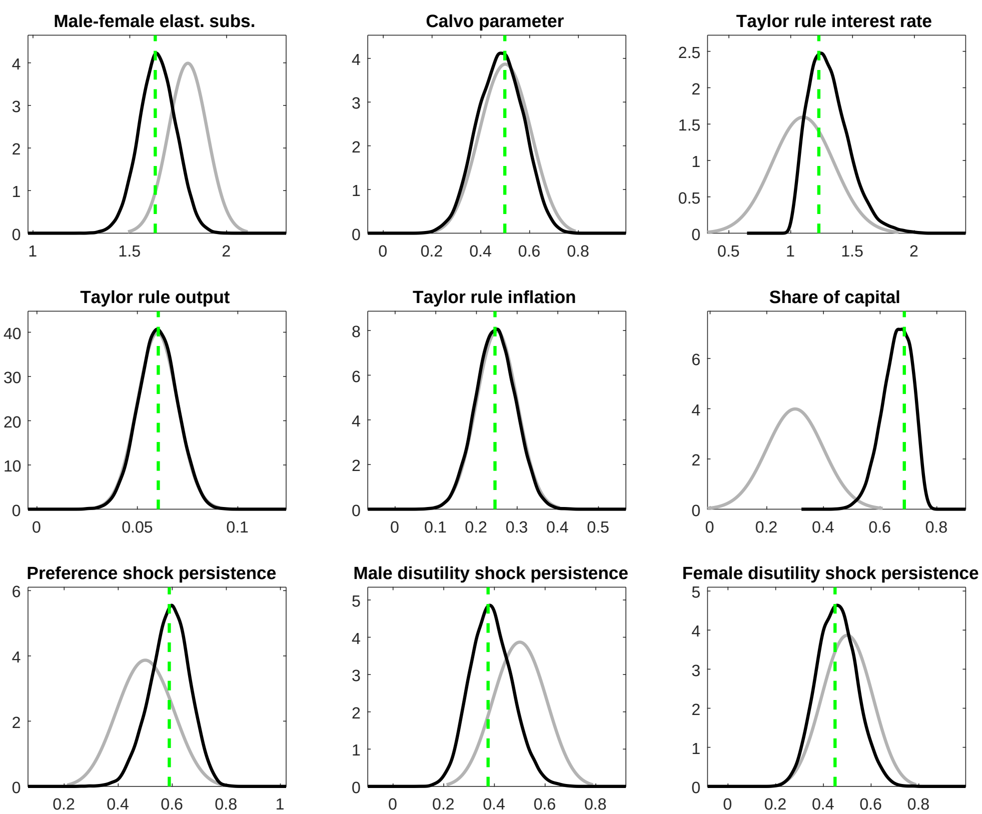


Figure 14: Prior and posterior distributions

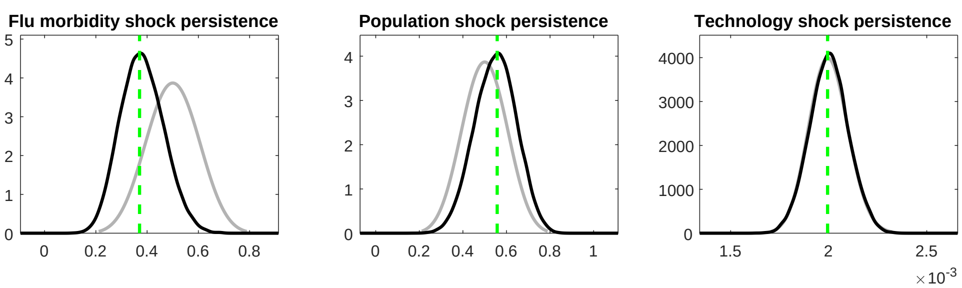


Figure 15: MCMC Univariate Convergence Diagnostics / Discount factor and male Frisch elasticity

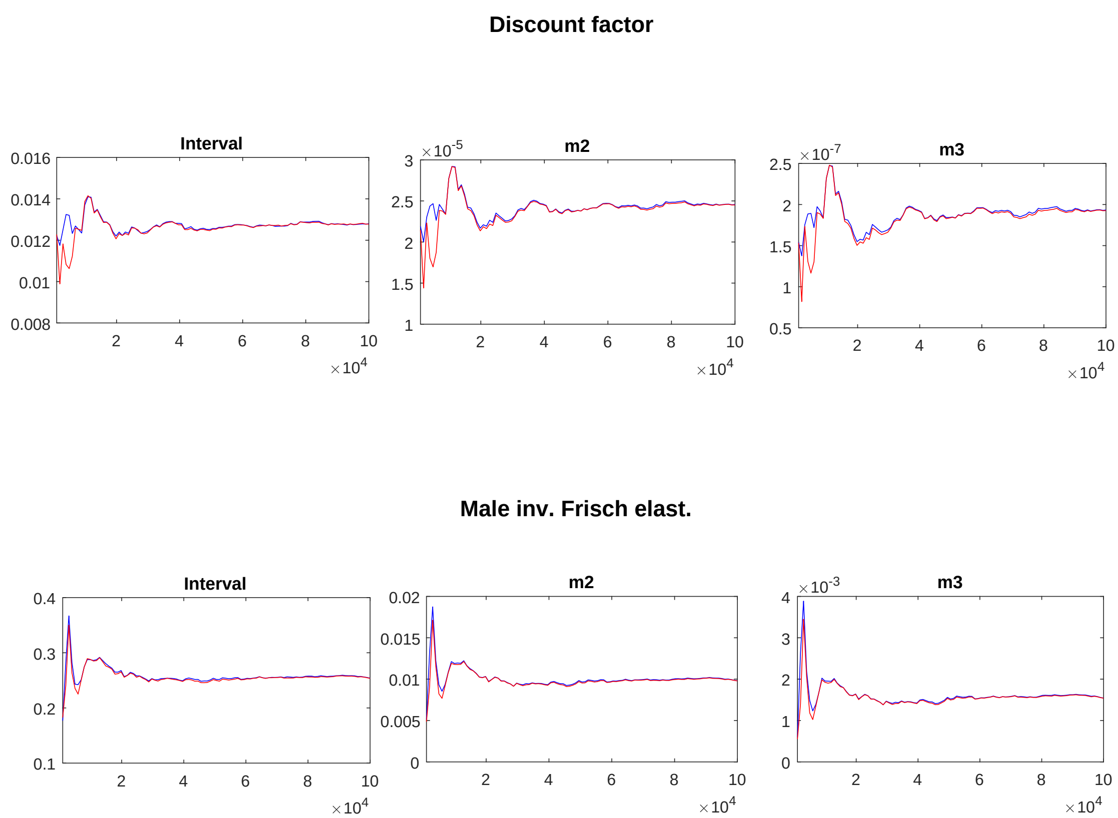


Figure 16: MCMC Univariate Convergence Diagnostics / Elasticity of substitution and female Frisch elasticity

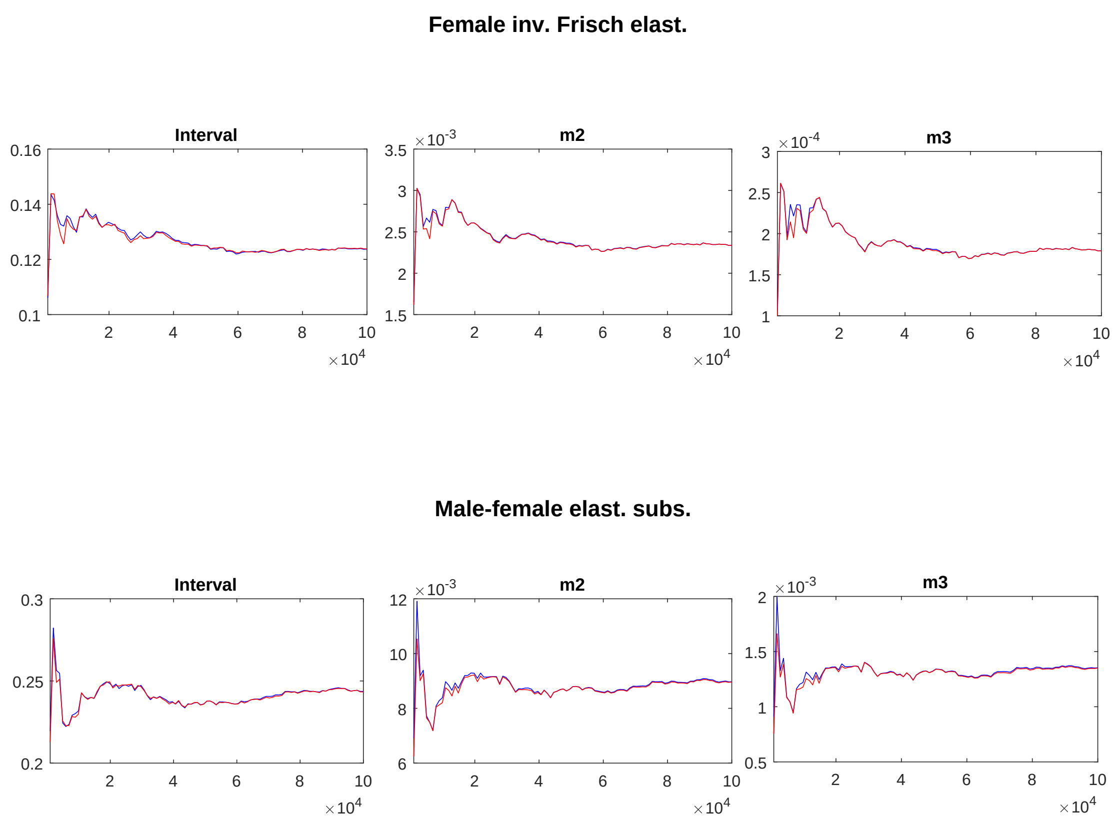


Figure 17: MCMC Univariate Convergence Diagnostics / Calvo and Taylor rule interest rate coefficient

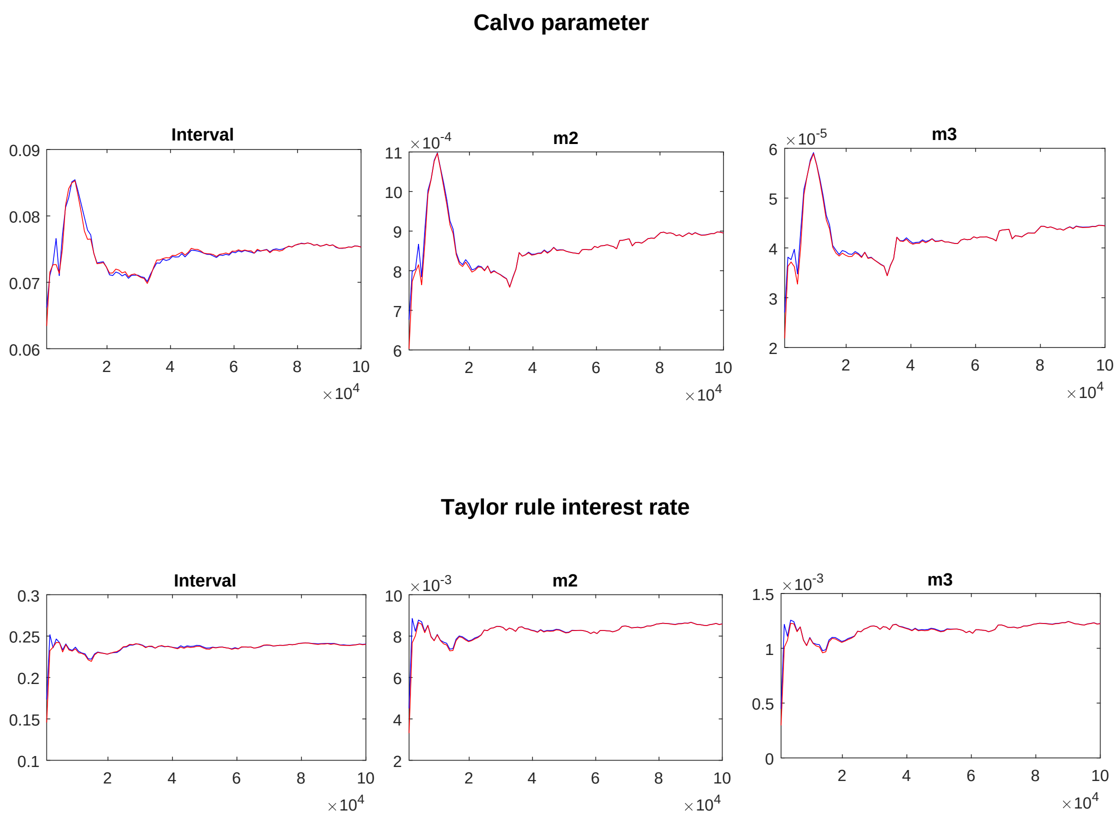


Figure 18: MCMC Univariate Convergence Diagnostics / Taylor rule output and inflation coefficient

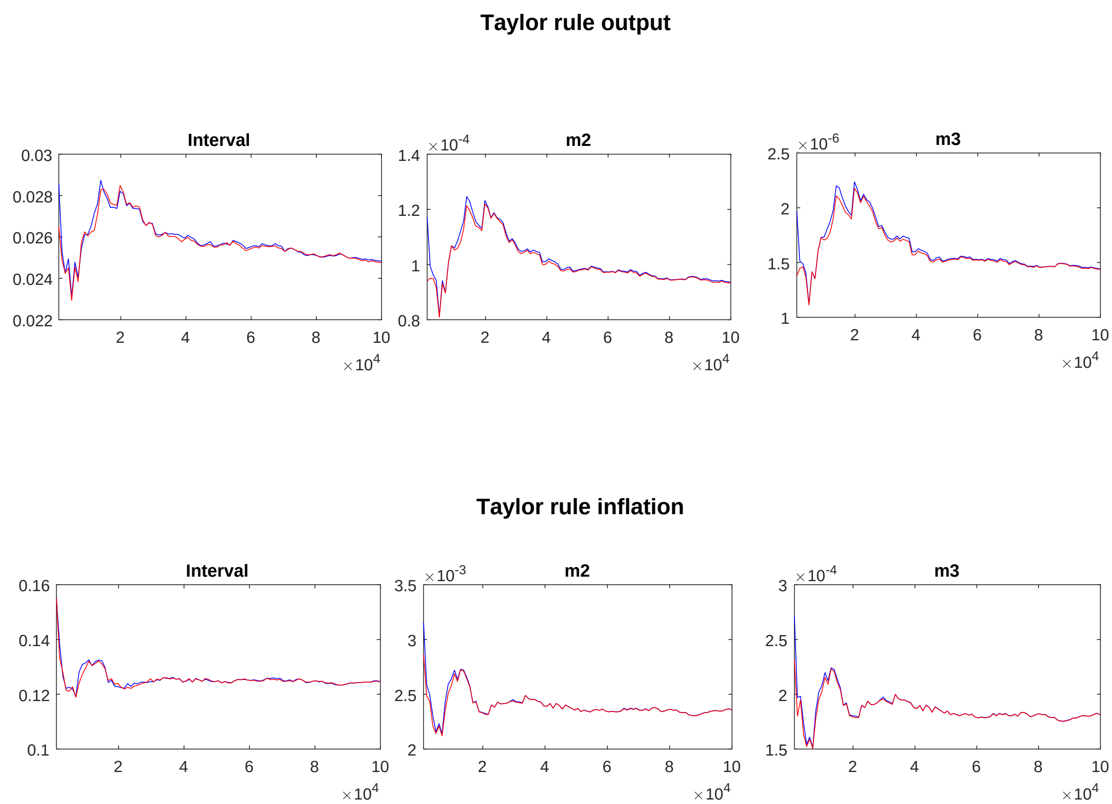


Figure 19: MCMC Univariate Convergence Diagnostics / Share of capital and preference shock persistence

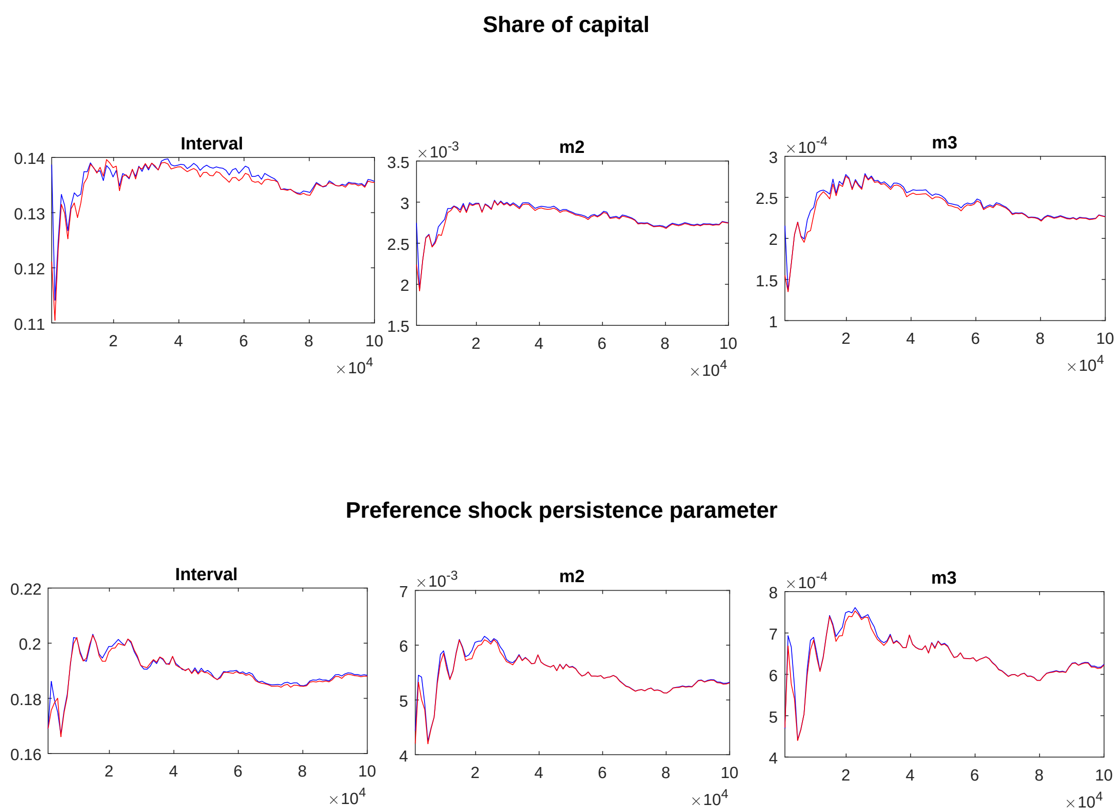


Figure 20: MCMC Univariate Convergence Diagnostics / Disutility shock persistence

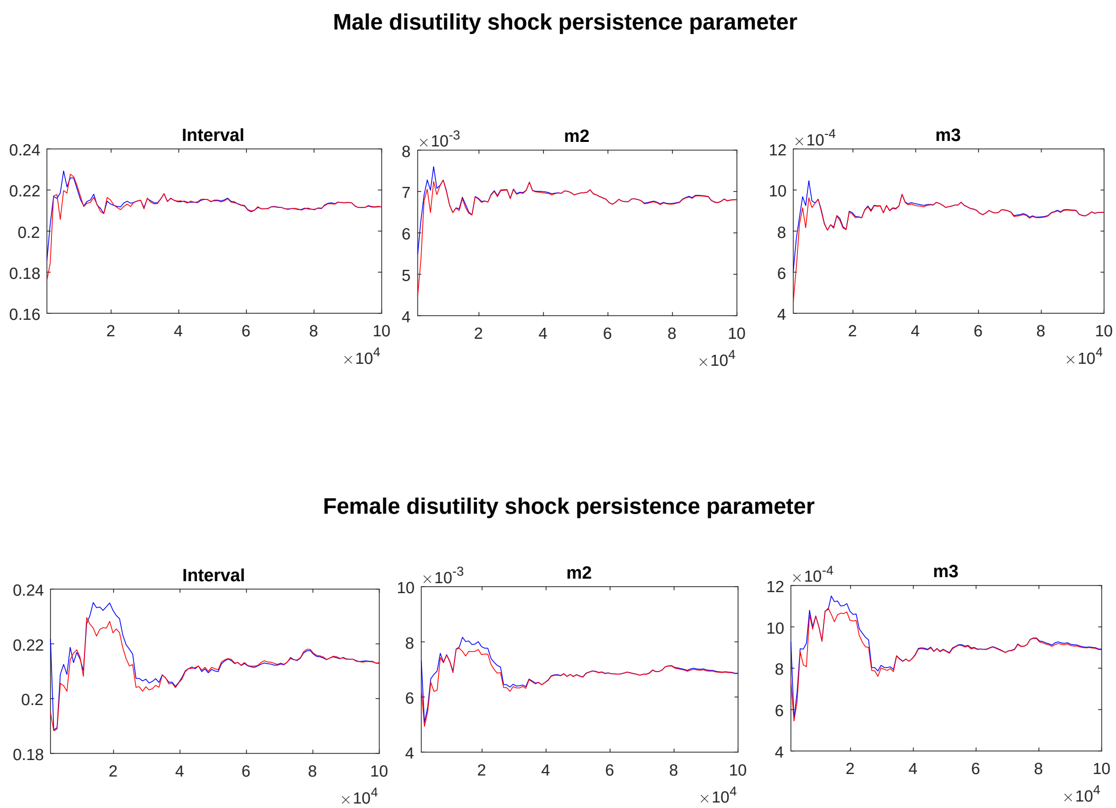


Figure 21: MCMC Univariate Convergence Diagnostics / Morbidity and population shock persistence

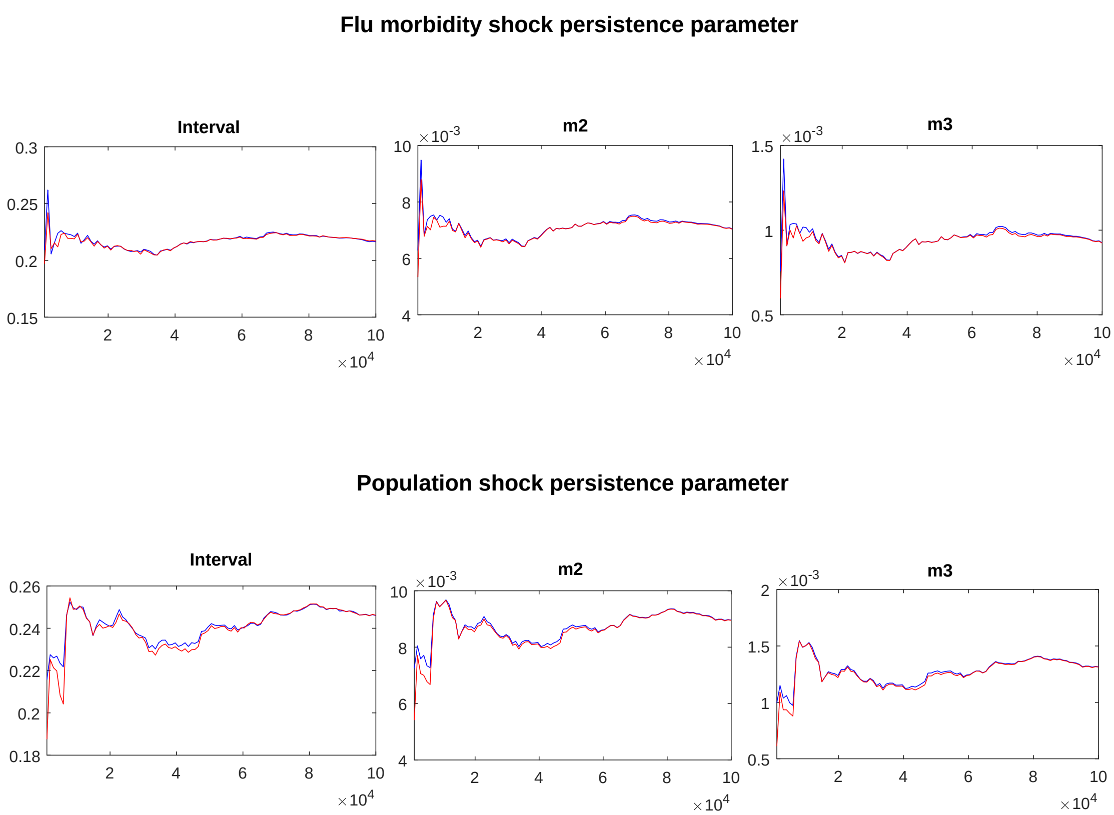


Figure 22: MCMC Univariate Convergence Diagnostics / Persistence of technology shock

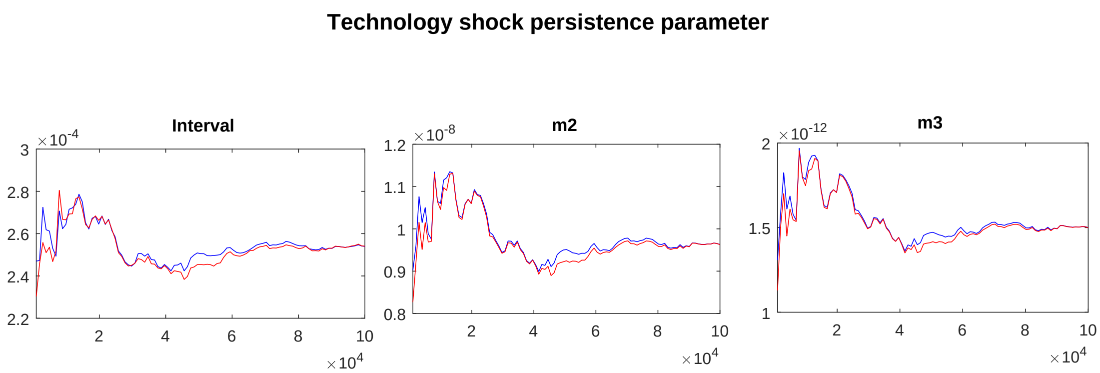


Figure 23: MCMC Univariate Convergence Diagnostics / Standard deviation technology and preference shocks

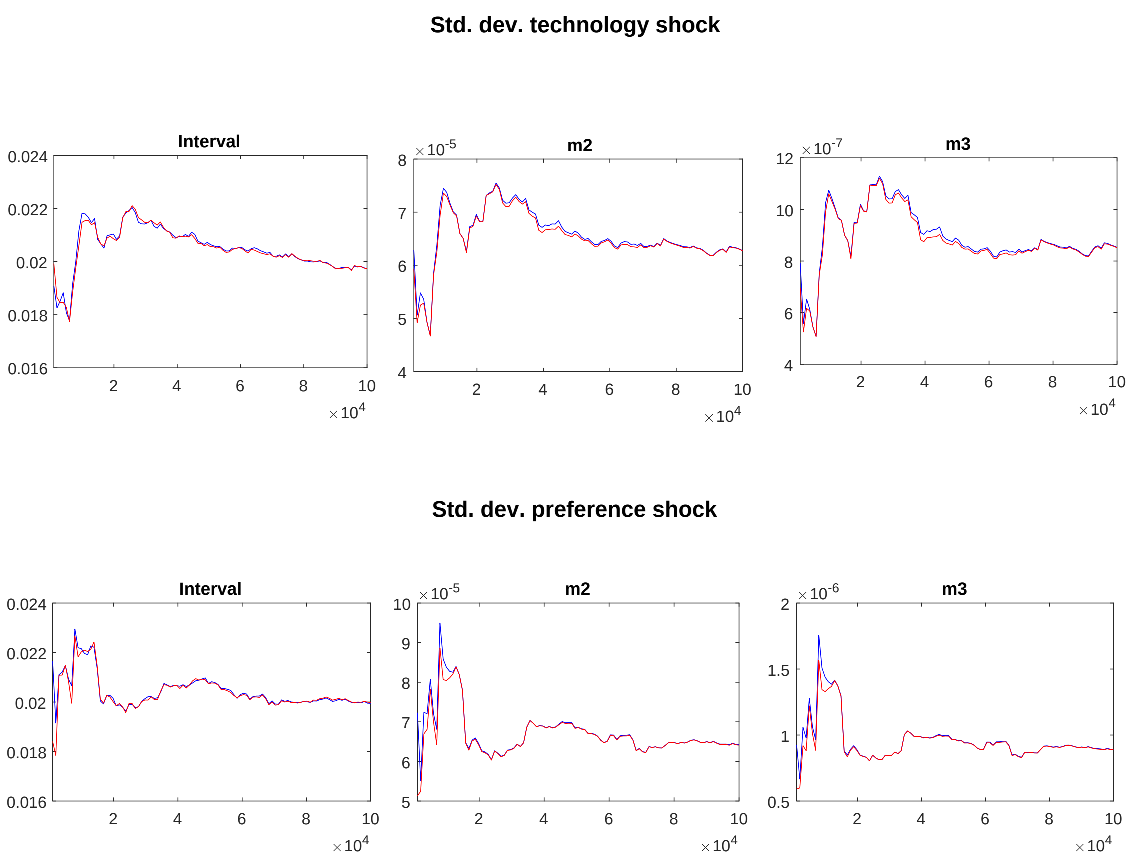


Figure 24: MCMC Univariate Convergence Diagnostics / Standard deviation disutility shocks

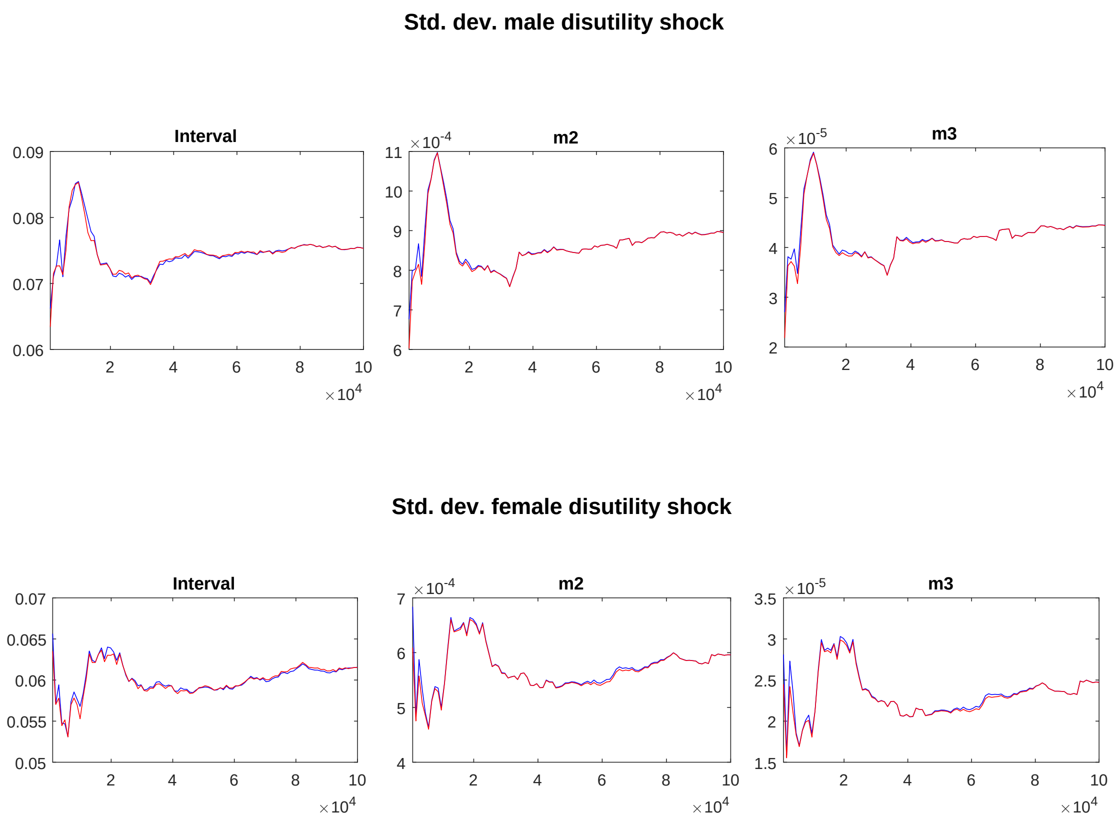


Figure 25: MCMC Univariate Convergence Diagnostics / Standard deviation flu and population shocks

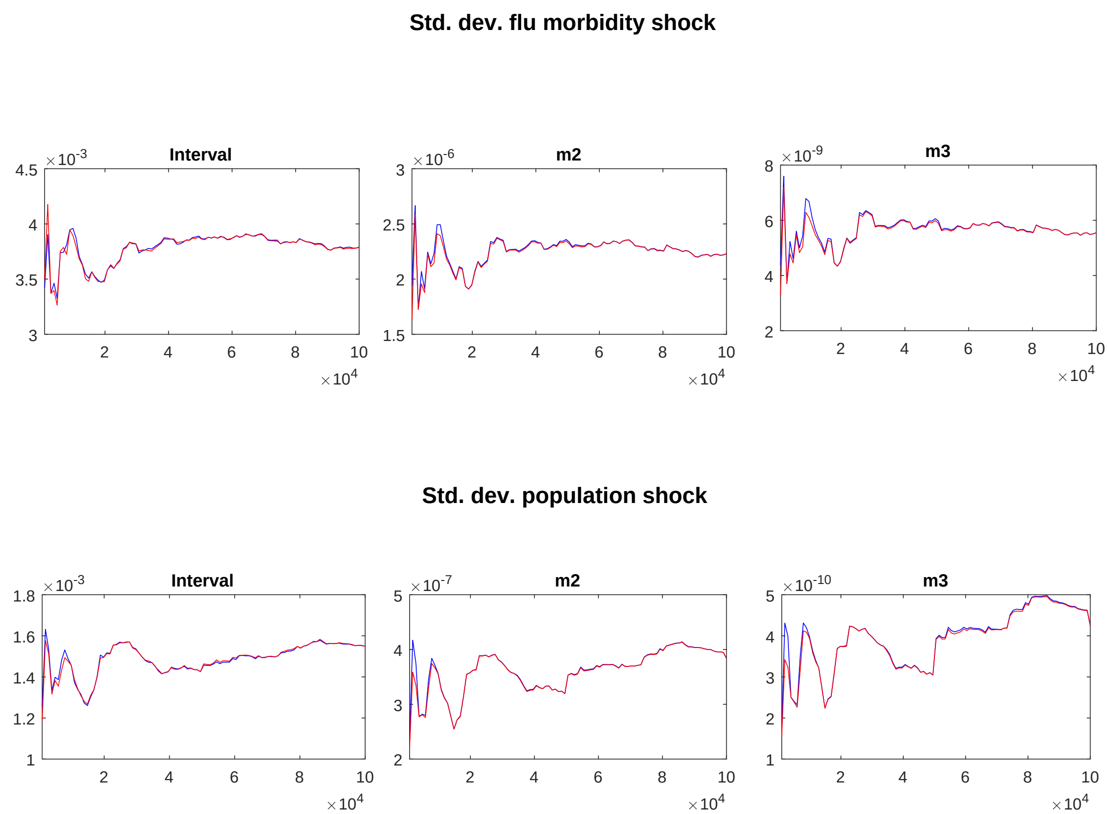
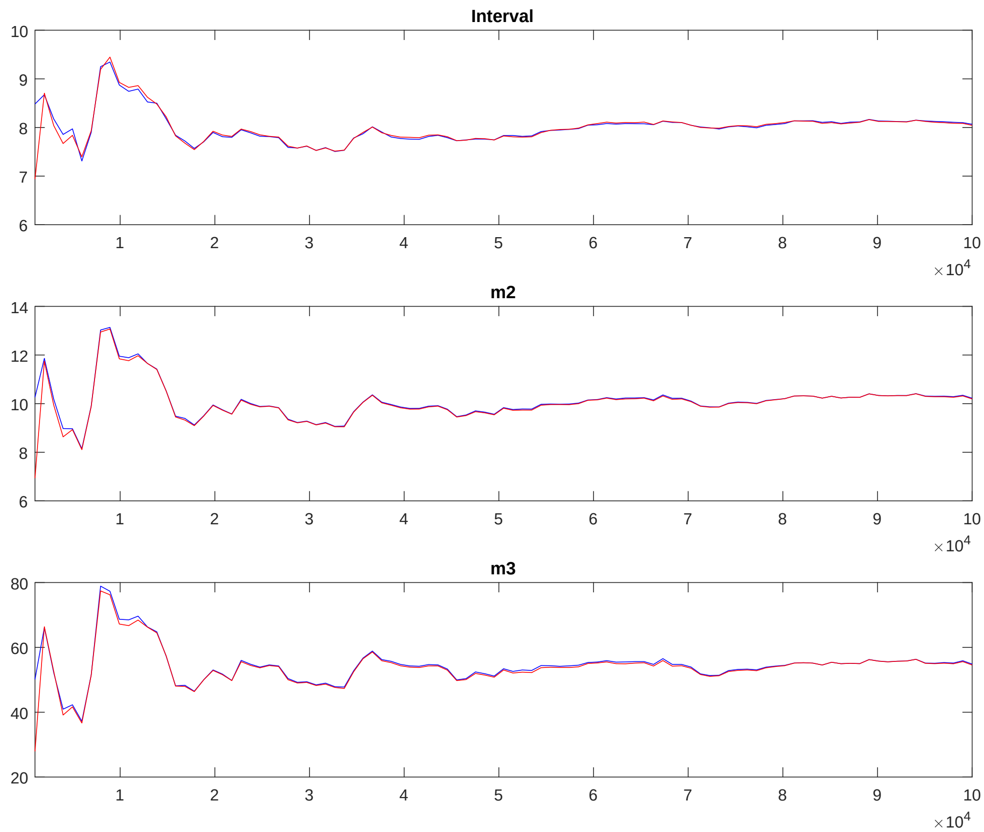


Figure 26: MCMC Multivariate Convergence Diagnostics



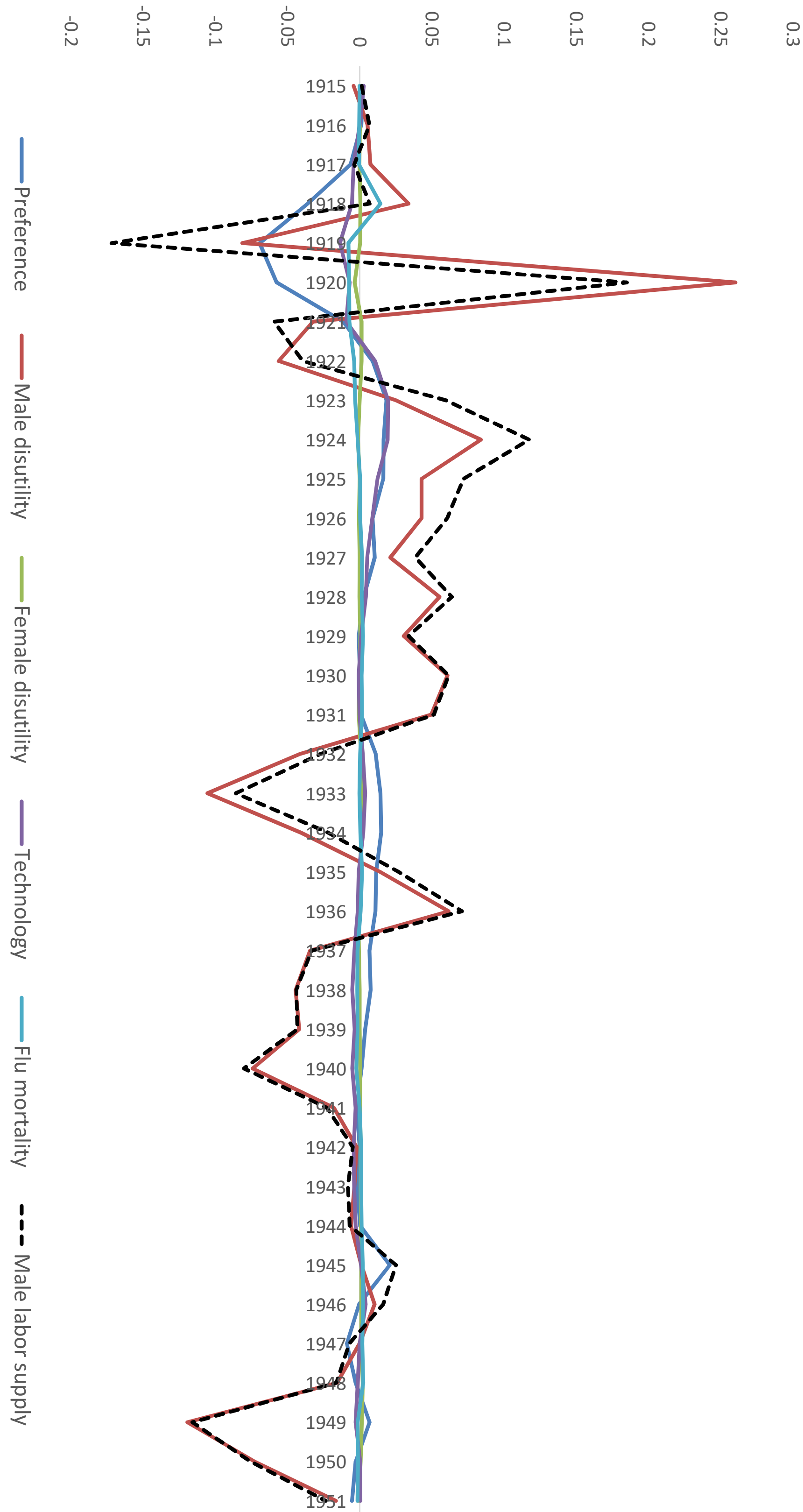


Figure 27: Estimated historical decomposition / Male labor supply (sensitivity check)

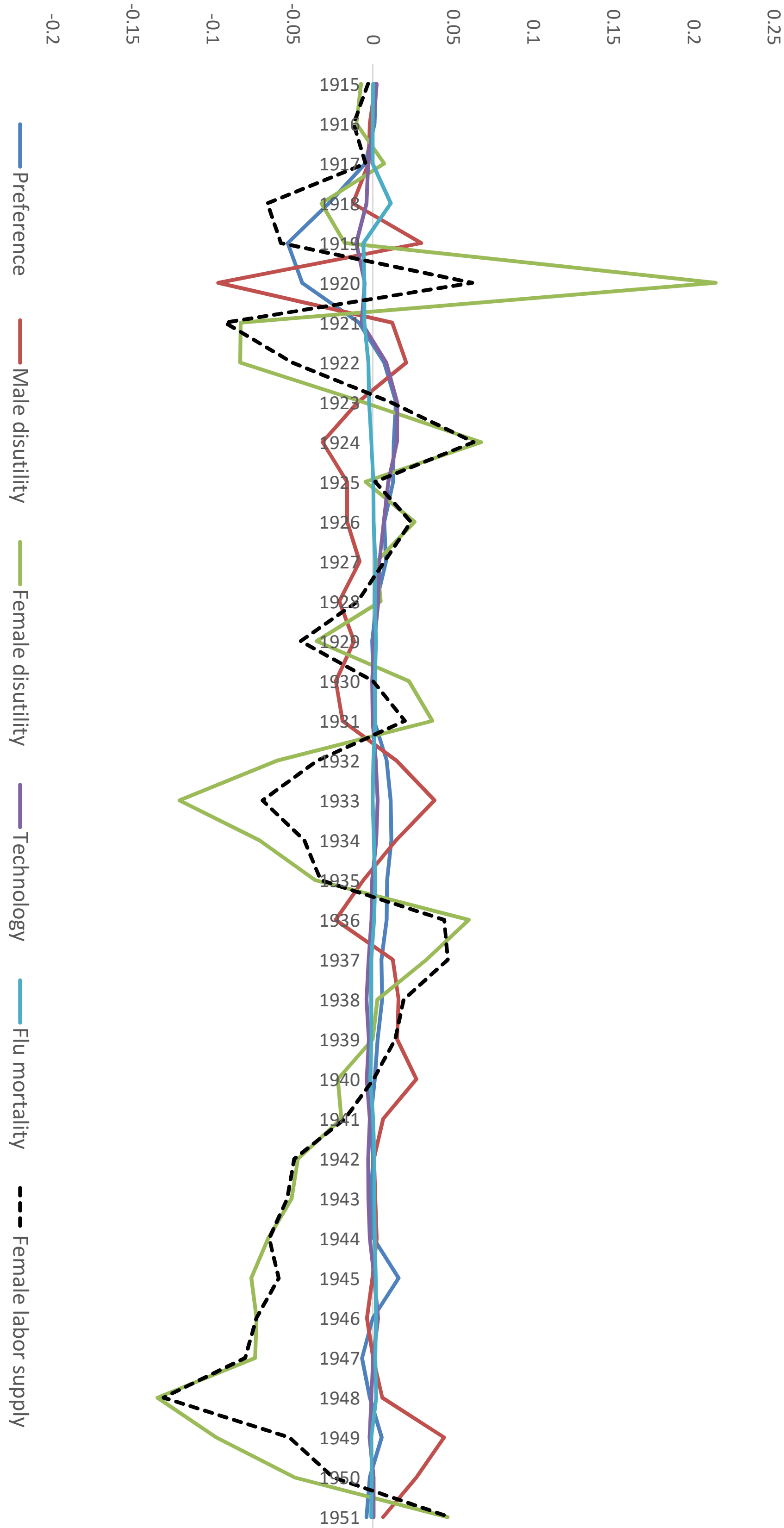
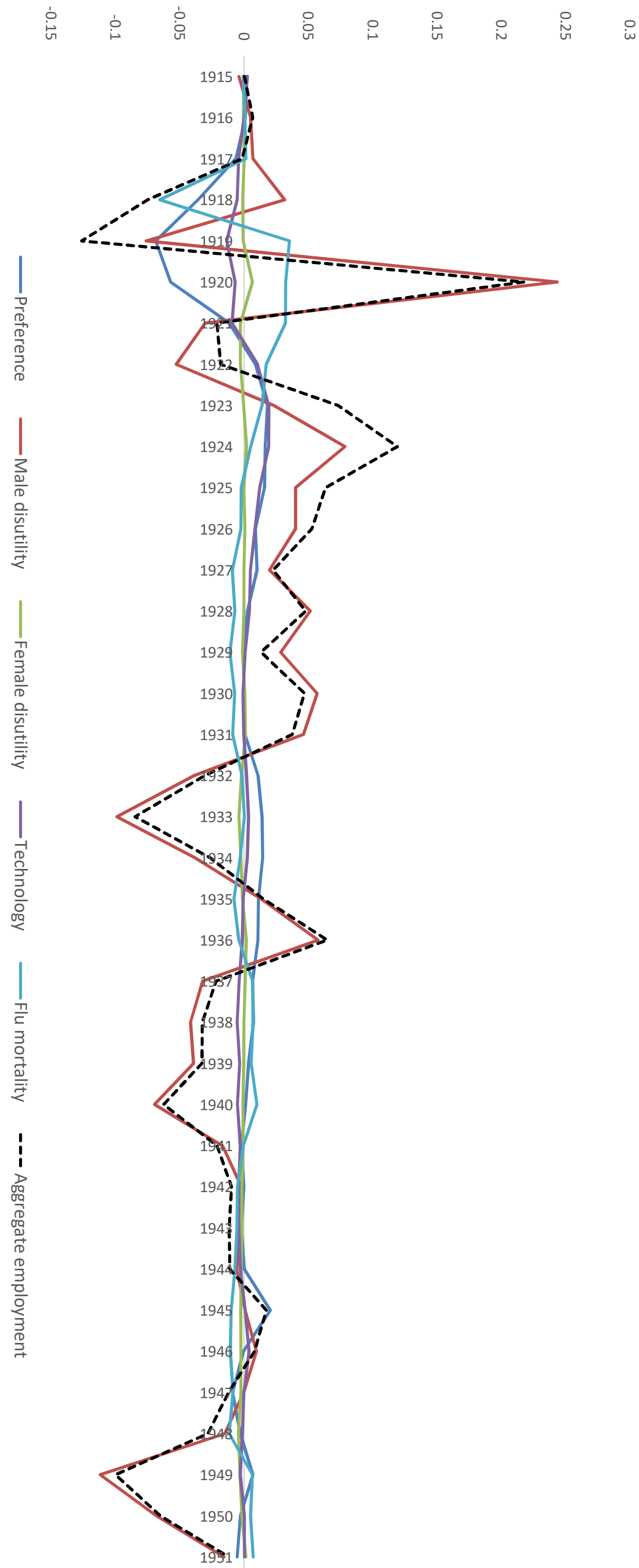


Figure 28: Estimated historical decomposition with mortality data / Female labor supply (sensitivity check)

Figure 29: Estimated historical decomposition with mortality data / Aggregate employment



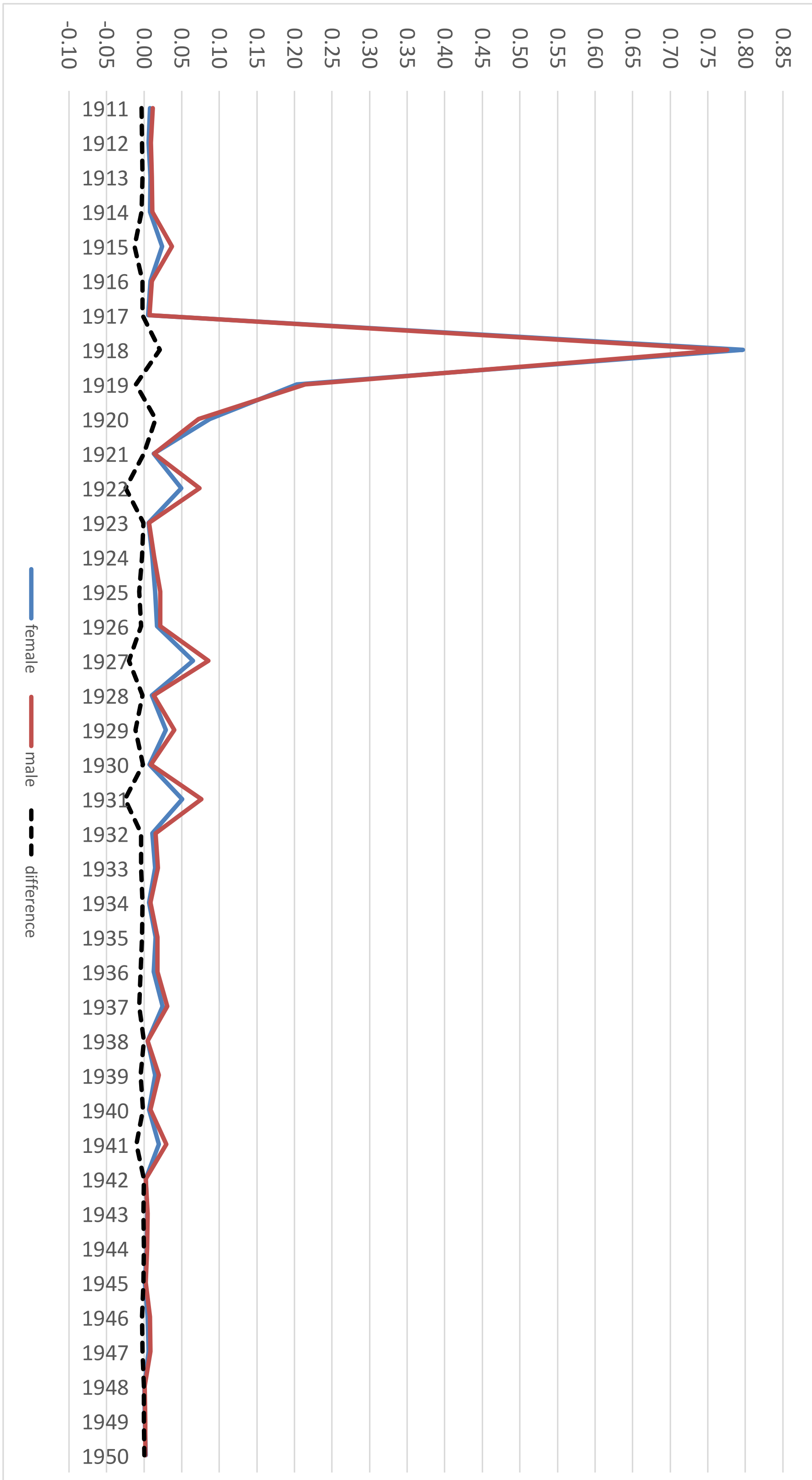


Figure 30: Gender distribution of number of deaths by influenza in Sweden as a share of corresponding working age population (1911-1950)