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Corrado Di Guilmi

Department of Economics, University of Technology Sydney
Centre for Applied Macroeconomic Analysis, ANU

Yoshi Fujiwara

Graduate School of Simulation Studies, University of Hyogo

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Address for correspondence:

(E) cama.admin@anu.edu.au

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Corrado Di Guilmi¹ and Yoshi Fujiwara²

*¹Department of Economics, University of Technology Sydney, Australia;
Centre for Applied Macroeconomic Analysis, Australian National University,
Canberra, Australia,*

²Graduate School of Simulation Studies, University of Hyogo, Kobe, Japan.

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1 Introduction

During the last four decades, the Japanese economy has faced a set of novel policy problems that macroeconomists had initially considered of little relevance for US and Europe. In more recent times, other developed nations have experienced a so-called “Japanization” of their economies, with sluggish price dynamics and flattening of the Phillips curve (see for example Ito, 2018). While the interconnections between stagnation and deflation in Japan have been extensively analyzed, the possible pitfalls of the structural changes in the job market, and in particular the growing precarization of labor, has received comparatively less attention and few attempts have been made it to link it to deflationary phenomena. Moreover, little is known from the empirical literature about the possible fallout in demand as the wage income of irregular employees can be considerably lower than the one of regular workers.

In particular from the lost decade onward, Japanese firms have exploited the loosening of regulation in the job market to employ a larger share of irregular employees, substantially altering the traditional characteristics of employment (figure 1). Empirical studies have already linked the slowdown in productivity observed in the last decades to the presence of a larger share of workforce with less training and lower attachment to the employer (Shinada, 2011; Fukao and Ug Kwon, 2006).

The change in the composition of the workforce can also alter the transmission of price shocks along the supply chain and may help explaining the evidence presented in Yoshikawa et al. (2015). They find that, in contrast with the popular price staggering mechanism by Calvo (1983), price adjust-

ments do not occur at regular intervals and firms that are downstream in the supply chain display a high degree of synchronization. Arguably, external shocks can lead firms to increase price competition, either through lowering profit margins or cutting costs. Resorting to irregular employment can be identified as a short-term cost cutting strategy.

The hypothesis of irregular employment as a financial buffer receives support by the investigation by Hosono et al. (2014). Using a panels of Japanese firms, they find that, during the Great Recession, Japanese firms that were more export-oriented reacted to the higher degree of uncertainty in their markets by resorting to agency workers to a larger extent. In particular they isolate two main factors that lead firms to hire agency workers. First, the use of secondary employment appears to be a substitute for the availability of liquid assets, as demonstrated by the fact that firms with lower cash deposits to total assets ratio made a large use of non-regular employees. Second, the volatility in sales induces firms to avoid a long-term commitment with the workforce.

This paper presents a stock-flow-consistent agent-based model calibrated on Japanese data to test the effect on aggregate demand and price dynamics of the use by Japanese firms of secondary (temporary, part-time, or agency) employees. The model is multi-sectoral with specific focus on the consumption-goods-producing sector in which firms' hiring decision and cost structure determine consumer prices. In particular, firms' costs are affected by the import price of raw material and by the relative proportions of primary and secondary workers. The existence of a dual labor market partially insulates the dynamics of monetary variables from the real economy for two main reasons: first, because of the changing proportion of the two categories of workers with different wages, and second because only the wage of secondary workers is directly affected by market conditions while the wages of primary workers are set by a firm-level bargaining. The framework is suitable for a series of policy experiments in different scenarios, and provides some indications about the possible causes of the observed evolution of output and inflation in Japan, together with prescriptions about the most effective combinations of policies in each possible situation.

Agent-based modeling can provide an original perspective for the joint investigation of labor precarization, slowdown in productivity, wage and price dynamics, and stagnation for two main reasons. First, given the non-ergodicity of economic time-series (for a recent treatment see Peters, 2019) and the often unexpected responses of Japanese macro-variables to aggressive

fiscal and monetary policy interventions, a modeling strategy that considers an open-ended state space, without necessarily implying the convergence to a stable steady state, can provide useful and original insights. Second, the presence of dynamically evolving heterogeneity of economic actors and their interaction can contribute to explain the evolution of prices at the firm level and their complex relationship with output and employment, especially for Japan where wage bargaining mostly happens at firm level. Moreover, the recent advancements in the calibration and estimation are contributing to make agent-based models more empirically relevant and more reliable for the study of different scenarios and economic policies.¹

To the best of our knowledge, this is the first attempt to provide a comprehensive agent-based macroeconomic model of the Japanese economy for the joint study of the policy issues identified above. Most of the relevant literature on the topic has investigated the Japanese credit network with a narrower scope (the latest example is Bargigli et al., 2018). Other (larger) agent-based models have attempted to reproduce a complete full-scale economic system either calibrating it on a generic economy Caiani et al. (2016) or with a specific focus (Deissenberg et al., 2008).

The paper aims to provide three main contributions. The first is to identify and test a possible financial channel to deflation, in which firms' financial distress and uncertain business environment contribute to a sluggish dynamics of wages and prices, even in the presence of output growth and decreasing unemployment. The analysis can contribute to explain the flat Phillips curve recently observed in Japan despite the historically low levels of unemployment. Second, the paper proposes a battery of possible policies alternative or complementary to the usual strategies pursued by the monetary authority, which have been widely discussed in the macroeconomic literature since the '90s. The third contribution relates to the technical aspects of the analysis, which makes use of original techniques for the estimation of the model and for the sensitivity analysis of behavioral and policy parameters.

The remainder of the paper is structured as follows. Section 2 presents the model. Section 3 illustrates the calibration and estimation strategy while section 4 introduces and discusses the results of the simulations. Finally, section 5 concludes.

¹For a recent survey on estimation methods see Lux and Zwinkels (2018). For stock-flow consistency in agent-based models see Caiani et al. (2016) and Di Guilmi (2017). Fagiolo and Roventini (2017) offers an insightful comparison of DSGE and agent-based models for policy analysis.

2 The model

We present a demand-driven agent-based model composed of six sectors: intermediate-goods-producing firms, final-goods-producing firms, households, banking sector, government, and foreign sector. The flow of funds between sectors are modeled in order to ensure accounting consistency.

The intermediate-goods producing firms buy raw material from abroad and transform it into intermediate products which are sold to consumption-goods producing firms. The final-goods producing firms produce a good that can be used for investment or consumption. For simplicity, both categories of firms produce on demand, abstracting from inventories. Downstream firms face fluctuations in demand hiring a number of secondary (temporary) workers that depends on the volatility in their demand and on their leverage ratio. The household sector is composed of workers and profit earners. Worker households consume domestic and foreign goods and hold savings that are not remunerated. Profit-earner households consume domestic and foreign goods and invest in firms stocks and risk-free deposits. The government collects taxes and makes anticyclical spending. The banking sector elastically supply credit at the risk free rate plus a risk premium, which depends on the firm's specific financial conditions. Profits are retained as a safety buffer. Exports and foreign price dynamics are estimated using real data.

Given the scope of our paper, we focus on the final-goods producing firms and specifically on their decisions about investment and hiring. Accordingly, we model this sector as agent-based while treating the other sector as an aggregate. This modeling choice allows us to abstract from a series of technical issues (such as the one-to-one matching in the markets for labor, intermediate goods, and credit) that are not essential for our analysis and can complicate the identification of the causal chains within the model. In terms of notation, firm-level variables are denoted by the subscript i whereas variables without the subscript denote aggregate quantities.

The sequence of events is as follows:

1. Firms decide about investment.
2. Aggregate demand is determined as the sum of investment, export, public expenditure, and consumption, which is based on households' earnings in the previous period.
3. Aggregate demand is allocated to each firm.

4. Firms determine labor demand and composition of the workforce.
5. Individual firms' prices are determined.
6. Firms' profits are determined.
7. Net financial positions for each firms are quantified and bankrupted firms are identified.
8. Risk premium for the following period is determined.
9. Consumption for the following period is determined.

Let us now present the behavioral assumptions of each sector in detail.

2.1 Intermediate-goods-producing firms

Intermediate-goods producing firms are modeled as an aggregate sector. They import raw material from abroad and transform it into goods that are used as inputs by the final-goods-producing firms. Their only input is imported raw materials R_t and they produce on demand an amount equal to H_t according to the following production function

$$H_t = \chi R_t \tag{1}$$

with χ as a constant technological parameter.

The demand for intermediate goods depends linearly on the production of the final goods according to the following linear technical relationship

$$H_t = Q_t^d \psi \tag{2}$$

such that the demand for raw materials depends on aggregate demand according to $R_t = Q_t^d \frac{\psi}{\chi}$.

Raw materials are priced at the foreign level of price P_{ft} , which depends on the exchange rate, and consequently the value of import of raw material in local currency is $P_{ft}R_t$. The price of intermediate goods P_{ht} is calculated assuming a constant mark-up μ_h on the production costs according to the following pricing rule

$$P_{ht} = (1 + \mu_h)\chi P_{ft} \tag{3}$$

2.2 Final-goods producing firms

Firms in this sector are modeled as agent-based. We present in the first subsection the assumptions for investment and pricing and in the second we discuss productivity dynamics and wage setting.

2.2.1 Investment, pricing, and profit

The investment function for a generic firm i is defined as follows

$$I_{it}/K_{it-1} = \alpha_1 \tilde{s}_{it}^I + \alpha_2 u_{it-1} - \alpha_3 r_{it} \quad (4)$$

where K_{it-1} is the outstanding capital stock, \tilde{s}_{it}^I is uniformly distributed idiosyncratic shock with $\mathbb{E}[\tilde{s}^I] = 1$, u_{it-1} is capacity utilization in the previous unit of time, r_{it} is the real interest rate demanded by the banking sector to the firm, and $\alpha_1, \alpha_2, \alpha_3$ are positive constants. In standard neo-Kaleckian models (Godley and Lavoie, 2007; Lavoie, 2014) the typical arguments in the investment function are the expected trend of growth in sales and capacity utilization. In (4), the average expected growth boils down to α_1 with the multiplicative shock \tilde{s}^I representing exogenous and heterogeneous entrepreneurial “animal spirits”. Further, we add to the standard Kaleckian investment a risk-aversion factor to account for the fact that heavily leveraged firms will prefer to hold back investment and use profits to deleverage (Koo, 2008; Minsky, 2008). Given that the level of interest rate depends on the leverage ratio of firms, as shown below, it can represent a suitable proxy for financial soundness.

Firms hold excess capacity and produce on demand. Accordingly, the demand for labor is residually determined once the firm knows the amount of its demand Q_{it}^d . As a consequence it is not possible to derive an explicit generic production function. Under the assumption of fixed coefficients, for each firm potential output will be equal to

$$Q_{it} = \min(\gamma_{it} L_{it}, \phi K_{it}) \quad (5)$$

where γ_{it} is the firm-specific labour productivity and ϕ is the homogeneous capital productivity. Assuming that output is always below potential ($Q_i^d \leq Q_i \Rightarrow u_{it-1} = \frac{Q_{it-1}^d}{Q_{it-1}} \leq 1$) and firms face no labor-supply constraint,² we can write $Q_i = \phi K_i$ (Di Guilmi and Carvalho, 2017).

²The assumption of perfectly elastic supply of labor prevents us from calculating the

Aggregate demand is given by

$$P_t Q_t^d = I_t + C_t + G_t + X_t \quad (6)$$

where C_t is households' consumption, G_t is government expenditure, and X_t is net export. Aggregate demand is allocated to each firm according to the following mechanism:

$$\mathbb{E}[Q_{it}^d] = \sigma Q_t^d \frac{K_{it}}{K_t} + (1 - \sigma) Q_{it}^d \tilde{s}_{it}^d \quad (7)$$

where $0 < \sigma \leq 1$ and \tilde{s}_{it}^d is a uniformly distributed random variable with $\sum_i \tilde{s}_{it}^d = 1$, which represent a *preferential attachment shock*.

Given that firms operate below capacity, the level of production that the firm needs to satisfy its demand is achieved by a suitable mix permanent (or primary p) and temporary (or secondary s) workers, so that

$$Q_{it}^d = L_{it}^p \gamma_{it}^p + L_{it}^s \gamma_{it}^s \quad (8)$$

where $\gamma_{it}^p, \gamma_{it}^s$ are the productivity levels for primary and secondary workers, respectively, whose quantification is presented below. Total labor costs for a single firm are given by

$$W_{it} = w_{it}^p L_{it}^p + w_{it}^s L_{it}^s \quad (9)$$

where w_{it}^p, w_{it}^s are the nominal wages for respectively primary and secondary workers, quantified according to the mechanisms described in the remainder of this section. Consequently, the total amount of wage income is $W_t = \sum_i W_{it}$.

The total nominal unitary costs for each firms are given by the cost of labour plus intermediate goods

$$TUC_{it} = \frac{W_{it} + P_{ht} H_{it}}{Q_{it}^d} \quad (10)$$

unemployment rate but also dispenses us from modeling demographic variables and the labor participation rate, which are not essential in our story. As we show in the simulation, the model well replicates the yearly average variation in the employed units of labor empirically observed.

Target price for each firm is given by production costs plus a constant and homogeneous mark-up according to the following rule

$$P_{it}^* = (1 + \mu)TUC_{it} \quad (11)$$

In order to replicate possible rigidities in the adjustment, price is set according to

$$P_{it} = (1 - \xi_P)P_{it}^* + \xi_P P_{it-1} \quad (12)$$

with $0 < \xi_P < 1$ as a constant. The price level of the economy will accordingly be given by

$$P_t = \frac{1}{Q_t^d} \sum_i P_{it} Q_{it}^d \quad (13)$$

Each firm sells its product at a different price but the acquisition (and valuation) price of capital goods is the average price of the market, implicitly assuming a centralized market for investment goods.

Firms' profits are

$$\pi_{it} = (P_{it} - TUC_{it})Q_{it} - i_{it}D_{it-1} \quad (14)$$

where i_{it} is the nominal interest rate and D_{it-1} is the outstanding debt. Let us indicate profits net of taxes as π_{it}^n , which are calculated as

$$\pi_{it}^n = (1 - \tau_\pi)\pi_{it} \quad (15)$$

Firms finance a constant share of investment η by issuing a quantity of new shares ΔE_{it}^s . Accordingly

$$P_{et}\Delta E_{it}^s = \eta P_{it} I_{it} \quad (16)$$

where P_{et} is the stock price, homogeneous across firms, and E_{it} is the quantity of firms' shares in circulation. The remainder is financed with internal resources, if available, and then, if they do not suffice, with credit. The firms' financial position A_i therefore evolves according to

$$A_{it} = A_{it-1} + s_f \pi_{it}^n - D_{it-1} - P_{it} I_{it} (1 - \eta) \quad (17)$$

where s_f is the profit retention rate. The formulation of (17) implies that profits are first used to pay back debt and then, if any excess remains, are accumulated to finance future activity.

If $A_{it} < 0$, the firm has a negative financial position and will resort to the credit market. The demand for debt, which is elastically supplied by the banking sector, is equal to

$$D_{it} = |A_{it}| \quad \forall i : A_{it} < 0 \quad (18)$$

The bankruptcy condition is dependent on the leverage ratio as in Chiarella and Di Guilmi (2011) and expressed as

$$D_{it}/(P_t K_{it}) \geq \nu \quad (19)$$

with $\nu > 0$.

2.2.2 Productivity dynamics and wage setting

The productivity of primary workers varies across firms and evolves according to the following rule

$$\gamma_{it}^p = \gamma_{it-1}^p [1 + \tilde{\gamma} - \beta_\gamma (\Lambda_{it-1} - \bar{\Lambda}_{t-1})] \quad (20)$$

where β_γ is a positive parameter, $\tilde{\gamma}$ is a constant estimated on real data, Λ_{it} is the ratio of secondary workers over total workers for firm i , and $\bar{\Lambda}_{t-1}$ is the cross average for Λ_{it-1} . Primary workers increase the productivity of the firm due their acquisition and refinement of skills through learning by doing. The formulation in (20) accounts for possible heterogeneity in firms productivity levels due to different use of secondary workers, according to the discussion in Shinada (2011).

The productivity of secondary workers is the same across the economy and depends on the average productivity of primary workers $\bar{\gamma}_t^p$:

$$\gamma_t^s = \bar{\gamma}_t^p / \Gamma \quad (21)$$

with $\Gamma > 1$.

Primary workers' wage are set through a firm-level Nash bargaining (Mortensen and Pissarides, 1994). The surplus for the workers is the difference between the primary workers' wage and the minimum wage, which is the worst possible outcome of negotiations, while the surplus for the firm is the net profit from a unit of labor $P_{it}\gamma_{it}^p - w_{it}^p$. Identifying with ρ the share of surplus going to the worker, we have that

$$w_{it}^{p*} - \bar{w} = \rho[(w_{it}^{p*} - \bar{w}) + (P_{it}\gamma_{it}^p - w_{it}^{p*})]$$

from which

$$w_{it}^{p*} = (1 - \rho)\bar{w}_t + \rho P_{it} \gamma_{it}^p \quad (22)$$

To account for the fact that in every period only a fraction of contracts are renegotiated, the actual wage is expressed as

$$w_{it}^p = (1 - \xi_w)w_{it}^{p*} + \xi_w w_{it-1}^p \quad (23)$$

The parameter $0 < \xi_w < 1$ quantifies the share of contracts that are carried from one period to another and can be considered as an index of wage stickiness.

The minimum wage in Japan is set at prefectural level, according to the guidelines of the Ministry of Health, Labor and Welfare, which are revised yearly. Given the impossibility of render such a discretionary process within a stylized model, the minimum wage \bar{w} is updated each period according to positive inflation:

$$\bar{w}_t = \begin{cases} \bar{w}_{t-1}(1 + \zeta_1 \tilde{P}_t) & \text{if } \tilde{P}_{t-1} \geq 0 \\ \bar{w}_{t-1} & \text{if } \tilde{P}_{t-1} < 0 \end{cases} \quad (24)$$

where $\tilde{P}_t = \frac{P_t - P_{t-1}}{P_{t-1}}$ is the one-period inflation and ζ_1 is a positive constant.

Supported by the findings by Munakata and Higashi (2016), we postulate that the secondary wage only depends on market conditions, giving the absence of “insiders” in the negotiations, as it is the case for primary workers. Munakata and Higashi (2016) find that the main determinant for different dimensional classes of firms is market tightness, proxied by the employment conditions as recorded in *Tankan*, which is a survey of the Bank of Japan on the business sentiment. In the absence of a comparable quantity in the model, we proxied it with the income growth, given the strong correlation of the employment condition question in *Tankan* with the lagged series of real GDP variation (0.92 in quartely data from 2000 to 2019). Accordingly, the evolution of the secondary workers’ wage is determined as

$$w_t^s = w_{t-1}^s(1 + \zeta_s \tilde{Q}_{t-1}) \quad (25)$$

where \tilde{Q}_t is the percentage variation of real GDP.

2.2.3 Hiring mechanism

Primary workers’ job contracts are carried on from one period to the following, while secondary workers sign one-period contracts. In every period,

firms that record an increase in demand preliminary verify whether they can satisfy the new higher level of production with the existing workers, considering the increase in productivity and the exogenous termination of contracts of primary workers λ_p . If not, they decide about the share of irregular workers to hire depending on market uncertainty and their financial condition. Let us define as \bar{Q}_{it} the level of production that can be achieved by firm i at time t employing the primary workers inherited from the previous period. Formally:

$$\bar{Q}_{it} = \gamma_t^p L_{it-1}^p (1 - \lambda_p) \quad (26)$$

The subset Ω_+ is composed by the firms for which $\bar{Q}_{it} < Q_{it}$ and therefore need to hire additional workforce. The share of the increase in demand that will be met with secondary workers λ_{it} is assumed to be given by:

$$\lambda_{it} = \begin{cases} \bar{\Lambda} + \beta_1 \sigma_{Q_{it}} + \beta_2 d_{it} & \forall i \in \Omega_{+t} \\ 0 & \forall i \notin \Omega_{+t} \end{cases} \quad (27)$$

where $\sigma_{Q_{it}}$ is the volatility in production over the past $\mathcal{T}_{\sigma Q}$ periods, β_1, β_2 are positive constants, $0 < \bar{\Lambda} < 1$ and

$$d_{it} = \frac{D_{it-1}/K_{it-1}}{\nu} \quad (28)$$

is an index that quantifies the financial soundness of a firm, being close 1 when the firm's leverage ratio approaches the bankruptcy threshold ν and equal to 0 when the firm has no outstanding debt.

Accordingly, the number of secondary workers for firm i in period t will be equal to

$$L_{it}^s = \lambda_{it} \frac{Q_{it}^d - \bar{Q}_{it}}{\gamma_t^s} \quad (29)$$

and the number of primary workers will be given by

$$L_{it}^p = \frac{Q_{it}^d - L_{it}^s \gamma_t^s}{\gamma_{it}^p} \quad (30)$$

The total number of workers per firm is given by

$$L_{it} = L_{it}^p + L_{it}^s \quad (31)$$

The share of secondary workers per firms is

$$\Lambda_{it} = L_{it}^s / L_{it} \quad (32)$$

At aggregate level the totals per category of workers are

$$L_t^s = \sum_i L_{it}^s \quad (33)$$

$$L_t^p = \sum_i L_{it}^p \quad (34)$$

2.3 Government expenditure and fiscal policy

Fiscal policy is modeled along the lines of Chiarella and Di Guilmi (2012) and Chiarella and Di Guilmi (2019).

The government decides the amount of the public expenditure counter-cyclically. In each period, non-discretionary public expenditure is assumed to be equal to a fixed proportion of GDP $0 \leq \theta_1 < 1$, such that $G_t^0 = \theta_1 P_{t-1} Q_{t-1}^d$. During recessions, the government supports private demand by partially filling the gap between current private expenditure and the expenditure at the peak of the cycle.

The level of aggressiveness of fiscal policy is quantified by the parameter $\theta_2 \in [0, 1]$, which affects the reactivity of the government to downturns through two channels. First, public expenditure is increased of a fraction θ_2 of the gap between current private aggregate demand and aggregate demand at the peak of the cycle, so that $G_t = G_t^0 + P_t \theta_2 (Q_{peak}^d - Q_{t-1}^d)$. A lag of one period is assumed for the government intervention. With regards to the second channel, once the cycle hits its trough and the economy starts to recover, the government keeps supporting aggregate demand until it is equal to at least a fraction θ_2 of the peak before the recession.

Government's revenues come from taxes. The fixed tax rates τ_w, τ_π are applied on wages and positive profits, respectively. The total amount of fiscal revenue is therefore equal to

$$T_t = \tau_w (w_t^p L_t^p + w_t^s L_t^s) + \sum_i \tau_\pi \pi_{it} \quad \forall i : \pi_t^i > 0. \quad (35)$$

where w_t^p is the weighted average of primary workers wage: $w_t^p = L_t^p \sum_i \frac{w_{it}^p}{L_{it}^p}$. Budget deficits are financed through issuance of perpetual bonds B purchased by private banks and yielding a return equal to r_f , while surpluses are used to withdraw outstanding bonds from the market. If $B_t < 0$, the government holds deposits remunerated at the risk free rate. Accordingly

$$B_t = B_{t-1}(1 + r_f) + (G_t - T_t) \quad (36)$$

2.4 Households

The household sector is treated as an aggregate. Households are classified into the two categories of wage earners and profit earners. Wage earnings from wages are allocated to consumption and deposits, profit earnings are allocated to consumption, deposits, and stocks.

Consumption and portfolio decision are modeled following Godley and Lavoie (2007, ch. 10) for the two classes of profit-earners and wage-earners. Consumption decisions are implemented with a one-period delay. Consumption is characterized by *habit formation*, motivated by the empirically verified reluctance of households to drastically change their consumption patterns. Borrowing from Russo et al. (2016), we assume that consumers do not reduce expenditure even when income contracts and we calculate consumption for profit earners as follows

$$C_{t+1}^c = \text{Max} [(1 - s_f)\Pi_t c^\pi + c^c CG_t; C_t^c] \quad (37)$$

where $\Pi_{t-1} = \sum_i \pi_{it-1}^n$, $CG_t = \frac{\Delta P_{et} E_{t-1}}{P_{et-1} E_{t-1}}$ are the capital gains, and $c^c, c^\pi > 0$.

The wealth of profit earners evolves according to the following rule

$$V_t^c = V_{t-1}^c + (1 - s_f)\Pi_t(1 - c^i) + CG_t - C_t^c(t); \quad (38)$$

where c^i is the propensity to consume foreign goods. In the case that $V_t^c < 0$, households borrow from banks at the risk free rate r_f .

The overall real return on investment per share \mathcal{R} is quantified by

$$\mathcal{R}_t = \frac{(1 - s_f)\Pi_t + CG_t}{P_t E_{t-1}}; \quad (39)$$

As in Chiarella and Di Guilmi (2011), profit earners invest a fraction of their wealth in the stock market in a proportion \mathcal{V} , which is given by

$$\mathcal{V}_t = \frac{1}{1 + \exp(-\varrho \mathcal{R}_t)} \quad (40)$$

such that the demand of equities is

$$P_{et} E_t^d = \mathcal{V}_t V_t^c \quad (41)$$

Equating (16) and (41) the equity price that clears the market is given by

$$P_{et} = P_{et-1} + \frac{\mathcal{V}_t V_t^c - \eta I_t P_t}{E_{t-1}} \quad (42)$$

Also workers' consumption depends on habit formation. Consumption given by current income depend on their wage earning and on the different propensities to consume. The consumption function for wage earners is then postulated to be equal to

$$C_{t+1}^w = \text{Max}[(1 - \tau_w)(c^p w_t^p L_t^p + c^s w_t^s L_t^s); C w_t] \quad (43)$$

Given the lower income for secondary workers, it is assumed that $c^s > c^p$. Accordingly the wealth of workers evolves according to

$$V_t^w = V_{t-1}^w + (1 - \tau_w)(1 - c^i)(w_t^p L_t^p + w_t^s L_t^s) - C_t^w \quad (44)$$

A negative value for the wealth of a category of households becomes negative implies that they are financed by credit supplied by the banking sector at the rate r_f .

2.5 Banking sector

A single banking sector supplies credit to firms in a perfectly elastic fashion but at different interest rates for each firm. The nominal interest rate is set as

$$i_{it} = r_f + r_{it}^p \quad (45)$$

where r_f is the risk free rate (assumed to be equal to the policy rate) and r_{it}^p is the risk premium asked to the firm which is equal to

$$r_{it}^p = d_{it-1} \omega \quad (46)$$

where $\omega \in (0, 1)$ is a constant parameter and d_{it} is calculated in equation (28). Accordingly, as the leverage ratio approaches the bankruptcy threshold ν , the risk premium becomes closer to its maximum ω . For firms with no debt, $r_{it}^p = 0$.

Consequently, the real interest rate is

$$r_{it} = i_{it} - \tilde{P}_t \quad (47)$$

For simplicity, the profit of the banking sector are accumulated as a precautionary buffer by banks (as in Godley and Lavoie, 2007).

2.6 Foreign sector

Gross exports are calculated as

$$X_t^g = (\mu_X + \sigma_X)Q_{t-1}^{dg} \quad (48)$$

where μ_X is the average share of gross export on gross demand $Q_{t-1}^{dg} = I_{t-1} + C_{t-1} + G_{t-1} + X_{t-1}^g$, and $\sigma_X \propto \mathcal{N}(0, \sigma_{XQ})$ with σ_{XQ} is the standard deviation of the ratio gross export over gross demand. Given that in our model exports are an exogenous source of volatility and shocks, it is convenient to use (48) in order to be able to keep a consistent size of shocks relative to the size of our virtual economy.

The dynamics of the import price P_{ft} is given by the following VAR(1)

$$P_{ft} = \varepsilon_1 + \varepsilon_2 P_{ft-1} + \tilde{\varepsilon}_3 \quad (49)$$

with $\varepsilon_1, \varepsilon_2 > 0$ and $\tilde{\varepsilon}_3 \propto \mathcal{N}(0, \sigma_\varepsilon)$ estimated on real data.

Total import is composed of import of consumption goods by households and import of raw materials by the producers of intermediate goods. Accordingly:

$$IM_t = c^i W_{t-1} (1 - \tau_w) + c^i (1 - s_f) \Pi_{t-1} + P_{ft} R_t \quad (50)$$

Net exports are therefore given by

$$X_t = X_t^g - IM_t \quad (51)$$

3 Calibration, estimation, and empirical validation

We classify parameters in three categories: behavioral parameters, policy parameters, and macro-parameters. Where possible, we estimate the value of the parameters of all the three groups by using empirical data or existing papers. The remaining behavioral parameters for firms are estimated according to the procedure detailed below while the remaining behavioral parameters for the other sectors are calibrated.

3.1 Empirically estimated parameters

When possible, parameters are estimated using the available macroeconomic data and relevant empirical literature as detailed in table 1. We use professional development (training and self-training) as a proxy for the relative productivity of primary and secondary workers, extrapolating it from the Basic Survey of Human Resources Development which shows that primary workers on average devote double the time with respect to irregular workers to self-training and accordingly we set $\Gamma = 2$. The tax rate on profit is set as the average of the upper two brackets (for the fiscal year 2018-2019). The tax rate on wages is the applicable tax rate for the average wage in Japan.

Since the ratio of gross over total demand has been very volatile from 2008, we calculate its average and standard deviation, needed for calculating gross export in (48), on the period 1990-2017 using OECD data. The foreign price P_f evolves according to a VAR estimated on the Japanese annual import price index for all commodities in the period 1991-2007 (St Louis FED data). The parameter $\bar{\Lambda}$, quantifying the minimum share of variation in production obtained by secondary workers, is estimated as follows: we calculated the average variation in the number of non-regular workers for the period 2000-2016 (Statistics Bureau of Japan data) and divided by the average variation in GDP in the same period, using only years with positive variations.

3.2 Estimation of firms' behavioral parameters

Given the scope of the paper, we narrow down the computational estimation of behavioral parameters to those concerning the final-goods producing firms. The estimation is performed through the following steps:

1. Selection of the parameters that mostly affect model's output through Sobol analysis of the variance;
2. Identification of a meta-model with the parameters previously selected;
3. Optimization of the meta-model against empirical data.

In step 1, we calculated the Sobol indexes (Sobol, 2001) for all the firms' behavioral parameters, through the Matlab routine developed in Cannavó (2012), for four outputs which are particularly important for the scope of our analysis and the characteristics of our virtual economy: the proportion

of secondary workers, the investment share of aggregate demand, the inflation rate, and the average growth. Given the focus of the paper on the role of secondary workers, in particular on price dynamics, we estimate the sensitivity on the average proportion of secondary workers and the average rate of inflation. We also selected the investment share in total output and average growth because we aim to realistically reproduce the composition of output in order to have a meaningful assessment of the effects of shocks and policy measures on aggregate demand. We focus on investment because it is the main autonomous expenditure in our model.

The Sobol index quantifies the shares in the total variance of output which depend on variations in the single parameters, providing a synthetic measure of the model’s sensitivity to each parameter. The parameters that we test are $\beta_1, \beta_2, \alpha_1, \alpha_2, \alpha_3, \eta, \zeta_s$. For all the three outputs, α_3, η explain less than 1% of the variance and were therefore excluded from the estimation and simply calibrated (figure 2).

In step 2, we estimate a Kriging meta-model. The Kriging approach is a spatial interpolation algorithm that: first, samples the parameter space for the construction of a Latin hypercube; second, estimates a surrogate model which has as input the subset of relevant parameters and as output the outcomes of the model’s simulations. We refer the interested reader to Saltelli et al. (2008) for a general treatment, and to Salle and Yildizoglu (2014) for a specific application in macroeconomic agent-based models. In our case, the parameters that will serve as inputs are those identified in step 1, and the outputs are the proportion of secondary workers and the inflation rate.³ The estimation of the meta-models is performed using the SuMo toolbox (Gorissen et al., 2010).

In step 3 the hyperparameters of the meta-model are optimized to match the empirical evidence for the average share of secondary workers and average inflation. The optimization is performed by `fgoalattain`, a Matlab algorithm that optimizes an external function in order to achieve a set of multiple goals. The algorithm uses a sequential quadratic programming method, defining a line search and estimating a merit function at each step in the parameters domain.

The results of the estimation procedure are reported in table 2 while the values for the calibrated parameters are reported in table 3.

³The number of outputs is reduced from step 1 to minimize the computational burden and improve the efficiency of the estimation.

3.3 Empirical validation

The results from Monte Carlo simulations are displayed in table 4. The empirical data are yearly averages from year 2000. In the table, the results for inflation and share of secondary workers are isolated because they are the results of the optimization in the parameter estimation. The model is able to replicate on average the main quantitative features of the Japanese economy of the last twenty years in terms of growth and demand structure. The job creation rate reported for the simulation is the variation in the aggregate number of permanent workers. The unit used for labor demand is the number of hours, which is a more suitable proxy for this specific quantity than the number of employees (which we use to measure the distribution of workforce between primary and secondary, in the absence of hourly data).

We employ impulse-response function to test the reaction of GDP to a shock in export (figure 3), the reaction of inflation to a shock in the exchange rate (figure 4), and the response of inflation to a shock in export (figure 5). In all cases the model satisfactorily mimics the outcome of the real data for direction and duration of the response. However, for the case of inflation and shock of export, the standard deviation appears to be too large to draw a definitive conclusion.

Figure 6 shows that the average individual firms decay in price correlation is faster than the aggregate price as found by Yoshikawa et al. (2015).

In terms of outcomes at the firm level, the size of firms measure by capital, number of workers, and sales all display right-skewed distributions. The lognormal distribution well fits the populations for capital and number of workers at each point in time, while for sales the tail is well approximated by a power law, as displayed in figure 7 (see Growiec et al., 2008, for a discussion of the emergence of power law and lognormal distributions in firms size).

4 Simulations

This section presents the results of single-run simulations and then discusses the sensitivity analysis to provide some policy indications.

4.1 Results

The single-run simulation results displayed in figure 8 show short-term boom-bust cycles, different for length and intensity, along a long-run growth path.

During periods of faster growth, the increase in capacity utilization boosts investment, profits, consumption, and creates asset price inflation. The strong demand generates a positive feedback loop by pushing for further increases in investment. As a side effect, the strong investment expenditure leads to increase in leverage (raising also the debt service) and share of secondary workers. At the peak, the decrease in consumption caused by secondary workers and the reduction in investment due to high interest rates and bankruptcies reach a critical threshold. The positive feedback of loop is now reversed as testified the increase in bankruptcy ratio and the decrease in secondary workers. These two effects, with the exit from the market of the weakest firms and the increase in the share of primary workers, pave the way for the transition to a new expansionary phase.

In our story, price evolution is partially disentangled from output (correlation approximately equal to 0.1) mostly because of the use secondary workers as a cost-containing strategy. Both primary workers' and secondary workers' wages are strongly and positively correlated with output (about 0.6), so in the absence of (large) wage differentials we would observe a standard cost-push inflation. However, the increase in the share of secondary workers that occurs during sudden jumps in aggregate demand drives costs down and contains the inflationary pressure. In fact, Λ_t is positively correlated with output (0.6) and negatively with inflation (-0.4).

As discussed with reference to figures 4-5, the model satisfactorily mimics the response of the aggregate economy to shocks. The agent-based approach allows for an investigation of the changes at the micro level that determine the macroeconomic outcomes. In particular, we focus here on the effect on inflation of shocks on foreign exchange and on export. Figure 9 shows the bivariate distribution for inflation and number of workers before and after a depreciation, which in this model is represented by an increase in the price of raw materials P_{ft} . The shock generates an increase in dispersion in both distribution and higher use of temporary workers, as testified by the movement of firms' density towards the South-East corner of the space. The median of the distribution of Λ shifts to the right, determining a change in the opposite direction for firm-level inflation. A decrease in employment and a proportionally larger use of secondary workers leads to a containment of the inflationary effect that would otherwise result from an exogenous increase in costs.

Figure 10 plots the same bimodal distribution, showing the changes caused by a negative variation in export. For this plot we simulated the same neg-

ative variation in export that Japan experienced in 2009, equal to 5 times the standard deviation of the export time series. After the shock, firms with relatively little secondary workforce absorb the shock by increasing the share of secondary workers, exacerbating the deflationary effect. As a consequence, the same type shift of the density towards the South-East corner recorded in the case of a negative exchange rate shock is observable. The results of the computational experiment are consistent with Hosono et al. (2014), showing how firms react to a negative output shock by using the secondary workforce as a financial buffer.

Figure 11 completes the analysis of the response to shock, showing the modifications in firm size distribution for the shock on export (results for the shock on the exchange rate are comparable). Besides the overall decrease in employment, the density appears to shift towards the bottom, implying a generalized decrease in price, which affects also the larger firms as testified by the increase in the clusters towards the right of the graph. This micro-level analysis reveals that the response to negative demand shock determines a deflationary effect, which can contribute to explain the modifications in the joint dynamics of output of prices.

The kurtosis in the distribution of price variation at firm level is negatively correlated with aggregate demand (-0.2) and Λ (-0.45). During a recession, all firms lay off secondary workers, but firms with lower productivity and worse financial conditions operates a relatively lower reduction of their secondary workforce, causing an increase in the dispersion in micro-level inflation.

4.2 Sensitivity analysis and policy prescriptions

The meta-modeling technique introduced in section 3 is applied also to perform global sensitivity analysis, to explore the space of parameters. Different meta-models are estimated for each subset of parameters under exam.

4.2.1 Dynamics of inflation and employment

The use of secondary workers to reduce excessive leverage heavily affects the price dynamics and its relationship with real economic variables. Figure 12 plots the levels of average inflation for different combinations of the two parameters that quantify the sensitivity of firms' decisions on hiring with respect to the volatility in output (β_1) and leverage (β_2). While β_2 appears

to have a negligible effect, larger β_1 lowers inflation and can bring it into negative territory. When volatility in demand affect price dynamics through the hiring of secondary workers, it is possible to expect an additional indirect effect of negative demand shock on prices, due to firms' reluctance of hiring permanent workers which determines lower costs. The results suggest that a more uncertain business climate, also due to the partial ineffectiveness of the policies enacted after the lost decade, might have increased firms' sensitivity to uncertainty and contributed to the long-run modifications in firms' hiring policies illustrated in figure 1.

Firms' hiring decisions seem also to play a role in the observed flattening of the Phillips curve, as shown by figure 13, which plots the variation in the correlation between aggregate employment and inflation for different combinations of β_1, β_2 ⁴. Again, the effect of β_2 is relatively less evident, but clearly high levels of β_1 disentangle price and employment dynamics. In particular, there is no correlation when $\beta_1 \cong 1$ and β_2 is either null or close to 1. Low but positive values of β_2 increase the probability of highly leveraged firms to avoid bankruptcy, possibly smoothing the effect of a high sensitivity to uncertainty. Firms may react unevenly to changes in their financial conditions of and asymmetrically to the business cycle (as the analysis of the kurtosis discussed above testifies). This factor may lead firms' costs to not monotonically and generally increase during an expansion, partially disentangling the dynamics of prices to the evolution of the real economy. In any case, when firms react to uncertainty of financial distress by hiring secondary workers, positive demand shocks have a limited or negligible effect on price due to the less than proportional increase in costs, confirming our initial hypothesis of a role played by the dual labor market in the flattening of the Phillips curve.

Since the precarization of the labour force has the side effect of reducing the bargaining power of workers and unions (see for example International Labor Office, 2013), it is interesting to test the effect of changes in the relative power of firm-level unions, which quantified in our model by the parameter ρ and estimated equal to 0.5 in Japan by Carluccio and Bas (2015). Figure 14 plots the average inflation as a function of the parameters β_1, β_2, ρ . For any possible combination of β_1, β_2 , relatively stronger workers and unions imply higher inflation. In particular while $\rho = 0.4$ determines deflation and for $\rho = 0.5$ we have inflation close to 0, for $\rho = 0.6$ (implying that unions

⁴Since we do not calculate unemployment in this model, we cannot directly observe a Phillips curve and we analyze the relationship between inflation and employment.

are stronger than employers in the Nash bargaining) inflation is clearly positive with values between 0.02 and 0.04. Higher bargaining power for unions also implies that primary workers' wages are more sensitive to market conditions and, as consequence, positively correlated with the level of employment. Figure 15 shows that the correlation between employment and inflation is generally higher for $\rho = 0.6$, except in the region indicatively delimited by $\beta_1 < 0.4, 0.5 < \beta_2 \leq 1$ for which the default value of $\rho = 0.5$ produces the highest correlation. When $\rho = 0.6$ and firms are particularly sensitive to leverage, the relatively higher primary workers' wages reinforce the decoupling between employment and wages generated by the precautionary hiring strategy of distressed firms. Finally, it is interesting to note that for $\rho = 0.4$, the correlation is always negative given that wages are not responsive to the evolution of the real economy.

To conclude, uncertainty and, to a lesser extent, financial distress lead firm to resort to secondary workers to meet positive demand shocks. The downward pressure on costs can reduce inflation, even in the presence of growing employment levels. The precarization of workers may also affect inflation indirectly by reducing workers' bargaining power, further compressing costs and prices.

4.2.2 Policy indications

The multidimensional exploration of the parameter space using meta-modeling techniques allows us to identify and study the effects of different combinations of monetary, fiscal, and regulatory policies.

Let us first assess the effectiveness of monetary policy for different levels of sensitivity of firms' hiring decisions to uncertainty (β_1) and leverage (β_2). Within our simplified economy, interest rates affect inflation through the balance sheet channel in two ways. First, lower interest rates reduce the debt burden of firms, increasing investment as per (4). The higher level of aggregate demand is expected to increase the wage of secondary workers according to (25). Second, the lower leverage reduce the share of secondary workers as per (27): low rates decrease the financial burden for firms, leading to a lower use of secondary workers and, through this indirect transmission mechanism, the higher costs are expected to increase the price level. Figure 16 plots inflation as a function of the two parameters and the risk free rate r_f . The first noticeable result is that behavioral factors appear to have a larger impact on inflation than the policy rate. Second, the effect on infla-

tion of monetary policy depends on the particular parameter combination. In particular, the expected effect (lower rate and higher inflation) is verified only for low values of β_1 and high β_2 . When firms are extremely sensitive to leverage, a difference in the rate of interest can have a considerable impact on hiring and, therefore, on inflation. On the contrary, for high β_1 and small β_2 , a lower rate determine a higher inflation through a relatively lower variance in output, due to a more stable investment rate by firms.

A very different picture emerges when we consider the adjustment parameter of the minimum wage to inflation (ζ_1). Figure 17 reveals that, for any possible combination of β_1, β_2 , inflation is higher when the minimum wage is more closely indexed to price variations, although the difference is decreasing in β_1 .

Figure 18 shows the different inflation rates generated by different combinations of fiscal policy activism (quantified by θ_2), policy rate (r_f), and adjustment parameter of the minimum wage to inflation (ζ_1). Clearly, the impact of monetary policy on inflation depends on the indexation of minimum wage and a visible effect on inflation seems to emerge only for a strong indexation of the minimum wage.

Looking at figure 18, for lower levels of ζ_1 , the policy rate appears to have a negligible effect on inflation, despite the fact that an expansionary monetary policy is expected to reduce the percentage of secondary workers, via a lower financial burden. The expected increase in cost is offset by the slow reaction of minimum wage to inflation, which on one side reduces the wage of primary workers due to the bargaining mechanisms implied by (22), and on the other side depresses real consumption, by preventing the increase of secondary workers' wage. For $\zeta_1 = 0.8$, the policy rate has a more sizable and nonlinear effect on inflation. For relatively high rates, the increase in financial commitments and secondary workers can determine a higher rate of bankruptcy, increasing costs through a larger turnover of firms which prevents productivity growth through the learning-by-doing rule implied by (20). Also in this scenario, lower rates can decrease the use of secondary workers. The increase in investment due to the lower leverage and the boost to consumption from the higher share of primary workers explain the increase in inflation, due to the faster dynamics of w^s in equation (25). The fact that Λ does not decrease for negative policy rates can be interpreted as a consequence of the stronger aggregate demand, and consequent requirement of secondary workers, that outpaces the decrease in leverage.

Figure 19 shows that an expansionary monetary policy is mostly effective

for high ζ_1 and a fairly activist fiscal policy. In general, very large values of ζ_1 may require a substantial government intervention since the higher wage bill for firms can increase their leverage and, if the liabilities grow faster than the capacity utilization, reduce their propensity to invest. As a consequence, the effects of a contractionary monetary policy, which aggravates the financial burden of firms, has a larger impact for higher ζ_1 .

Our results confirm the conclusions of recent studies on minimum wage at the zero lower bound. In particular, Glover (2019), using a New Keynesian model, finds that increasing the minimum wage is inflationary and can dampen the contractionary effects of the zero lower bound. As we discussed in section 3, the parameter ζ_1 has no empirical counterpart at national level since in Japan the minimum wage is set by the single prefectures. However, for a comparison, we can consider the actual correlation between lagged minimum wage and inflation, which is 0.32, while the correlation between lagged minimum wage and positive inflation is ≈ 0 . According to the simulation results, this level appears to be too low to generate appreciable inflationary effects and to amplify the impact of an expansionary monetary policy.

Given the results' sensitivity to the relative power in bargaining ρ detected in the previous analysis, it is worth to investigate the outcomes of different policy mixes as dependent on the bargain regimes. Figure 20 confirms that, regardless of the particular policy mix, a higher bargaining power of worker is highly inflationary and no combination of monetary and fiscal policy seems to be able to dampen the deflationary effects of low ρ .

Although the model was calibrated without a consumption tax, it is possible to run some computational experiments to verify the consequences of different consumption tax rates (which was increased in Japan last October from 8 to 10% for most standard consumption goods). Unsurprisingly, in our framework a higher consumption tax rate increases inflation more than any possible combination of fiscal and monetary policy (figure 21). At the same time, an exogenous increase in the price of consumption goods implies a lower level of consumption in real terms. The historical experience of Japan show that raises in the consumption tax rates have generated a short time spike in the inflation rate in the month in which they were introduced (for example in April 1997 and in April 2014) before returning to its long-term average. At the time of writing the recent hike has generated a moderate increase in the CPI variation rate in November 2019. The consistently higher inflation rates predicted by the model and not recorded in the data are possibly due to price competition mechanisms that the model does not capture

by construction. The sensitivity analysis also reveals a strong recessionary impact of higher tax rates, as displayed by figure 22. This is in line with the empirical evidence and in particular with the dramatic slowdown recorded by the Japanese economy in the second quarter of 2014 after the April tax increase. Regardless from the economic policy enacted by government and central bank, the model predicts that a higher consumption tax rate causes lower growth, due to a lower real value of consumption expenditure.

5 Concluding remarks

The paper presents a medium scale model of the Japanese economy, with specific focus on the consumption-goods producing sector, in order to introduce and study a scenario in which financial distress and uncertain business environment can lead to deflation even in the presence of growing employment, and to test a battery of possible policies and policy mixes.

The sensitivity analysis produces a set of relevant results. First the inflation rate is strongly dependent on the sensitivity of firms' hiring decisions to uncertainty, proxied by the standard deviation of demand over recent periods. The elasticity of firms' hiring of secondary workers to leverage and uncertainty can explain the low correlation between employment and prices in a dual labour market with different wage setting mechanisms. Second, this conclusion is straightened by the high sensitivity displayed by both inflation and employment-price correlation to the primary workers' bargaining power. In particular, higher bargaining power for workers determines higher inflation and higher employment-price correlation for any mix of monetary and fiscal policy and for most of the parameter space for firms' hiring decisions. Third, the effect of the policy rate on inflation depends on the firms' reactions to leverage and, mostly, on demand volatility. In any setting, a stronger indexation of minimum wage to price dynamics generates higher inflation and can boost the expansionary effects of a loose monetary policy. Finally, the model captures the spike in inflation generated by increases in the consumption tax rate (although it seems to overestimate the long-term effects) and predicts its strong recessionary effects, in line with the empirical evidence.

Overall the analysis suggests that the interaction between firms' financial fragility and the different factors affecting wages in a dual labor market affects the outcomes of economic policy and can generate unwanted or unexpected effects. In a context where monetary policy is exhausting its options, bringing

inflation closer to the Bank of Japan target of 2%, requires a comprehensive strategy aimed at supporting wage dynamics, through suitable institutional arrangements for minimum wage and wage bargaining.

The planned further steps in this research project involve the microfoundation of the intermediate-goods producing firms and of the household sector. In particular, we intend to study the network of upstream and downstream firms using the available data on the commercial credit network in Japan. Although the model captures the negative trend in labor units, an aspect that admittedly has been at least partially left out at this stage is the study of the possible consequences of tightening in the labor market, which will require an explicit modeling of labor supply.

Finally, since other economies are experiencing low inflation and flattening of the Phillips curve, it may be interesting to generalize the model's settings to carry on a comparative analysis. Although the model is built and calibrated on the Japanese economy, the framework is flexible enough to assess whether our conclusions are valid in other institutional contexts.

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Symbol	Value	Description	Source
δ	0.15	depreciation rate	OECD
μ, μ_h	1.2	price mark-up of the price	OECD data, av. 2004-2012
$\bar{\gamma}$	0.00365	yearly labor productivity growth	OECD data, av. 2000-2016
λ_p	0.14	share of job destruction rate	Liu (2018)
Γ	0.5	second. over prim. workers product.	BSHRD
ξ	0.66	wage stickiness	Muto and Shintani (2014)
c_s	0.6	propensity to consume sec. workers	Statistics Bureau of Japan
c_p	0.9	propensity to consume prim. workers	Statistics Bureau of Japan
r_b	0.0	interest rate on gov. bonds	FED St. Louis, av. 2000-2018
ρ	0.5	workers bargaining power	Carluccio and Bas (2015)
τ_π	0.3	tax rate on profits	Japan External Trade Org.
τ_w	0.2	tax rate on wages	Japan External Trade Org.
s_f	0.65	retention rate on profit	Morningstar Invest. Manag.
$\bar{\Lambda}$	0.29	Min. var. in production by sec. workers	Our elaboration
μ_X	0.09	average gross export over production	Our elaboration
σ_{XQ}	0.018	st. dev. gross export over production	Our elaboration
ϵ_1	0.203307	constant for VAR for import price	Our elaboration
ϵ_2	0.804644	autoreg. coeff. for VAR for import price	Our elaboration
σ_ϵ	0.000743289	st. dev. for VAR for import price	Our elaboration

Table 1: Parameters estimated using empirical data.

Symbol	Value	Description
β_1	0.3484	elasticity of firms' hiring decision to volatility
β_2	0.5172	elasticity of firms' hiring decision to financial soundness
α_1	0.0980	elasticity of investment to outstanding capital
α_2	0.5386	elasticity of investment to capacity utilization
η	0.0862	Prop. of investment financed with new shares

Table 2: Parameters estimated by optimizing the surrogate model.

Symbol	Value	Description
α_3	0.00005	elasticity of investment to interest rate
c^i	0.1	propensity to import
c^π	0.6	propensity to consume out of profits
c^c	0.005	propensity to consume out of capital gains
ρ	4	sensitivity of investors to return on equity
ζ_m	0.25	sensitivity of secondary wage to GDP
σ	0.5	share of demand allocated according to size
$\mathcal{T}_{\sigma Q}$	4	time span for variance calculation in (27)

Table 3: Parameters calibrated.

Variable	Empirical	Simulation	Source
Share secondary workers	0.34	0.37 ± 0.00	SBJ
Inflation rate	$\cong 0.00$	0.00 ± 0.00	St. Louis FED
GDP autocorr.	0.95	0.98 ± 0.01	Our calculation
GDP growth rate	0.91%	$1.10\% \pm 0.04$	St. Louis FED
Cons. share of GDP	0.57	0.49 ± 0.00	World Bank
Investment share of GDP	0.24	0.26 ± 0.00	World Bank
Gov. exp. share of GDP	0.19	0.19 ± 0.00	World Bank
Net export share of GDP	0.00	0.07 ± 0.00	World Bank
Job creation rate	0.14	0.15 ± 0.02	Liu (2018)
Productivity growth	$0.36\% \pm 0.01$	$0.38\% \pm 0.01$	OECD
Variation in labor units	$-0.31\% \pm 0.44$	$-0.30\% \pm 0.00$	OECD (hours)

Table 4: Empirical validation

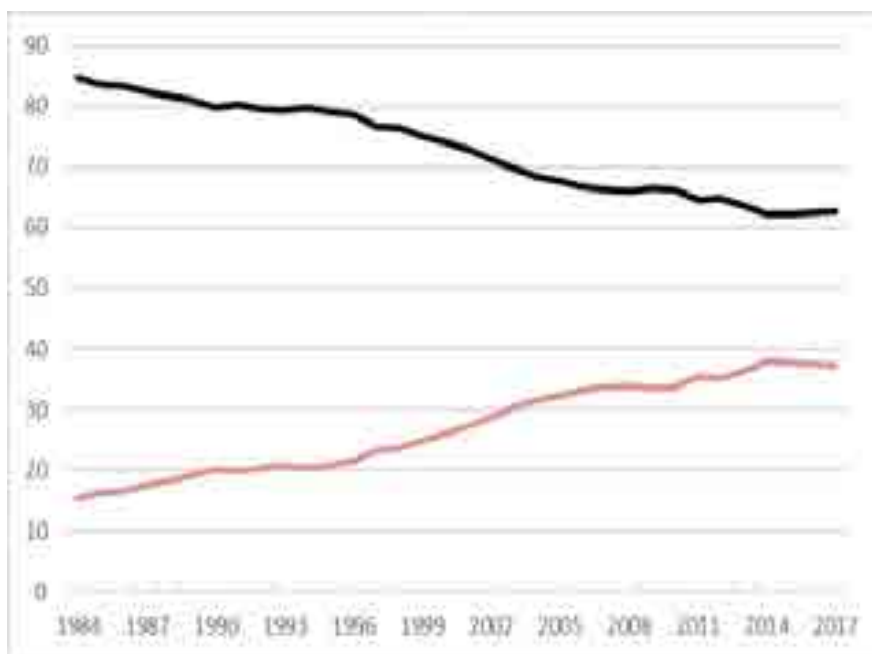


Figure 1: Percentage of primary (black line) and secondary employees (red line) for Japan. Source: “The Special Survey of the Labour Force Survey” from 1984 to 2001 (February data), “Labour Force Survey (Detailed Tabulation)” since 2002 (January to March average data).

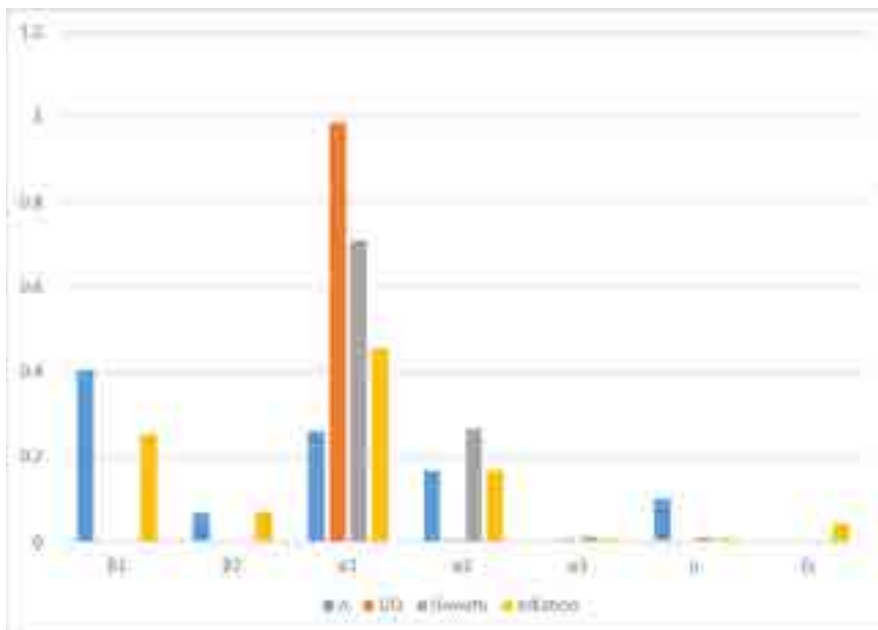
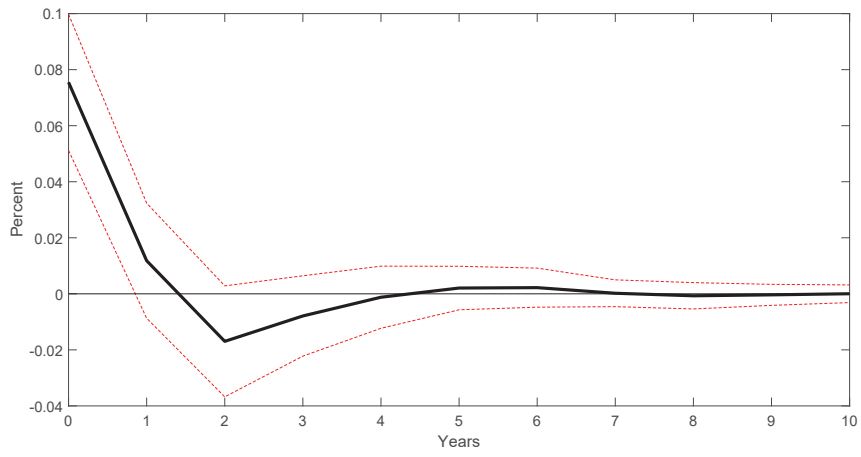
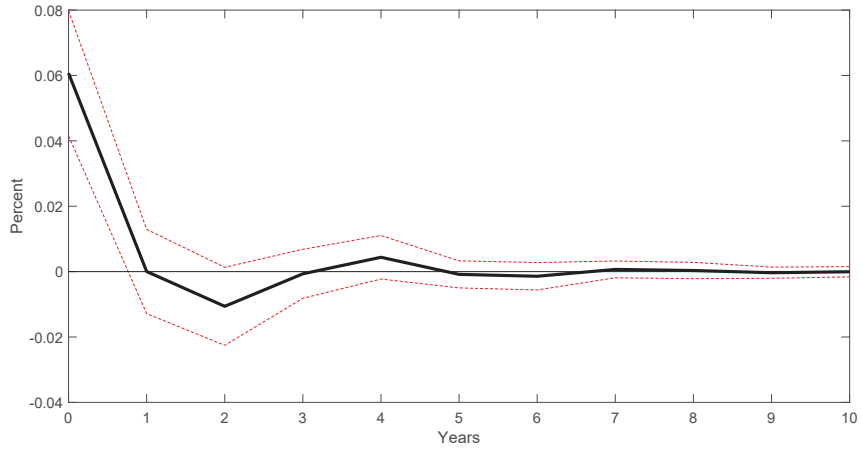


Figure 2: Sobol indexes for variance decomposition.

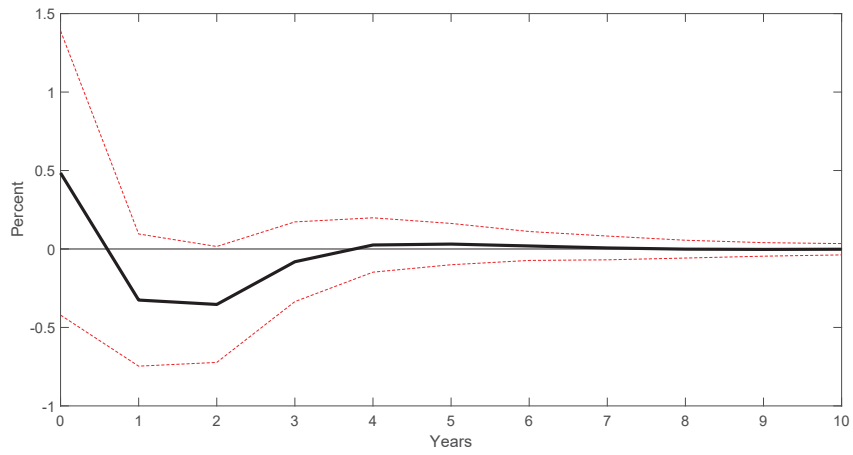


(a)

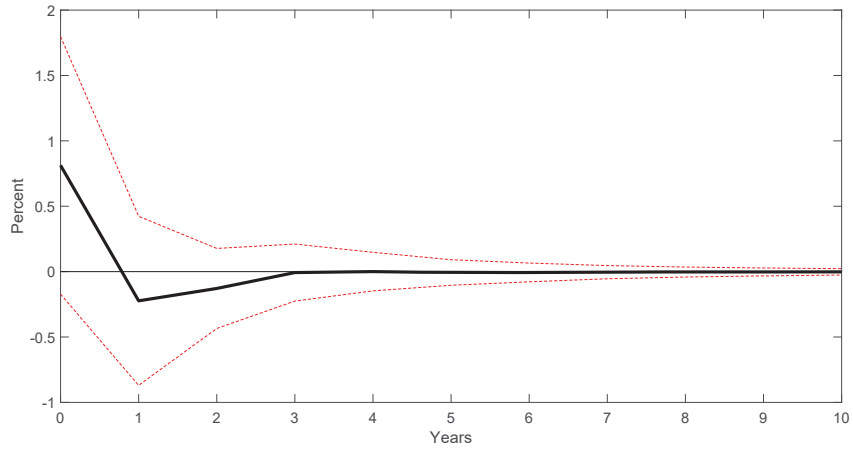


(b)

Figure 3: Impulse response function for GDP and shock on export: Japan (a) and simulations (b).

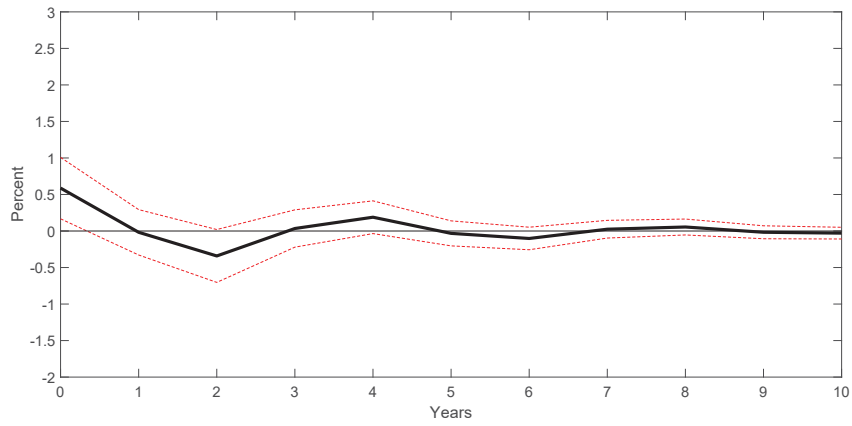


(a)

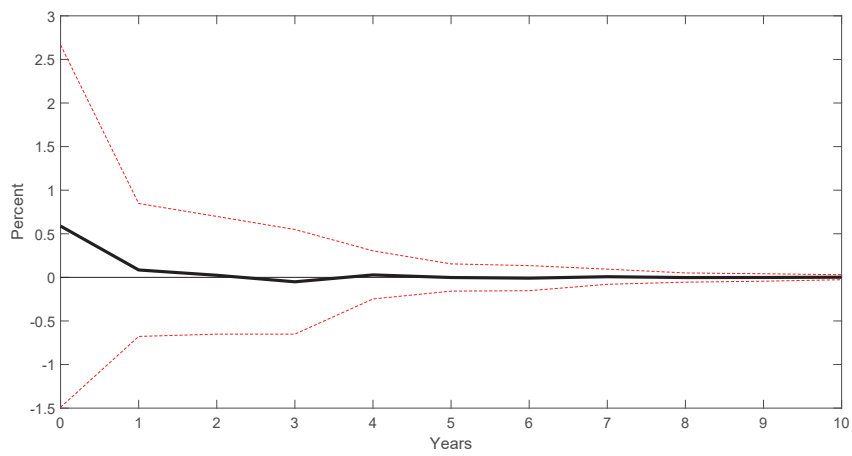


(b)

Figure 4: Impulse response function for inflation and shock on exchange rate: Japan (a) and simulations (b).



(a)



(b)

Figure 5: Impulse response function for inflation and shock on exchange rate: Japan (a) and simulations (b).

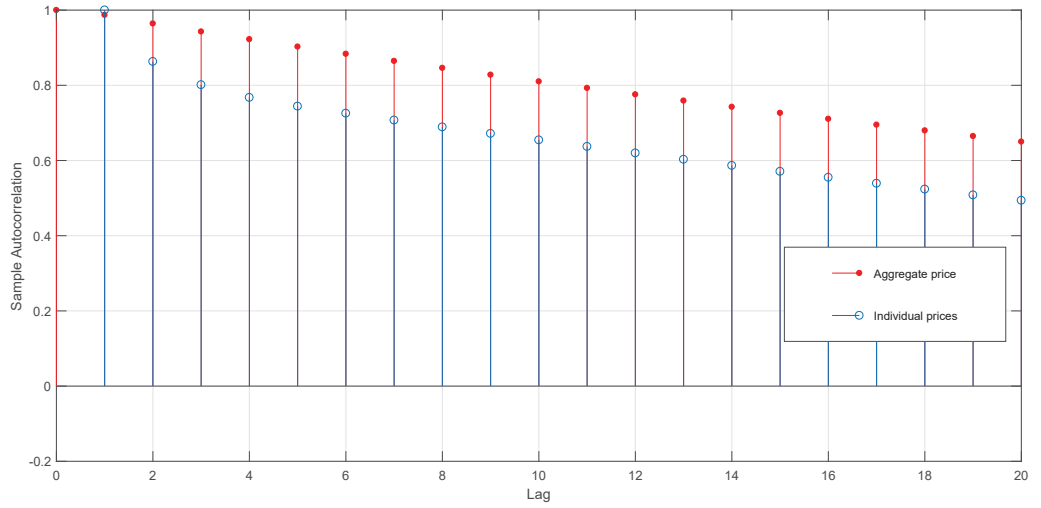


Figure 6: Autocorrelation for individual and aggregate prices.

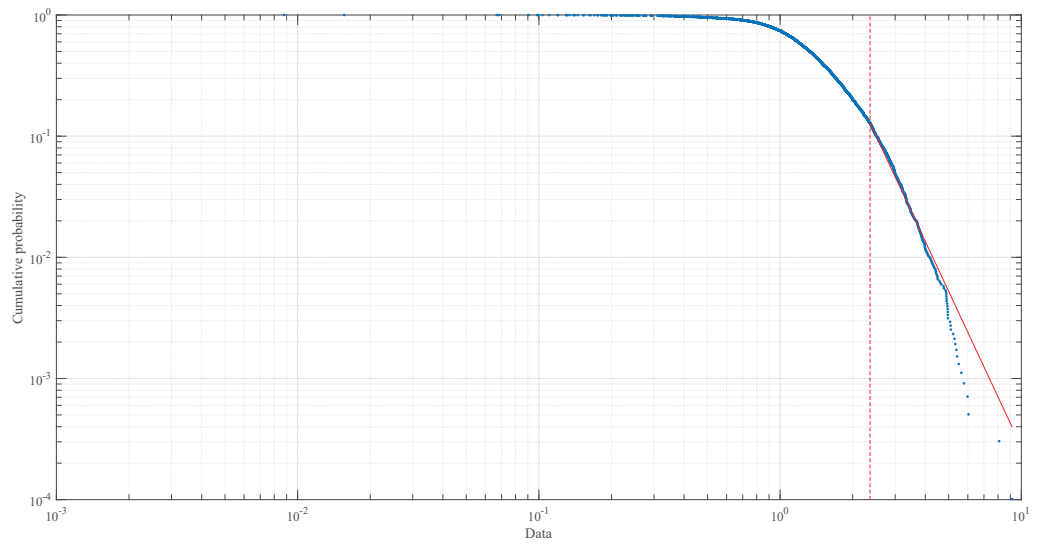


Figure 7: Frequency distribution for firms' sales with power law fit.

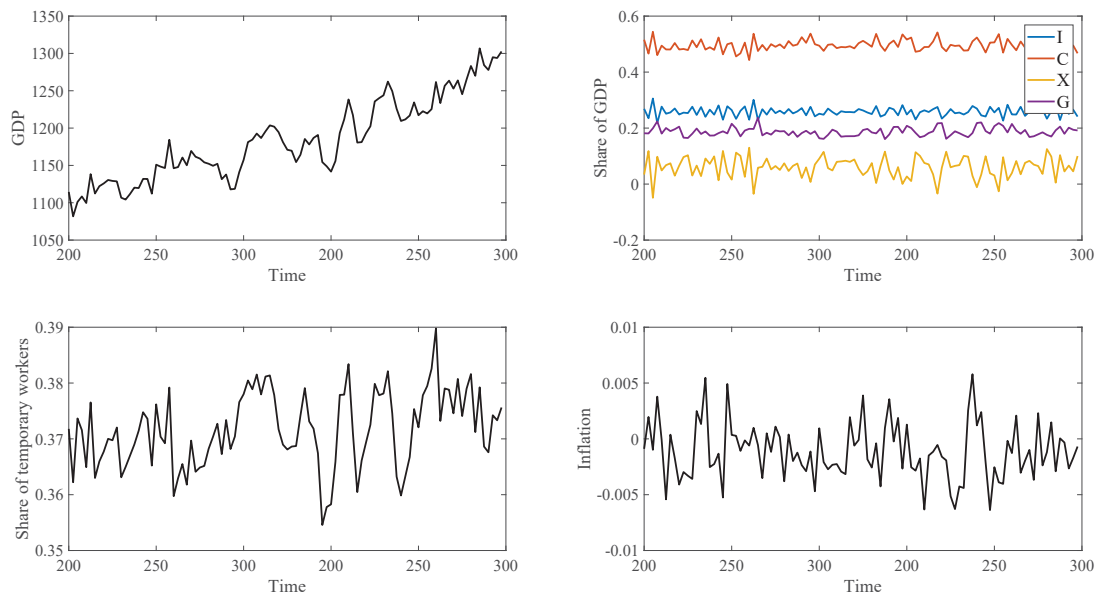


Figure 8: Results from single run simulation.

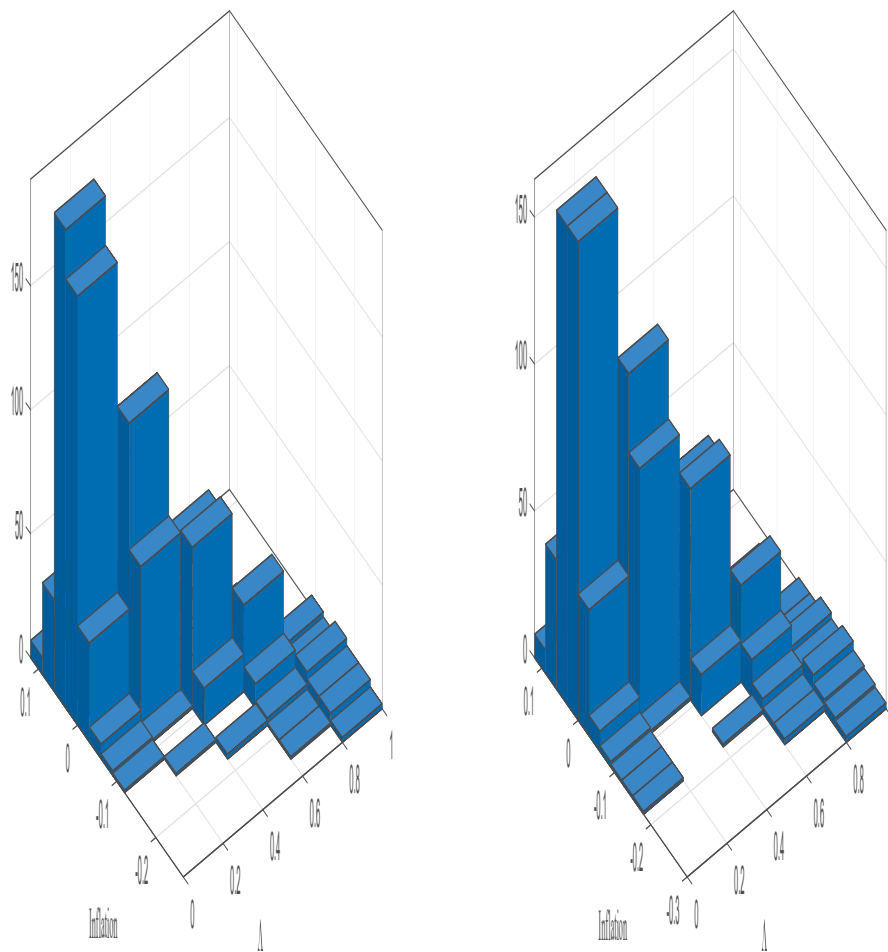


Figure 9: Exchange rate shock: Λ and price-variation joint distribution pre-shock (left) and post-shock (right).

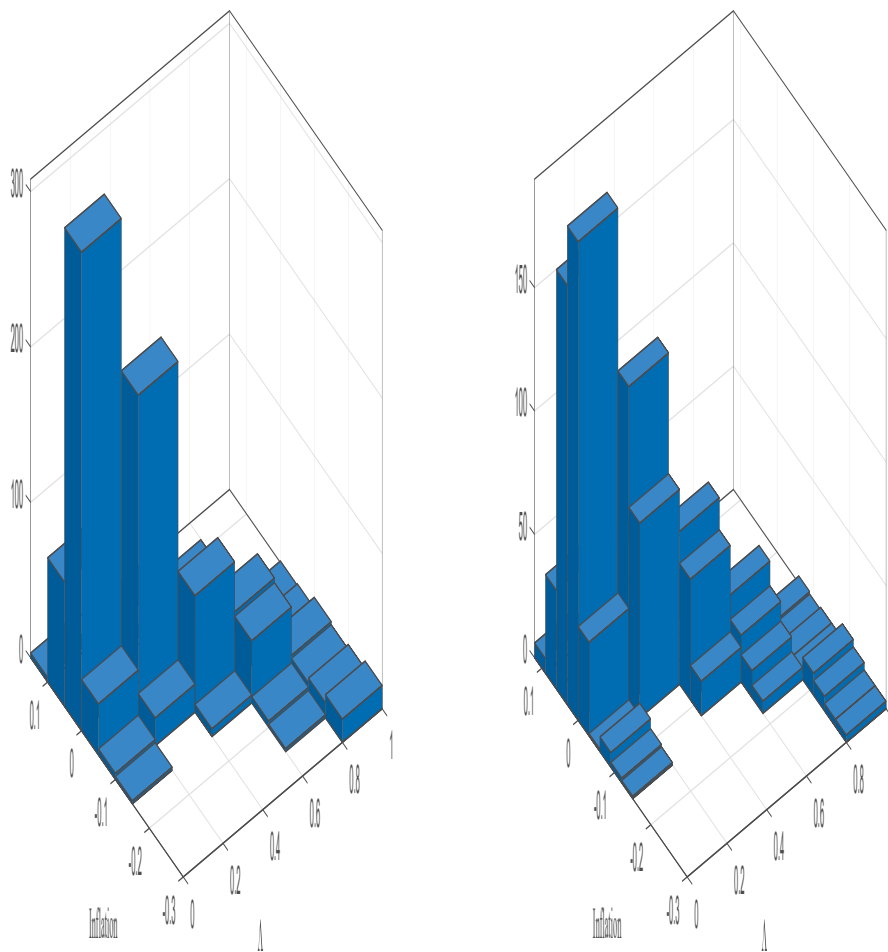


Figure 10: Shock on export: Λ and price-variation joint distribution pre-shock (left) and post-shock (right).

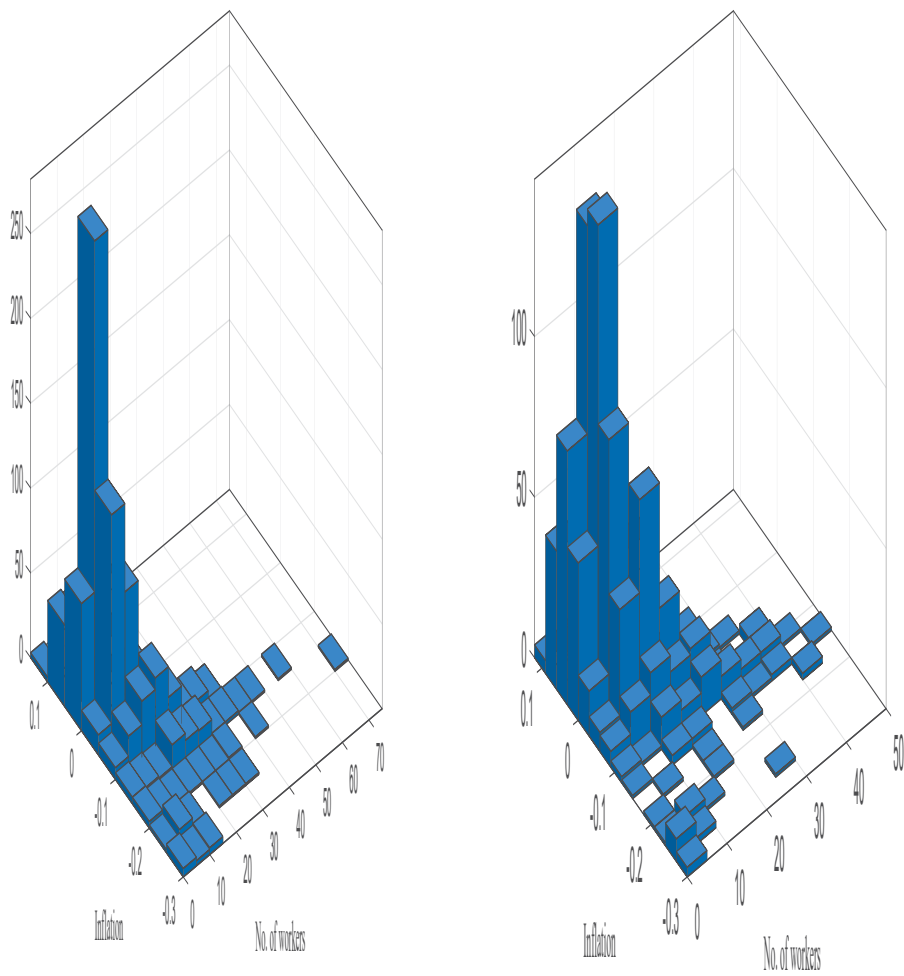


Figure 11: Shock on export: number of workers and price-variation joint distribution pre-shock (left) and post-shock (right).

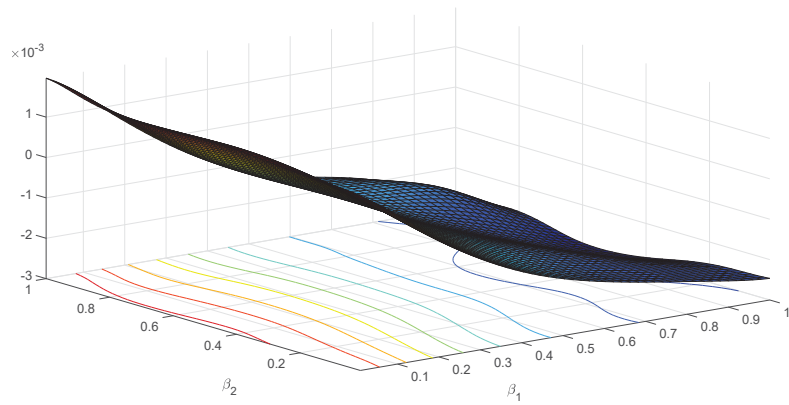


Figure 12: Inflation rate and units of labor for different β_1, β_2 .

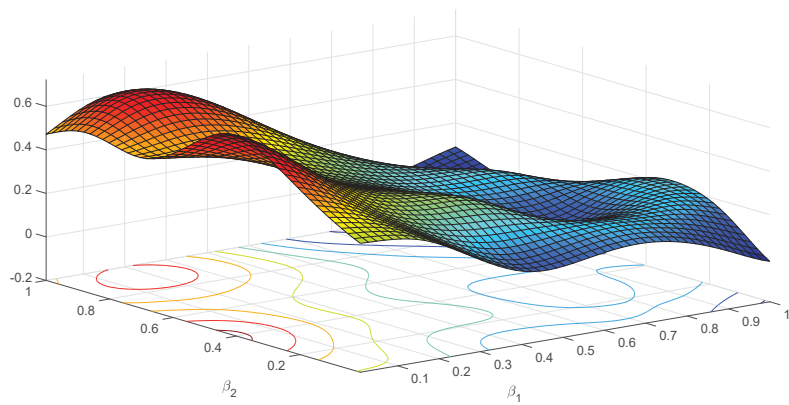


Figure 13: Correlation between inflation rate and units of labor for different β_1, β_2 .

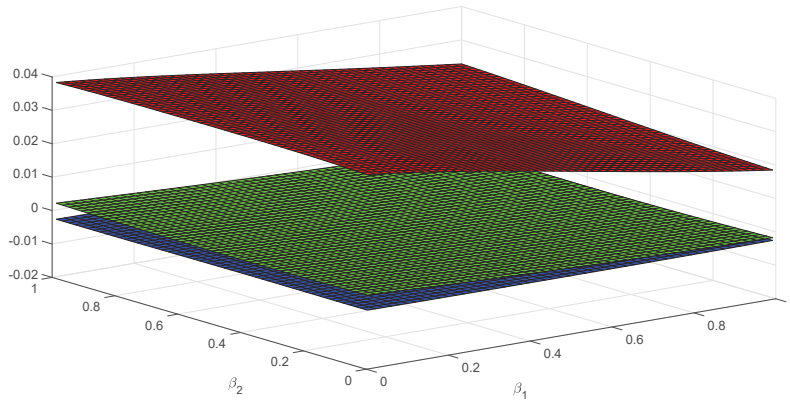


Figure 14: Inflation rate and units of labor for different β_1, β_2 and $\rho = \{0.4(\text{b}), 0.5(\text{g}), 0.6(\text{r})\}$.

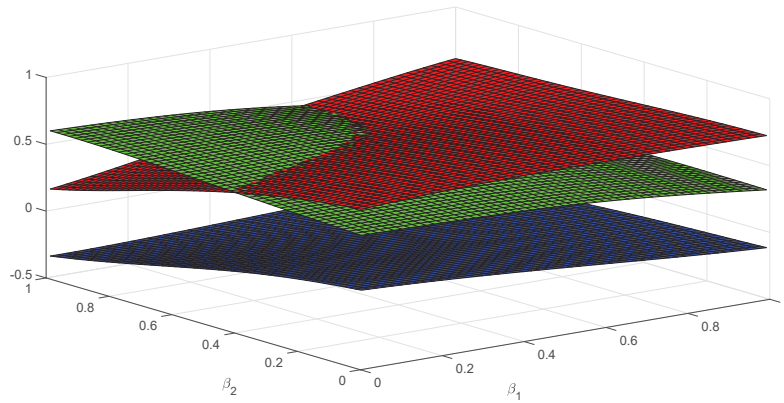


Figure 15: Correlation between inflation rate and units of labor for different β_1, β_2, ρ and $\rho = \{0.4(\text{b}), 0.5(\text{g}), 0.6(\text{r})\}$.