

MEASURING THE REDISTRIBUTIVE EFFECTS OF MONETARY POLICY: AN APPLICATION TO THE CHILEAN ECONOMY

Emiliano Luttini
The World Bank

Ernesto Pastén
Central Bank of Chile

Elisa Rubbo
University of Chicago

Active recent literature shows that monetary policy has heterogeneous effects on workers in different demographic groups.¹ In this paper, we build on the framework in Rubbo (2023) to estimate how monetary policy affects real incomes across demographic groups in the Chilean economy.

Specifically, Rubbo (2023) considers a multisector economy where different households are subject to different degrees of wage rigidity, are employed by industries with different price stickiness and capital intensity, and consume different bundles of goods. In this context, it provides an analytical expression for the effect of monetary policy on real incomes across households, depending on which industries they work in and which goods they consume. Rubbo (2023) shows that expansionary monetary policy increases employment relatively more for households that (i) have more flexible wages or work in

We thank the participants to the XXV Annual Conference of the Central Bank of Chile for their comments, and Ludwig Straub for an insightful discussion. We also thank Matías Pizarro and Rachel Coroseo for their excellent research assistance. Opinions and conclusions expressed in this paper are those of the authors' alone and do not necessarily represent the views of the Central Bank of Chile. All results have been reviewed to ensure no confidential data are disclosed.

1. See Coglianesi and others (2023), Andersen and others (2022), Minton and Wheaton (2023).

Heterogeneity in Macroeconomics: Implications for Monetary Policy, edited by Sofía Bauducco, Andrés Fernández, and Giovanni L. Violante, Santiago, Chile. © 2024 Central Bank of Chile.

sectors with more flexible prices; (ii) have more elastic labor supply or are complementary with other elastically supplied primary factors; and (iii) consume sticky-price goods. Moreover, controlling for the workers' own wage rigidity and labor-supply elasticity, monetary policy increases the relative wages of workers employed by sectors with more flexible prices or who are complementary with elastically supplied primary factors. Overall, nominal incomes unambiguously increase for these workers. Through its effect on consumption prices, expansionary monetary policy also increases the real income of households that purchase relatively more sticky-price goods or goods that rely on elastically supplied factors.

Rubbo (2023) summarizes these redistributive effects of monetary policy by using two cross-sectional multipliers, describing the relative response of employment and income across households. These multipliers account for all the channels described above and for their interactions through the input-output network and through general equilibrium effects.

We compute these two cross-sectional multipliers by using data for the Chilean economy to obtain the cumulative impulse responses of employment and income to a monetary shock across 50 demographic groups. Demographic groups are distinct by gender, age, and initial income quintiles. We construct measures of the exposure of each worker group to each industry through the employment and consumption channels by using detailed microdata available at the Central Bank of Chile. We first construct an input-output network of expenditure shares of each industry i on products from each industry j . We then combine the input-output network with measures of the expenditure shares of (i) each industry i on workers of each group g (to compute the exposure of workers to industries through the employment channel) and (ii) each worker group g on goods from each industry i (to measure the workers' exposure to each industry through the consumption channel). Finally, we merge these data with measures of price and wage adjustment probabilities, also obtained from microdata available at the Central Bank of Chile.

Our baseline results show significant heterogeneity in the degree of nominal rigidities that households face in the labor market, through both heterogeneous wage stickiness and heterogeneous price stickiness of the industries where they are employed. Older and higher-income workers tend to sort into industries with stickier prices. By contrast, we find little heterogeneity in the price stickiness of consumption goods across demographic groups. These differences result in a range

of cumulative employment responses that spans from 0.7 percent for middle-aged, middle-income men to 5.3 percent for high-income men over 54, while income responses span from 0.8 percent to 5.4 percent.

We also account for heterogeneous capital intensity across industries. While capital intensity varies significantly across industries (with capital shares ranging from 0.1 to 0.8), the average employer's capital share is similar across demographic groups. This suggests that interacting demographic characteristics with the industry of employment would uncover even larger heterogeneity. Nonetheless, even with our currently available data, accounting for the presence of semifixed capital assets amplifies the cross-sectional dispersion of employment responses.

The paper is organized as follows: Borrowing from Rubbo (2023), section 1 describes the environment, and section 2 presents cross-sectional employment and income multipliers. Section 3 then illustrates the Chilean data, and section 4 presents the calibration results. Section 5 concludes.

Related literature. This paper provides an empirical implementation of the framework in Rubbo (2023) to the Chilean economy. Rubbo (2023) considers a New Keynesian model with heterogeneous agents to study how monetary policy affects different households depending on their exposure to different sectors of the economy. The HANK literature² also considers New Keynesian frameworks with heterogeneous agents. In HANK models, however, heterogeneity is driven by the agents' saving decisions as they face different discount factors and borrowing constraints, while in Rubbo (2023) and in this paper, monetary policy has heterogeneous effects through the households' real incomes.

The framework in Rubbo (2023) is similar to Baqaee and Farhi (2018), who study the propagation and aggregation of exogenous productivity and markup shocks in economies with multiple agents and a general input-output network. Different from Baqaee and Farhi (2018), in both Rubbo (2023) and our framework, markups change endogenously due to sticky prices.

A large literature studies the implications of input-output networks for aggregate monetary non-neutrality in single-factor models,³ while

2. See Kaplan and others (2018), Auclert (2019), Auclert and others (2021).

3. See Basu (1995), Carvalho (2006), Nakamura and Steinsson (2010); Pastén and others (2019), La'O and Tahbaz-Salehi (2019); Rubbo (2020).

the currency union literature⁴ introduces heterogeneous agents in simple Armington-style production structures. By using the framework in Rubbo (2023), this paper jointly accounts for heterogeneous agents and a quantitatively realistic input-output network and proposes a novel characterization of cross-sectional monetary non-neutrality which uses Phillips curve slopes as sufficient statistics.

Based on detailed micro-level data from Denmark and Sweden, Andersen and others (2022) and Coglianesi and others (2021) empirically document heterogeneous effects of monetary policy depending on the individuals' employment and consumption. Minton and Wheaton (2023) also study the differential response of employment to monetary policy across U.S. States with different mandatory minimum wages. Their results are in line with the theoretical predictions of Rubbo (2023) and with the calibration results in this paper.

1. ENVIRONMENT

This section sets up a New Keynesian model, with monopolistic competition and sticky prices, featuring multiple heterogeneous industries, workers, and capital assets. It lays out the assumptions about preferences, production, and policy instruments, derives optimality conditions for consumers and producers, and defines the general equilibrium.

1.1 Final Users

1.1.1 Consumption

Preferences. There are N_w household groups, indexed by $h \in \{1, \dots, N_w\}$. We denote the set of households by $\mathcal{N}_w$. Each group has a representative consumer-worker who supplies a distinct labor type and whose per-period preferences are described by the utility function

$$U_{ht} = \frac{C_{ht}^{1-\gamma_h}}{1-\gamma_h} - \frac{L_{ht}^{1+\varphi_h}}{1+\varphi_h}. \quad (1)$$

4. See Aoki (2001); Benigno (2004); Devereux and Engel (2003); Huang and Liu (2007); Gali and Monacelli (2008).

All households enjoy consumption (C) and dislike labor (L), with heterogeneous income effects on labor γ_h and Frisch elasticities of labor supply $\frac{1}{\varphi_h}$. Consumption aggregators $C_{ht} \equiv C_h(c_{1ht}, \dots, c_{Nht})$ are homothetic over the N goods produced in the economy, and can differ across groups.

Budget constraint. Each household h owns shares of all industries, as described by the ownership matrix Ξ , whose elements Ξ_{ih} denote the share of profits from sector i accruing to type- h agents. Hence the matrix Ξ , governs the allocation of the firms' profits Π_{it} , net of lump-sum taxes T_{it} paid by firms to the government.

Agents also own shares in the capital assets, as described by the matrix $\mathcal{Z}$, whose elements $\mathcal{Z}_{fh}$ denote the share of asset f owned by worker type h .

Agents maximize the present discounted value of per-period utility flows, with the same discount factor ρ , subject to group-specific budget constraints

$$P_{ht}^C C_{ht} \leq W_{ht} L_{ht} + \sum_f \mathcal{Z}_{fh} \frac{\varphi_f}{1 + \varphi_f} R_f K_f + \sum_i \Xi_{ih} (\Pi_{it} - T_{it}) + T_{ht}, \quad (2)$$

where P_{ht}^C is the price index implied by the consumption aggregator C_h , W_{ht} is the nominal wage earned by labor type h , $\frac{\varphi_f}{1 + \varphi_f} R_f K_f$ is income from capital asset f (as explained below), and $\{T_h\}_{h=1}^{N_w}$ are zero-sum income transfers between agents. In the analysis below we will assume financial autarchy and consider the transfers $\{T_h\}_{h=1}^{N_w}$ as exogenous. If we allowed for borrowing and lending across agents, the transfers would be determined endogenously. Endogenous and exogenous transfers enter our expressions for cross-sectional employment in the same way, and their role is negligible quantitatively.

Consumption-leisure tradeoff. The optimal consumption-leisure tradeoff satisfies the first-order condition

$$\frac{W_{ht}}{P_{ht}^C} = C_{ht}^{\gamma_h} L_{ht}^{\varphi_h}, \quad (3)$$

where W_{ht} is the flexible wage. Our modeling of wage rigidities is detailed in section 1.2 below.

1.1.2 Investment

There are N_f capital assets in the economy, indexed by $f \in \{1, \dots, N_f\}$. We denote the set of capital assets by N_f . Each capital asset is produced by combining a fixed endowment ($\bar{K}_f$) with an investment good I_f , according to the production function

$$K_f = \left[(1 + \varphi_f) I_f \right]^{\frac{1}{1+\varphi_f}} \bar{K}_f. \quad (4)$$

For convenience, we assume that the investment component I_f fully depreciates from one period to the next, while the endowment component $\bar{K}_f$ never depreciates.

In turn, investment is produced with constant return to scale, using as inputs a combination of labor (L_{fh}), capital (K_{fg}), and intermediate goods (X_{fi}), according to the production function

$$I_f = G_f(\{L_{fh}\}, \{K_{fg}\}, \{X_{fi}\}). \quad (5)$$

There are N_f investment producing sectors, one for each asset type f , that sell the investment good at marginal cost P_f^I to capital retailers. Retailers purchase capital endowments from the agents, combine them with the investment good, and sell capital services to the firms for a rental rate R_f in a perfectly competitive market. Capital retailers are owned by the agents in proportion to their ownership shares $\mathcal{Z}$ in the capital endowments and rebate their profits accordingly.

Profit maximization yields the capital supply curves

$$U_f^{\varphi_f} = \frac{R_f}{P_f} \bar{K}_f, \quad (6)$$

where

$$U_f \equiv \left[(1 + \varphi_f) I_f \right]^{\frac{1}{1+\varphi_f}} \quad (7)$$

can be interpreted as a measure of capital utilization. Profits are given by

$$\frac{\varphi_f}{1 + \varphi_f} R_f \bar{K}_f, \quad (8)$$

while investment expenditures are equal to

$$\frac{1}{1 + \varphi_f} R_f \bar{K}_f. \quad (9)$$

1.2 Production

There are N good-producing industries in the economy (indexed by $i, j \in \{1, \dots, N\}$). Within each industry, there is a continuum of firms producing differentiated varieties.

All firms z in industry i have the same constant returns to scale production function (omitting time subscripts for legibility)

$$Y_{iz} = G_i \left(\{L_{ihz}\}, \{K_{ifz}\}, \{X_{ijz}\} \right), \quad (10)$$

where L_{ihz} is type- h labor hired by firm z in industry i , K_{ifz} is type- f capital used by firm z , and X_{ijz} is intermediate input j used by the firm.

Customers (consumers and other producers) buy a constant-elasticity-of-substitution (CES) bundle of sectoral varieties, with elasticity of substitution ϵ_i . The industry output is given by

$$Y_i = \left(\int Y_{if}^{\frac{\epsilon_i - 1}{\epsilon_i}} df \right)^{\frac{\epsilon_i}{\epsilon_i - 1}}, \quad (11)$$

and the implied sectoral price index is

$$P_i = \left(\int P_{if}^{1 - \epsilon_i} df \right)^{\frac{1}{1 - \epsilon_i}}. \quad (12)$$

We follow a standard practice in the literature and assume proportional input subsidies are in place to eliminate the markup distortions arising from monopolistic competition. This assumption eliminates the incentive to use expansionary monetary policy to reduce markups. Sectoral subsidies τ_i^* are given by

$$1 - \tau_i^* = \frac{\epsilon_i - 1}{\epsilon_i}. \quad (13)$$

All producers minimize costs given input prices. With constant returns to scale, marginal costs are the same for all firms within a sector i , and they all use inputs in the same proportions. The marginal

cost of sector i , denoted by MC_i , is the solution to the cost minimization problem (again omitting time subscripts for legibility)

$$MC_i = \min_{\{X_{ij}\}, \{L_{ih}\}} \sum_h W_h L_{ih} + \sum_f R_f K_{if} + \sum_j P_j X_{ij} \text{ s.t. } G_i(\{L_{ih}\}, \{K_{if}\}, \{X_{ij}\}) = 1. \quad (14)$$

Price rigidities are modeled à la Calvo: in every sector i , a randomly selected fraction δ_i of firms can update their price at each given period. They set it to maximize the present discounted value of profits at each future period $t + s$, in the event that they are unable to update their price until $t + s$:

$$P_{it}^* = \frac{\epsilon_i (1 - \tau_i^*)}{\epsilon_i - 1} \frac{\mathbb{E}_t \sum_s \left[SDF_{t+s} (1 - \delta_i)^s Y_{ift+s} (P_{it}^*) MC_{it+s} \right]}{\mathbb{E}_t \sum_s \left[SDF_{t+s} (1 - \delta_i)^s Y_{ift+s} (P_{it}^*) \right]}, \quad (15)$$

where $SDF_{t+s} = \rho^s \frac{U_{ct+s}}{U_{ct}} \frac{P_t^c}{P_{t+s}^c}$ is the households' stochastic discount factor, demand functions are given by $Y_{ift+s}(P_{ft}) = Y_{it} \left(\frac{P_{ft}}{P_{it}} \right)^{-\epsilon}$, and $\frac{\epsilon_i (1 - \tau_i^*)}{\epsilon_i - 1} = 1$. The firms f that cannot adjust their price have $P_{ift} = P_{ift-1}$ and their markup $\mathcal{M}_{ift}$ must absorb any cost changes.

Factor marketplaces. To model sticky factor prices, we assume that primary factors (workers and capital assets) are first purchased by marketplaces, which then sell their services to producers in all the different sectors. Each marketplace deals with only one primary factor. Marketplaces are treated like any other industry. In particular there is a continuum of marketplaces for each type, with fixed unit mass, facing Calvo-style price rigidities.

1.2.1 Aggregation

Definition 1 introduces our notion of nominal GDP, while Definitions 2 and 3 allow us to compute infinitesimal changes in real GDP and the GDP deflator around an initial equilibrium (denoted by starred variables).

Definition 1. Nominal GDP is the sum of consumption and investment expenditures

$$GDP = \sum_h P_h^C C_h + \sum_f P_f^I I_f. \quad (16)$$

Definition 2. Infinitesimal changes in real GDP $d\log Y_t$ around an initial equilibrium (denoted with starred variables) are given by

$$d\log Y_t = \sum_{h \in \mathcal{N}_w} \frac{P_h^* C_h^*}{GDP^*} d\log C_{ht} + \sum_{f \in \mathcal{N}_f} \frac{P_f^* I_f^*}{GDP^*} d\log I_{ft}. \quad (17)$$

Definition 3. Changes in the GDP deflator $d\log P_t^Y$ are defined as

$$d\log P_t^Y = \sum_h \frac{P_h^* C_h^*}{GDP^*} d\log P_{ht}^C + \sum_f \frac{P_f^* I_f^*}{GDP^*} d\log P_{ft}^C. \quad (18)$$

Remark 1. As a consequence of constant returns to scale, changes in real GDP equal the income weighted sum of changes in primary factor quantities:

$$d\log Y = \frac{\sum_{h \in \mathcal{N}_w} W_h^* L_h^* d\log L_h + \sum_{f \in \mathcal{N}_f} R_f^* K_f^* d\log K_f}{\sum_{h \in \mathcal{N}_w} W_h^* L_h^* + \sum_{f \in \mathcal{N}_f} R_f^* K_f^*}. \quad (19)$$

1.3 Monetary Policy

At each period, the economy is subject to an aggregate cash-in-advance constraint whereby nominal GDP cannot exceed the money supply M_t , chosen by the central bank:

$$P_t Y_t \leq M_t. \quad (20)$$

Seignorage revenues are distributed in proportion to the agents' consumption shares, so that—to a first order—seignorage rebates are exactly equal to the amount of new money that the agents need to purchase in order to finance consumption, and the two cancel out from the budget constraint.

Below, we sometimes use a static version of the cash-in-advance model, with $\rho = 0$, to provide intuition. In this model, firms enter each period t with pre-set prices, and only a fraction δ_i of producers in each sector can update them after the new money supply is announced. We usually assume that the economy enters period 0 in steady state, so that pre-set prices from $t = -1$ are equal across producers, as they expect real money balances to remain constant.

1.4 Equilibrium

The equilibrium concept adapts the definition in Baqaee and Farhi (2020) to account for the endogenous determination of markups given pricing frictions and shocks. Given sectoral markups, all markets must clear. In turn, the evolution of markups must be consistent with Calvo pricing and the realization of monetary policy.

Definition 4. At each period t , for given sectoral probabilities of price adjustment δ_i and money supply M_t , the general equilibrium is given by a vector of firm-level markups $\mathcal{M}_{it}$, a vector of sectoral prices P_{it} , a vector of agent-specific nominal wages W_{ht} , a vector of labor supplies L_{ht} , a vector of capital supplies K_{ft} , a vector of sectoral outputs Y_{it} , a matrix of intermediate input quantities X_{ijt} , a matrix of final consumption C_{iht} , and a matrix of investment demand U_{ift} such that: (i) a fraction δ_i of firms in each sector i charges the profit-maximizing price given by (15); (ii) the markup charged by adjusting firms is given by the ratio of the profit-maximizing price and marginal costs, while the markups of nonadjusting firms are such that their price remains constant; (iii) households maximize utility subject to their budget constraint; (iv) investment producers maximize profits given input prices; (v) producers in each sector i minimize costs and charge the relevant markup; and (vi) markets for all goods and all primary factors clear.

Remark 2. This equilibrium concept nests the standard one with flexible prices, which is obtained as a special case when $\delta_i = 1$ for every sector i .

1.5 Log-Linearized Model

We log-linearize the model around an efficient equilibrium with flexible prices, unit nominal GDP ($\sum_h P_h^* C_h^* + \sum_f P_f^* I_f^* = 1$) and zero transfers ($T_h^* = 0 \forall h$). Monetary policy is the only source of shocks. Tables 1, 2, 3, and 4 introduce the variables and parameters that govern the dynamics of our economy.

Input-output definitions. To a first order, the production structure is fully characterized by equilibrium input and final use shares and by the relevant Allen elasticities of substitution. Our representation follows the same structure as the National Accounts and is summarized in table 1.

Table 1. Input-Output Definitions

Consumption shares	$\beta_C \in \mathbb{R}^{N \times H}, \beta_{ih} = \frac{P_i C_{ih}}{P_h^C C_h}$
Investment expenditure	$\beta_I \in \mathbb{R}^{N \times F}, \beta_{if} = \frac{P_i X_{if}}{P_f^I I_f}$
Labor shares	$\alpha_L \in \mathbb{R}^{N \times H}, \alpha_{ih} = \frac{W_h L_{ih}}{MC_i Y_i}$
Capital shares	$\alpha_K \in \mathbb{R}^{N \times F}, \alpha_{if} = \frac{R_f X_{if}}{MC_i Y_i}$
Input-output matrix	$\Omega \in \mathbb{R}^N \times \mathbb{R}^N, \Omega_{in} = \frac{P_n X_{in}}{MC_i Y_i}$
Substitution elasticities	$\{\theta_{jn}^i\}$ production ϵ_i between varieties

Source: Authors' calculations.

Table 2. Input-Output Definitions: Parameters

Leontief inverse	$(I - \Omega)^{-1}$
Domar weights	$\lambda \in \mathbb{R}^{N \times (H+F)}, \lambda^T = \beta^T (I - \Omega)^{-1}$
Final expenditure shares	$s_h = \frac{P_h^C C_h}{GDP}, s_f = \frac{P_f^I I_f}{GDP}$
Factor income shares	$\Lambda = \alpha^T \lambda s, \mathcal{L} \equiv \text{diag}(\Lambda)$

Source: Authors' calculations.

Table 3. Other Parameters

Sector ownership	$\Xi \in \mathbb{R}^{N, H+F}, \Xi_{ih} \equiv \frac{\Pi_{ih} - T_{ih}}{\Pi_i - T_i}, \Xi_{if} \equiv 0$
Capital ownership	$Z \in \mathbb{R}^{F, H}, Z_{fh} \equiv \frac{R_{fh} K_{fh}}{R_f K_f}$
Factor supply elasticities	$\Phi \equiv \text{diag}(\gamma_1, \dots, \gamma_H, 0, \dots, 0) \mathcal{W} \mathcal{L}$ $+ \text{diag}(\phi_1^L, \dots, \phi_H^L, \phi_1^K, \dots, \phi_F^K)$

Source: Authors' calculations.

The elasticity of substitution of sector i between inputs j and k is defined as

$$\theta_{jk}^i \equiv \frac{\text{dlog} \frac{X_{ij}}{X_{ik}}}{\text{dlog} \frac{P_j}{P_k}}. \quad (21)$$

With a slight abuse of notation, here X_{ij} and X_{ik} indifferently denote either primary factors or material inputs. Table 2 introduces useful derived parameters.

Factor supply and ownership shares. Table 3 summarizes the parameters which govern the supply of labor and capital, and the allocation of income from profits and capital assets.

In table 3 we denote the $N_w + N_f \times N_w + N_f$ matrix

$$\mathcal{W} \equiv \begin{pmatrix} I & \mathcal{Z}^T (I + \Phi_K)^{-1} \\ \mathbb{O} & (I + \Phi_K)^{-1} \end{pmatrix}, \quad (22)$$

whose elements $\mathcal{W}_{hn}$ can be interpreted as the fraction of factor n 's income which accrues to factor h . Specifically, income from labor is entirely earned by the workers (corresponding to the identity matrix on the top left), while income from capital assets is divided between the profits of investment producers, which are rebated to households $(\mathcal{Z}^T (I + \Phi_K)^{-1})$ and investment expenditures $((I + \Phi_K)^{-1})$.

Price rigidity parameters. As explained below, sectoral inflation rates depend on an increasing and convex function $\hat{\delta}_i$ of the Calvo parameters δ_i , given by

$$\hat{\delta}_i(\rho, \delta_i) \equiv \frac{\delta_i (1 - \rho(1 - \delta_i))}{1 - \rho\delta_i(1 - \delta_i)}. \quad (23)$$

We denote by Δ the diagonal matrix collecting sectoral parameters $\{\hat{\delta}_i\}_{i=1}^N$.

Table 4. Model Variables

Employment gaps	$\ell_t = (l_{1t} \quad \dots \quad l_{Ht}, \quad u_{1t} \quad \dots \quad u_{Ft})^T$
Factor prices	$\mathbf{w} = (w_1 \quad \dots \quad w_H, \quad r_1 \quad \dots \quad r_F)^T$
Good price inflation	$\pi_t = (\pi_{1t} \quad \dots \quad \pi_{Nt})^T, \pi_{it} \equiv p_{it} - p_{i,t-1}$

Source: Authors' calculations.

Notation. We include factor marketplaces and retailers among the production sectors. With this modeling choice, the matrices α , β and Ω take the specific form illustrated below. We ordered the good-producing sectors first, then the factor marketplaces, and lastly the final consumption and investment retailers.

$$\Omega = \begin{bmatrix} \Omega_P & \Omega_M & \mathbb{O}_{N, N_w + N_f} \\ \mathbb{O}_{N, N_w + N_f} & \mathbb{O}_{N_w + N_f} & \mathbb{O}_{N_w + N_f} \\ \Omega_C & \mathbb{O}_{N_w + N_f} & \mathbb{O}_{N_w + N_f} \end{bmatrix}, \alpha = \begin{bmatrix} \mathbb{O}_{N, N_w + N_f} \\ I \\ \mathbb{O}_{N_w + N_f} \end{bmatrix}, \beta = \begin{bmatrix} \mathbb{O}_{N, N_w + N_f} \\ \mathbb{O}_{N_w + N_f} \\ I_{N_w + N_f} \end{bmatrix} \quad (24)$$

Variables. Table 4 introduces the variables. Lower-case letters denote log deviations from a steady state with no monetary shocks.

Remark 3. Table 4 defines employment and utilization gaps for primary factors, rather than for each sector. These are sufficient to characterize the evolution of prices as well.

Definition 5. The aggregate output gap is given by

$$\bar{y} = \sum_{h \in \mathcal{N}_h} \Lambda_h l_h + \sum_{f \in \mathcal{N}_f} \Lambda_f u_f. \quad (25)$$

2. CROSS-SECTIONAL MULTIPLIERS

Following Rubbo (2023), the employment of primary factors changes according to the cross-sectional employment multiplier

$$\tilde{\ell} = (I - \mathcal{X}_\ell)^{-1} \left[1 \bar{y} + \mathcal{D}_p (I - \mathcal{V}) (p_{t-1} + \rho \mathbb{E} \pi_{t+1}) \right]. \quad (26)$$

Equation (26) isolates a direct effect of increasing the aggregate output gap on cross-sectional employment (given by vector 1) and a

multiplier $(I - \mathcal{X}_\ell)^{-1}$ that captures the propagation of the shock in general equilibrium. Intuitively, through the direct effect, final users expand their demand for all goods proportionately. However even proportional changes in demand can have an effect on relative prices because the wage of inelastically supplied factors increases and the relative price of more flexible sectors also increases. In turn, this increases the demand for goods and factors that have become relatively cheaper.

This feedback—from demand to prices and back into demand—is captured by the multiplier

$$\mathcal{X}_\ell \equiv \text{Cov}_s \left(\mathcal{L}^{-1} \alpha^T \lambda, S^{-1} \mathcal{W} \mathcal{L} \right) + \mathcal{D}_p \kappa \Phi. \quad (27)$$

The first term in equation (27) says that employment increases for the primary factors that are used more intensively in the consumption basket of households whose income increased, as measured by the correlation between factor contents in consumption $(\alpha^T \lambda)$ and the households' income from primary factors $(S^{-1} \mathcal{W} \mathcal{L})$.

In the second term, the $\bar{N} \times (N_w + N_f)$ matrix $\kappa \Phi$ is the slope of sector-by-factor Phillips curves, which maps changes in the employment of primary factors into changes in prices. See the appendix for a definition of $\kappa \Phi$ in terms of primitives. The $(\bar{N}_w + N_f) \times N$ matrix $\mathcal{D}_p$ instead describes how changes in relative prices feed back into relative demand through income reallocation or substitution. See the appendix for a definition of $\mathcal{D}_p$ in terms of primitives. Intuitively, employment increases for the primary factors that are demanded by final users whose relative income increased or for factors whose relative price decreased or for whom the price of complementary factors decreased, and so on.

Employment also responds to past price changes and future expected inflation because they induce changes in current relative prices. The response is mediated by the $\bar{N} \times \bar{N}$ matrix $\mathcal{V}$ (defined in the appendix).

The income of each primary factor changes according to the cross-sectional income multiplier

$$\mathbf{w} + \ell = (I - \mathcal{X}_\ell)^{-1} \left[1 (\bar{w} + \bar{\ell}) - \hat{\mathcal{D}}_p (I - \hat{\mathcal{V}}) (\chi + \rho \mathbb{E} \pi_{t+1}) \right]. \quad (28)$$

Again, monetary policy affects incomes through a direct effect and a general equilibrium multiplier

$$\mathcal{X}_I \equiv \text{Cov}_s \left(\mathcal{L}^{-1} \alpha^T \lambda, S^{-1} \mathcal{W} \mathcal{L} \right) + \hat{\mathcal{D}}_p \kappa \Phi. \quad (29)$$

There are two key differences between the employment and income multipliers. First, the elasticity of factor and good prices with respect to income is smaller than with respect to employment. This is intuitive: both changes in employment and income shift the labor-supply curve through a wealth effect, but changes in employment also move workers along their labor supply-curve. Second, unlike employment, income shares are not always decreasing in price. This is captured by the matrix $\mathcal{D}_p$, which is different from $\mathcal{D}_p$ in (26). While higher prices reduce factor demand, they also increase income. These two effects exactly offset when demand is Cobb-Douglas. The direct effect on income prevails—and income shares are increasing in relative prices—when primary factors are complementary (in an aggregate sense). Vice versa, income shares are decreasing in relative prices when primary factors are substitutes.

Section 4 computes the employment and income multipliers in (26) and (28) for 50 demographic groups in the Chilean population, highlighting significant heterogeneity in the incidence of monetary policy.

3. CALIBRATION

3.1 Data

We use confidential administrative data from the Chilean Internal Revenue Service (SII) as well as detailed, disaggregated publicly available National Accounts data for Chile to calibrate several aspects of the model.

Cluster-level employment shares. We use firms' monthly payments to the unemployment insurance administrator, which reports the total labor compensation for each worker employed. A crucial characteristic of this dataset is that it contains demographic information at the workers level, such as age and gender. By using the universe of workers in this dataset in 2018, we compute the wages for quintiles of the distribution of labor compensation.

This way, we classify workers in each of the 111 industries into 50 clusters according to their combination of gender, labor compensation quintiles, and age categories: 18–24, 25–34, 45–54, and over 54 years old. We drop all workers under 18 and those over retirement age—60 for women and 65 for men. Then, we compute the whole-sample average of the share of workers in each cluster from the total number of individuals employed.

Cluster-level labor shares. By using the same classification as for employment shares described above, we compute the industry-level average of the share of labor compensation of each cluster over the total labor compensation for firms in each industry. We normalize these shares such that the total industry-level labor shares coincide with the same object computed from the 2017 National Accounts Input-Output Matrix data for the same 111 industry classification.⁵ As the model is a closed economy, we adjust totals by excluding exports and imports.

Industry-level Input-Output linkages. From the 2017 Input-Output Matrix data, we compute the share of each industry in the total of intermediate inputs purchased from each of the 111 industries. These shares are normalized such that their sum for a given buying industry coincides with the share in costs of intermediate inputs reported in the National Accounts once exports and imports are excluded.

Industry-level capital shares. These shares are computed as the difference between one and the sum of the industry-level labor and intermediate inputs shares described above.

Industry-level consumption shares. Also the 2017 Input-Output Matrix data report the total use of industrial production as final consumption. We simply transform them to shares once exports and stock variation are excluded.

Industry-level nominal price rigidity. We use confidential V.A.T. electronic invoices at the transactional level from 2015 to 2022—the results are robust to exclude the COVID episode, the 2020–2022 period. This dataset reports quantities and prices of all products involved in firm-to-firm transactions. We interpret the degree of nominal price rigidity at the industry level as the industry average of the frequency of price adjustment. To compute it, we first follow the algorithm proposed by Acevedo and others (2022), which identifies individual products by matching the text field included in VAT invoices for the description of all products. Then we collapse this information at the daily frequency using the intra-day mode to obtain a daily time series of prices for each identified product for each selling firm. We compute the frequency of price changes each month, as the number of varieties with price changes divided by the total number of varieties in the firms' sales of each product. Then we classify firms into 111 industries using the official CAE-111 classification for National Accounts in Chile. Using this classification, we compute the average

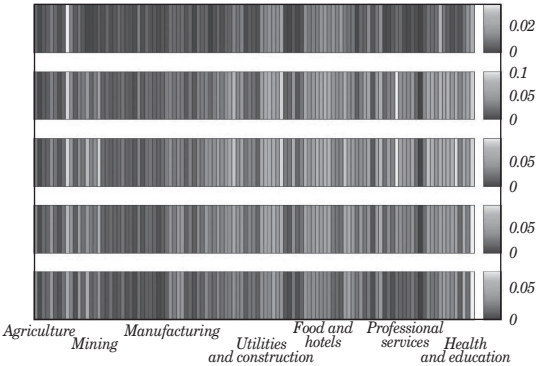
5. <https://www.bcentral.cl/contenido/-/detalle/cuentas-nacionales-chile-2013-2019-2019>

frequency of price changes at the industry level by weighting each product sold by each selling firm by their share of nominal sales for the whole sample.⁶

3.2 Summary Facts

We now discuss heterogeneity across Chilean population groups. **Employment shares.** First, we show that different groups are likely to be employed by different industries. Figures 1 through 4 plot heatmaps of the probabilities that each group is hired by each sector. Different subplots correspond to different groups (either by income or by education), and different columns correspond to different industries. **Price rigidity across industries.** Figure 5 displays a bar chart of price adjustment probabilities across sectors, which shows substantial heterogeneity. Below, we show that different workers have different exposure to sticky-price vs. flex-price sectors through the employment and consumption channels.

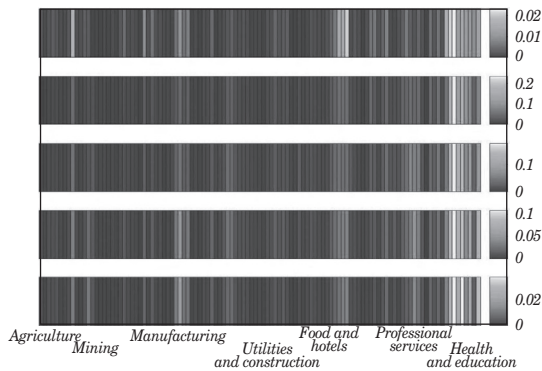
Figure 1. Employment by Age – Men



Source: Authors' calculations.
Note: Rows correspond to age quintiles, columns correspond to industries. Lighter colors correspond to higher employment shares.

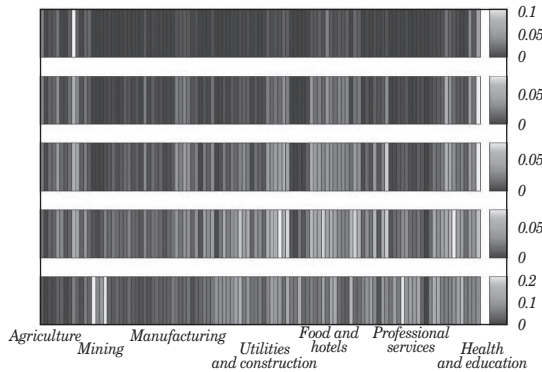
6. For those sectors for which electronic invoices do not have good information on prices, mostly services, we use data from the National Statistics Institute (INE) from January 2019 to March 2022 to calculate the frequency of price changes.

Figure 2. Employment by Age – Women



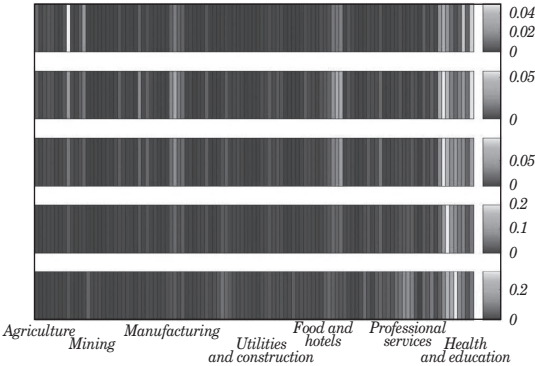
Source: Authors' calculations.
Note: Rows correspond to age quintiles, columns correspond to industries. Lighter colors correspond to higher employment shares.

Figure 3. Employment by Income – Men



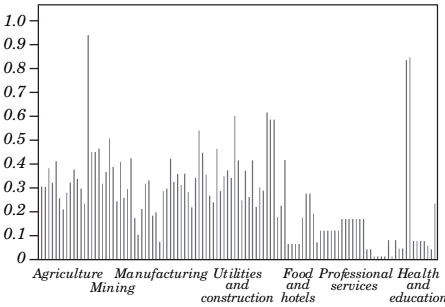
Source: Authors' calculations.
Note: Rows correspond to income quintiles, columns correspond to industries. Lighter colors correspond to higher employment shares.

Figure 4. Employment by Income – Women



Source: Authors' calculations.
Note: Rows correspond to age quintiles, columns correspond to industries. Lighter colors correspond to higher employment shares.

Figure 5. Price Adjustment Probabilities by Industry

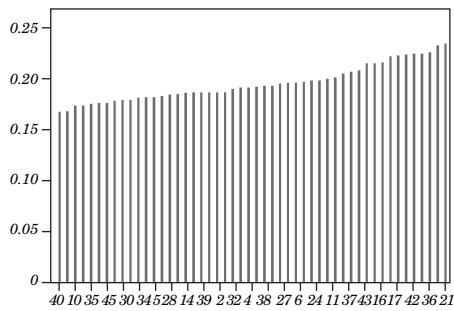


Source: Authors' calculations.

Price rigidity and workers. Figures 6 and 7 show which clusters of workers are more exposed to price rigidity through final consumption and through employment. As we discussed in section 2, the effect of monetary policy across different households depends crucially on these two objects.

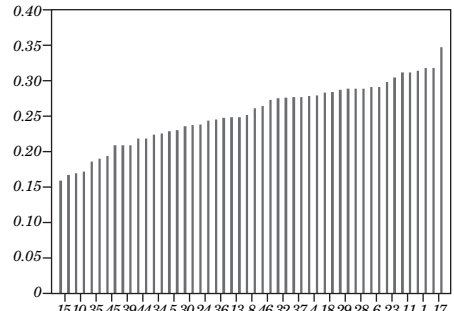
In figure 6 we display price rigidity of the consumption basket, weighting price rigidity of each economic sector by the consumption share of that sector in the consumption of goods of a given cluster. We find limited heterogeneity in this dimension.

Figure 6. Price Rigidity of Consumption Basket



Source: Authors' calculations.
Note: Cluster numbers on the x-axis correspond to men (1-25) or women (25-50), in ascending order by age groups, and by income quintile within age groups.

Figure 7. Price Rigidity of Employer Industries

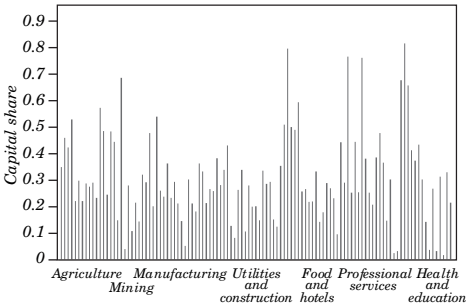


Source: Authors' calculations.
Note: Cluster numbers on the x-axis correspond to men (1-25) or women (25-50), in ascending order by age groups, and by income quintile within age groups.

Figure 7 displays price rigidity of the hiring sector, weighting price rigidity of each economic sector by the probability that a given cluster is hired by that sector. We find important heterogeneity as employer's price stickiness varies from 15 percent to 35 percent across clusters.

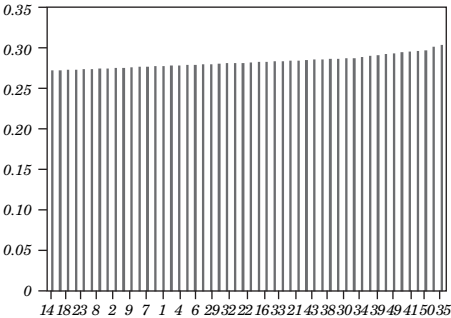
Capital shares across industries and workers. Finally, figure 8 displays a bar chart of capital shares across industries, showing substantial heterogeneity. Nonetheless, figure 9 shows that this generates only limited variation in the capital intensity of industries that hire different worker groups. This result suggests that interacting industry-by-demographic group would imply even more heterogeneous responses to monetary policy than we find in section 4.

Figure 8. Capital Shares across Industries, Sorted in Ascending Order



Source: Authors' calculations.

Figure 9. Capital Share of Employer Industries



Source: Authors' calculations.
Note: Cluster numbers on the x-axis correspond to men (1-25) or women (25-50), in ascending order by age groups, and by income quintile within age groups.

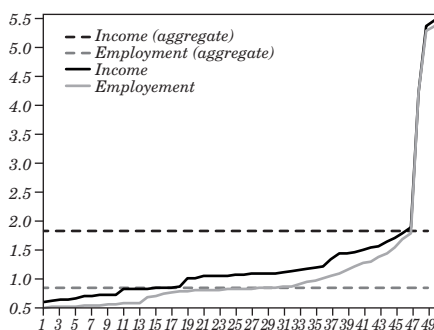
4. QUANTITATIVE RESULTS

Figure 10 shows cumulative employment and income responses to a real money supply shock. The responses are normalized by the cumulative size of the shock and sorted in increasing order across demographic groups.

The employment responses display vast heterogeneity, ranging from 0.5 percent to more than 5 percent. The solid lines show employment and income of households only, while the dashed lines correspond to aggregate employment and income including capital assets.

Figure 11 compares cross-sectional and aggregate employment responses in the baseline calibration versus an otherwise identical model with no input-output linkages. As it is well known, the presence of input-output linkages increases monetary non-neutrality (i.e., it amplifies the response of employment to monetary shocks). In the Chilean economy, however, the effect of input-output linkages is very small due to a much smaller input-output multiplier than, for example, the United States.⁷

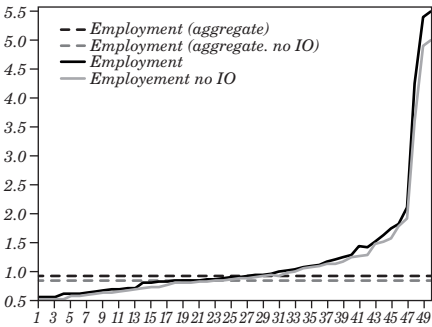
Figure 10. Cumulative Impulse Responses of Employment and Income to Monetary Shock



Source: Authors' calculations.

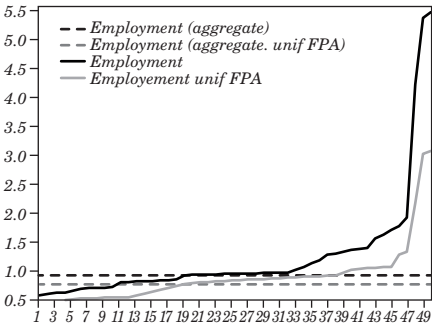
7. See Pastén and others (2019).

Figure 11. Employment Responses with and without Input-Output Linkages



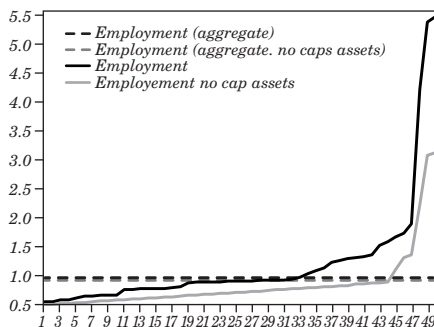
Source: Authors' calculations.

Figure 12. Employment Responses in the Baseline Model and in a Counterfactual Model with Uniform Price Adjustment Probabilities



Source: Authors' calculations.

Instead, figure 12 shows that heterogeneity in price adjustment frequencies across sectors is a major driver of cross-sectional non-neutrality. As it is well known from input-output New Keynesian models with a representative household, heterogeneous price adjustment frequencies increase the aggregate non-neutrality. Figure 12 shows that it also amplifies the cross-sectional dispersion of employment responses, as employment increases by more for demographic groups that are employed in sticky-price industries.

Figure 13. Employment Responses with and without Capital Assets

Source: Authors' calculations.

Finally, figure 13 compares cross-sectional and aggregate employment responses in the baseline calibration versus a model with no capital assets. The figure shows that ignoring the presence of semifixed capital assets would lead to underestimating the cross-sectional range of employment responses.

5. CONCLUSION

By using rich microdata from the Central Bank of Chile, we showed that Chilean households in different demographic groups are subject to different degrees of wage rigidity and are employed in industries with different price rigidity and capital shares. We then used the framework in Rubbo (2023) to compute the implications of heterogeneity for the response of employment and income to monetary policy across households. The model predicts significant heterogeneity in the response of employment and income across households, with larger employment effects for households that are employed by sticky-price sectors. These households have higher incomes and are in the higher age quintiles.

REFERENCES

- Andersen, A., E.T. Hansen, K. Huber, N. Johannesen, and L. Straub. 2022. "Disaggregated Economic Accounts." Technical Report W30630, National Bureau of Economic Research.
- Aoki, K. 2001. "Optimal Monetary Policy Responses to Relative-Price Changes." *Journal of Monetary Economics* 48(1): 55–80.
- Auclert, A. 2019. "Monetary Policy and the Redistribution Channel." *American Economic Review* 109(6): 2333–67.
- Auclert, A., B. Bardoczy, M. Rognlie, and L. Straub (2021). "Using the Sequence-Space Jacobian to Solve and Estimate Heterogeneous-Agent Models." *Econometrica* 89(5): 2375–408.
- Baqae, D.R. and E. Farhi. 2018. "Macroeconomics with Heterogeneous Agents and Input-Output Networks." NBER Working Paper No. 24684.
- Baqae, D.R. and E. Farhi. 2020. "Productivity and Misallocation in General Equilibrium." *Quarterly Journal of Economics* 135(1): 105–63.
- Basu, S. 1995. "Intermediate Goods and Business Cycles: Implications for Productivity and Welfare." *American Economic Review* 85(3): 512–31.
- Benigno, P. 2004. "Optimal Monetary Policy in a Currency Area." *Journal of International Economics* 63(2): 293–320.
- Carvalho, C. 2006. "Heterogeneity in Price Stickiness and the Real Effects of Monetary Shocks." *B.E. Journal of Macroeconomics* 6(3): 1–58.
- Coglianese, J., M. Olsson, and C. Patterson. 2023. "Monetary Policy and the Labor Market: A Quasi-Experiment in Sweden. University of Chicago, Becker Friedman Institute for Economics Working Paper No. 2023–123.
- Devereux, M.B. and C. Engel. 2003. "Monetary Policy in the Open Economy Revisited: Price Setting and Exchange-Rate Flexibility." *Review of Economic Studies* 70(4): 765–83.
- Gali, J. and T. Monacelli. 2008. "Optimal Monetary and Fiscal Policy in a Currency Union." *Journal of International Economics* 76(1): 116–32.
- Huang, K.X.D. and Z. Liu. 2007. "Business Cycles with Staggered Prices and International Trade in Intermediate Inputs." *Journal of Monetary Economics* 54(4): 1271–89.
- Kaplan, G., B. Moll, and G.L. Violante. 2018. "Monetary Policy According to HANK." *American Economic Review* 108(3): 697–743.

- La'O, J. and A. Tahbaz-Salehi. 2019. "Optimal Monetary Policy in Production Networks." Working Paper No. 3488415, SSRN Electronic Journal.
- Minton, R. and B. Wheaton. 2023. "Minimum Wages and the Rigid-Wage Channel of Monetary Policy." American Economic Association. American Economic Association.
- Nakamura, E. and J. Steinsson. 2010. "Monetary Non-Neutrality in a Multisector Menu Cost Model." *Quarterly Journal of Economics* 125(3): 961–1013.
- Pastén, E., R. Schoenle, and M. Weber. 2019. "The Propagation of Monetary Policy Shocks in a Heterogeneous Production Economy." *Journal of Monetary Economics* 116: 1–22.
- Rubbo, E. 2020. "Networks, Phillips Curves, and Monetary Policy." *Econometrica* 91(4): 1417–55.
- Rubbo, E. 2023. "Monetary Non-Neutrality in the Cross-Section." Working paper.