Social Security Reform in the Presence of Informality*

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Abstract

As populations age, countries across the globe are dealing with the issue of how to fund retirement consumption for their workers. The design of Social Security programs is more difficult when the country also exhibits an informal economy where workers avoid the taxation of the government and are not entitled to its benefits. In this paper, I study the example of Chile– a country that transitioned from a pay-as-you-go Social Security system to a system of private, individual retirement accounts in 1981 and also exhibits a significant informal sector–in order to quantify the transitional welfare impact of Social Security privatization when workers have the option to evade the public system through informality. I construct an OLG model which allows households to split working time between a taxed formal sector, an untaxed informal sector, and home production. I find large long-run welfare gains of roughly 10 and 15 percent for low and high-productivity workers, respectively. However, these gains come at the expense of losses for two groups: low-productivity workers who are retired at the time of the reform and high-productivity workers within 5 years of retirement at the time of the reform. The presence of informality leads to conflicting mechanisms: (1) the elasticity channel decreases welfare gains from reform: including informality as imperfectly substitutable with formality in utility decreases labor supply elasticity and renders the pay-as-you-go payroll tax less distortionary, and (2) the market wage channel increases welfare gains from reform: the privatization of the Social Security system causes wage growth which informal workers can receive without facing the distortions of any remaining taxation in the formal sector. Quantitative results indicate the elasticity channel is stronger in the case of Chile, and the inclusion of informality decreases the long-run welfare gains from privatizing Social Security.

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1 Introduction

As world populations age, many governments are dealing with the issue of how to provide retirement income for citizens. There is ample research that pay-as-you-go (PAYG) Social Security programs are unsustainable, especially in the presence of these aging populations. As the ratio of workers to retirees falls, the burden of the government to provide retirement consumption for the population increases. Previous work has shown there are long-run welfare gains from reforming from a pay-as-you-go Social Security program to a system of private, individual retirement accounts. However, this work also shows that these long-run gains are often financed by welfare losses for workers who live through the transition between the programs. As the economy transitions between the programs, the government loses payroll tax income from new workers. At the same time, it must also compensate older workers and current retirees for prior contributions to the pay-as-you-go system.

This transition between PAYG and individual accounts and its welfare impact is influenced by how agents augment their savings, consumption, and–of particular importance for this study–labor choices in response to the policy change. The presence of outside options to working in the market is key in understanding the labor market response of workers. Recent estimates indicate that over 60 percent of the world's employed population works in the informal economy, and some areas of the globe may experience informality rates of nearly 90 percent.[1] Due to the large size of this sector in many countries, understanding how policy changes interact with the size and behavior of this sector is important to understand possible impacts of such reforms.

Changes in the taxation and benefits associated with policy reforms change the incentives for formal, informal and home sector work. In particular, as taxes increase or the benefits that a worker is eligible for based on formal work decrease, the incentives for households to avoid regulation and work informally or at home increase. Therefore, as taxes and transfers adjust throughout a transition between a PAYG pension program and an individual account system, the sizes of the informal economy and the home production sector change. These changes have a direct impact on the size of the tax base, the transfers workers are entitled to, and, thus, the government budget constraint. Therefore, movements in the size of the various labor sectors in response to a policy change can affect the long-run impact of the reform.

In 1981, Chile became the first country to amend its PAYG Social Security system and begin the transition to a mandatory savings program consisting of private, individual retirement accounts. In the years that followed, this change has inspired other countries in Latin America, as well as countries throughout the world, to make changes to their own retirement systems. In the aftermath of the Chilean reform, ten other countries within Latin America took on reformed programs inspired

[1]The International Labour Office finds a global informality rate 61.2 percent. They also measure that this rate is as high as 85.8 percent in Africa, 71.4 percent in Asia, 68.6 percent in the Arab states and 53.8 percent in the Americas.

by the new Chilean system.[2] Additionally, countries all across the globe have reformed their Social Security systems[3] to include individual retirement accounts.[4] Many other countries, including the United States, however, have not moved away from their PAYG systems. For this reason, Social Security in Chile stands as an example for pension systems across the globe.[5] Additionally, the Chilean economy exhibits a significant informal sector. Therefore, Chile provides a case study of not only Social Security privatization, but also of the impact of such a reform in the presence of outside options to formality.

To address this question, I build an overlapping generations model including three key features. First, I include age and productivity heterogeneity to study how the reform impacts welfare for different age groups and income levels. Second, I model the government policy after the specifics of the Chilean reform to isolate the impact of various aspects of this reform. Finally, and unique in my analysis, I include a household decision to split working time between a taxed formal sector, an untaxed informal sector, and home production to focus on how movements between sectors impact the outcomes of the reform.

Formality, informality, and home production have distinct roles within the model. The formal sector of the market allows workers to receive a market wage and a retirement pension based upon their formal earnings. However, workers must also pay taxes on the income earned for work in the formal sector. Home production, which previous literature has shown to be important in household decisions, gives households an outside option to working in the market. Home production produces a non-tradable good which is substitutable with market goods. Workers can use home production to avoid taxation while continuing to consume. However, the worker forgoes the wage they would have received for market work. Informality fills a gap between the formal sector and the home production sector. The informal sector gives workers a way to earn a market wage while also avoiding the taxation of the formal sector.

The way in which formal and informal labor are modeled is crucial for this work. I highlight two methods through which informal work affects households: through government policies and through utility. First, households pay taxes on income earned formally. Only this formal working income is used to calculate the pension in the PAYG system. As the household spends more time working informally, its taxes and average taxable earnings decrease. Therefore, the pension the household is

[2]The Latin American countries that reformed to systems inspired by the Chilean model are: Argentina (1994), Bolivia (1997), Colombia (1993), Costa Rica (1995), Dominican Republic (2003), El Salvador (1998), Mexico (1997), Panama (2008), Peru (1993), and Uruguay (1996).

[3]Countries included in this category are: Bulgaria (2000), Croatia (2001), Denmark (2002), Estonia (2002), Hungary (1998), Kazakhstan (1998), Kosovo (2002), Latvia (2001), Nigeria (2001), Poland (1999), Russia (2002), Singapore (1997), Slovakia (2005), and Sweden (1999).

[4]These countries may not have systems that are entirely funded by private accounts, but at least part of their retirement funding programs include private, individual retirement accounts.

[5]Recent events have led Chilean citizens and the Chilean government to pursue changes to the system. The 1981 reform, however, will remain an example of a transition from PAYG to individual accounts.

eligible for also decreases. Second, I highlight non-pecuniary aspects of formal and informal work by modeling these sectors as imperfectly substitutable in household utility. Because formality and informality are substitutes, there is movement between the sectors as the labor tax–the relative price of formal work–moves. However, these sectors are imperfectly substitutable so there will always be strictly positive hours in both sectors. Fear of punishment if caught working informally, the need to work formally to gain access to credit markets or social programs, lack of access to formal sector jobs, and other non-pecuniary differences between the sectors are captured in this inability of labor to respond to only the taxation of the formal sector. An additional benefit of this modeling choice is the Chilean micro-data can be used to measure the relationship between formal and informal work.

Using micro-data for the Chilean economy, I estimate the parameters that discipline the relationship between home production and market labor as well as those that discipline the relationship between formal and informal labor supply. In addition to using this micro-data, I ensure that the model is consistent with various macroeconomic aggregates and use the government policy to construct historical series for the fiscal variables. By using this data, I can quantitatively measure the welfare impact of the transition between the pay-as-you-go program and the privatized system of individual accounts.

In order to measure the welfare impact, I simulate two demographics transition paths for the economy: one in which the reform occurs as it did historically, and a second as if the economy remained in the PAYG system from 1980. The results of this experiment show that long-run welfare gains are present due to the reform. Manual laborers, who pay lower contribution rates and receive less generous PAYG pensions, experience gains of nearly 10 percent of lifetime consumption and employees and managers, who pay higher contribution rates and receive larger pensions prior to the reform, experience gains of roughly 15 percent. However, generations that live through the transition between the two programs experience welfare losses up to around 10 percent of remaining lifetime consumption. Manual laborers who are retired at the time of the reform experience losses due to falling government transfers; employees and managers who are nearing retirement at the time of reform experience losses as the transitional policy pays them a smaller pension than they would have received under the pay-as-you-go program.

The inclusion of home production and informality together lead to higher long-run welfare gains. However, these gains can be further decomposed into the portion caused by the inclusion of home production and the portion caused by the option of informality. Similar to other research, I find that including only home production increases aggregate welfare gains as home production increases the elasticity of the labor supply. This leads the Social Security payroll tax to be more distortionary than in an economy without the option of home production. Therefore, the economy experiences larger long-run welfare gains when the payroll tax is removed through the reform.

Informality, on the other hand, causes two mechanisms which have conflicting impacts on long-

run welfare gains. First, including the option of informality as an imperfect substitute in the utility of the household decreases the elasticity of the labor supply as the ability to move between the sectors is limited by the degree of substitutability between them. Therefore, in contrast to home production, including informality renders the PAYG payroll tax less distortionary and decreases long-run welfare gains. Second, informality gives households an opportunity to receive a market wage without facing any additional labor income taxation in the formal sector. Since the transition between a pension systems leads to increased wages, including informality increases long-run welfare gains from reform. Quantitatively, the first mechanism dominates; in an economy including informality, privatization of the pension system leads to smaller welfare gains than the same reform in an economy with only formality.

The paper precedes as follows. Section 2 introduces the related literature. Section 3 describes the model. Section 4 discusses the background of the Chilean pension system before and after the reform. Section 5 details how parameters are estimated from the data. Section 6 presents the transitional results. Section 7 discusses how including informality and home production impact the long-run results. Section 8 concludes.

2 Related Literature

My work contributes most directly to two large bodies of literature: studies of Social Security reforms and studies related to outside options to formal work. Specifically, within the area of Social Security reform, my work contributes to studies of the macroeconomic effects of privatizations of Social Security as well as microeconomic studies of the Chilean reform. Related to outside options to formal work, my paper contributes to understanding home production, informality, and how these options impact reforms such as a change to Social Security.

Most papers involving the transition to a system of individual accounts in the United States come to a similar conclusion that there are positive long-run gains to switching from a pay-as-you-go system to an individual account system. These papers, however, disagree on whether it is possible to devise a system in which the welfare gains of future generations are not financed by welfare losses for those living through the transition.

Huang, Imrohoroglu, and Sargent (1997) study a transition in which the government compensates the current generations by issuing debt. Although future taxes can be lowered, the taxes must remain high while the government pays off the debt. Kotlikoff, Smetters, and Walliser (1999) study many different policies and find that privatization has long-run gains that come with short-run costs. Finally, studies such as Conesa and Krueger (1999), Nishiyama and Smetters (2007), Huggett and Parra (2010), and Imrohoroglu and Kitao (2012) find that adding uncertainty makes the transition to privatization even more challenging due to losses in the insurance provided by the Social Security

program. On the other hand, papers such as McGrattan and Prescott (2017) are able to find a system in which all agents experience welfare gains by flattening the tax schedule and removing the difference between average and marginal tax rates. Although they disagree on the transitional dynamics, all these papers document the long-run welfare gains of a reform in the United States.

Reforms in other countries, however, is a smaller literature. Feldstein (1998) presents a series of papers that discuss privatization of Social Security programs in various countries, including Chile. Edwards (1998) provides a background of the economy of Chile prior to and after the reform as well as transitional issues associated with the reform.[6]

Much of the literature on the Chilean reform is concentrated on micro-level implications of the reform. Specifically, the literature focuses on the impact on savings or on the labor force decisions of agents. Arenas de Mesa et. al. (2007) assesses the reformed system through studies of coverage, outcomes, and financial literacy 25 years after the reform; Acua and Iglesias (2001) address the impacts on similar variables after 20 years. Much work in this literature also comes in response to additional changes made to the Chilean system in 2008.[7] Behrman et. al. (2011) analyzes the effects of the minimum pension levels on the household income, labor choices, health status, and spending behavior of the individuals. Additionally, Joubert (2010) and Joubert (2015) study the relationship between the design of the pension system and how it impacts the labor decision of the agent. Joubert and Todd (2011) and Arenas de Mesa and Montecinos (1999) extends the work of the prior two papers to study how the design impacts men and women differently. Specific to the economy of Chile, these papers, as well as Attanasio, Meghir, and Otero (2011), examine the impact that the pension changes have on the labor force participation in both the formal and the informal sectors of the economy. They find that increases in self-financed pension wealth negatively affect labor force participation in the formal sector. This paper highlights that workers move between the formal sector and the informal sector–an outside option to formal work–in response to the reform.

The second area to which I contribute is the literature on outside options to formal market work. Similar to this paper, Dotsey, Li, and Yang (2015) study how the inclusion of home production affects the transitional welfare results from Social Security reform. They find that the option to work at home increases labor supply elasticity and leaves the Social Security payroll tax more distortionary. Therefore, the inclusion of home production increases the long-run welfare gains from the reform.

I also contribute to the empirical literature on home production. I contribute by using micro-data to empirically measure the elasticities of substitution associated with informality and home produc-

[6] Additional details of the Chilean system before and after the reform can be found in Kritzer (2005, 2008) and Kritzer, Kay, and Sinha (2011).

[7] The 2008 changes to the Social Security system were made in response to problems with agents, specifically women, not being able to accumulate a sufficient pension. The additional reforms made it possible for women to receive benefits without working 20 years, allowed her to be entitled to half of her husband's pension after a divorce, and gave a credit to a woman's for having a child. I will not consider the details of this reform when I analyze the impacts of the 1981 reform.

tion in Chile. A large literature, including Benhabib, Rogerson, and Wright (1991), has studied home production and the implications of including home production in economic models. Additionally, previous literature has also used data to measure the parameters that drive the interaction between market and home production. Using data from the United States, various papers such as Rupert, Rogerson, and Wright (1995), McGrattan, Rogerson, and Wright (1997), Chang and Schorfheide (2003), Fang and Zhu (2012), and Aguiar, Hurst, and Kararbarbounis (2013), estimate the elasticity of substitution between market and home production to be between 1.81 and 2.3. I use micro-data for Chile in order to estimate the same elasticities for the Chilean economy, while also extending the method to estimate a similar elasticity for informality.

Finally, my paper contributes to the literature of understanding informality and its impact on the economy. The informality literature is vast but lacks consensus on the sources of informality– as discussed in Maloney (2004). Initial work in Lewis (1954) proposed that formal and informal markets are segmented; some workers do not have access to formal jobs. However work including Magnac (1991), Maloney (2004), Pratrap and Quintin (2004), Amaral and Quintin (2006), and Ulyssea (2010) has questioned the importance of this segmentation between formality and informality in many economies and looked at other drivers of informality–such as credit constraints on firms. Other work, such as De Soto (1989), proposes that regulation and taxation, rather, determines the size of the informal sector. However, this explanation ignores non-pecuniary motives for informality or formality. This result is reinforced by Bujanda and Samaniego de la Parra (2020) which finds there is no wage benefit to formalizing; there must be other forces which create informality in an economy. A paper most related to my own, Galiani and Weinschelbaum (2007), combines these ideas by using a model with heterogeneity in firms and workers which highlights many motives for informality. My work provides another tractable way to bring together the ideas of both pecuniary and non-pecuniary factors impacting the presence of informality through use of imperfect substitutability between formality and informality in the preferences of workers.

3 Model

I use an overlapping generations model with heterogeneous households to analyze the impact of the 1981 Chilean Social Security reform. The economy is populated by households that differ in age and productivity. Productivity is constant throughout a household's lifetime. Time since entry into the workforce is called the age of the household and denoted by j. There is no survival uncertainty in the economy, and all households die at age J. All households retire at age R, $R < J$. A measure $\mu_t^{1,\varepsilon}$ enter as working age (age 1) households with skill level ε at the beginning of period t. $\mu_t^{j,\varepsilon}$ is the measure of households of age j and skill level ε at time t.

The parameters $\mu_t^{1,\varepsilon}$ define the population dynamics. In particular,

$$\mu_{t+1}^{1,\varepsilon} = (1+g_t)\,\mu_t^{1,\varepsilon} \tag{1}$$

with $\sum_\varepsilon \mu_0^{1,\varepsilon} = 1$. The growth rate of households entering the workforce is given by g_t. This parameter is assumed to be the same across productivity levels but is permitted to vary across time.

3.1 State Vector

The state vector of the economy, S_t, is defined as:

- t: the time period
- $\left(a^{j,\varepsilon}, \bar{y}^{j,\varepsilon}, \mu^{j,\varepsilon}\right)$: the joint distribution of assets and average taxable earnings of an age j and skill level ε household and the measure $\mu^{j,\varepsilon}$ of these households
- K_m : the aggregate stock of market capital
- B, G, τ : the government fiscal policy variables (the series for debt, government spending, and taxes on consumption, labor, and firm profits and dividends)

3.2 Household's Problem

The value function of an agent of age $j \in \{1, ..., J\}$ with skill or productivity level ε is given by:

$$V_{j,\varepsilon}(a_t, \bar{y}_t; S_t) = \max_{a_{t+1}, c_{mt}, d_t, h_{ft}, h_{it}, h_{ht}} u(c_t, l_t) + \beta V_{j+1,\varepsilon}(a_{t+1}, \bar{y}_{t+1}; S_{t+1}) \tag{2}$$

Households of age j and productivity ε enter period t with asset holdings a_t and average taxable income $\bar{y}_t$. These households also face the aggregate state S_t. Utility takes consumption and leisure as inputs into the function $u(\cdot)$. These inputs are defined by:

$$c_t = h(c_{mt}, c_{ht}) \tag{3}$$

$$l_t = 1 - h_{ht} - h_{mt} \tag{4}$$

Consumption is defined by a function, h, of consumption of a tradable market good, c_{mt}, and consumption of a non-trabable home produced good, c_{ht}. Leisure is a linear function of hours at home, h_{ht}, and hours spent working in the market, h_{mt}. As informality is an important part of the labor market in many countries, including Chile, I include an option for households to work in either the formal or the informal sector of the market economy. In the model, informal labor will show up in two places: in the utility function and in the net tax function. First, market labor is a function of

the time spent working in the formal sector and the time spent working in the informal sector of the economy. Therefore, utility is function of both formality and informality. The function $\Gamma(\cdot)$ defines this relationship:

$$h_{mt} = \Gamma\left(h_{ft}, h_{it}\right) \tag{5}$$

I take the function $\Gamma(\cdot)$ to be convex so that formality and informality are imperfectly substitutable in the utility of the household.

In addition to the utility relationship between formal and informal labor, there is also a wage benefit to working as well as taxes the workers must pay. These taxes paid are different in the formal and informal sectors. Both the wages and these taxes will enter into the market budget constraint faced by the household. The budget constraint for market goods is given by the following:

$$(1+\tau_{ct})(c_{mt}+d_t)+a_{t+1} = (1+i_t)a_t + w_t\varepsilon\left(h_{ft}+h_{it}\right) - T_t^j\left(w_t\varepsilon h_{ft}, \bar{y}_t\right) \tag{6}$$

Households choose consumption of the market consumption good, c_{mt}, and spending on durable goods, d_t. The household pays a consumption tax, τ_{ct}, on consumption of both goods. Additionally, the household chooses savings for period $t+1$, a_{t+1}. The income side of the market budget constraint is made up of three items. First, the household receives interest on the savings from the previous period, $(1+i_t)a_t$. Second, the household receives a wage, w_t, for hours worked in both the formal and informal sectors of the economy.[8] Total labor income in these sectors is given by $w_t\varepsilon\left(h_{ft}+h_{it}\right)$. Finally, the household pays taxes and receives transfers according to a net tax function, T_t^j. This net tax function is given by the following equation:

$$T_t^j = (\tau_{ht}+\tau_{sst})w_t\varepsilon h_{ft} - \psi_j^R(\bar{y}_t) - \psi^c \tag{7}$$

The household pays a general labor income tax, τ_{ht} as well as a Social Security contribution rate τ_{sst}, on the income received for work in the formal sector of the economy. It then receives a retirement transfer during retirement years, $\psi^R(\bar{y}_t)$, which is dependent on the average taxable earnings in period t, $\bar{y}_t$. Finally, the household receives a common transfer, ψ^C which is independent of age, skill, and lifetime labor supply decisions.

Spending on durable goods, d_t, from the market budget constraint and the hours spent working in the home production sector are used as inputs into the production of the non-tradable home produced good. The budget constraint for home production states that consumption of the home produced

[8]The assumption of the same wage in both sectors may seem restrictive. However work such as Bujanda and Samaniego de la Parra (2020) finds that when a formal sector firm moves a worker from an informal job to a formal one, the move is not associated with a wage increase. Rather wage increases are driven by outside options that workers may receive once formalized. As this work focuses on formal sector firms, the same wage assumption reflects this finding.

good must be equal to the output of the home production function, $g(\cdot)$.

$$c_{ht} = g(d_t, h_{ht}) \tag{8}$$

The individual states, a_t and $\bar{y}_t$, evolve based on the choices of savings, a_{t+1}, and formal sector work, h_{ft}. Specifically, savings are set as the chosen asset holdings for period $t+1$ and average taxable income evolves based on the following equation:

$$\bar{y}_{t+1} = \begin{cases} \frac{(j-1)\bar{y}_t + w_t \varepsilon h_{ft}}{j} & ,\text{if } j \leq R \\ \bar{y}_t & ,\text{if } j > R \end{cases} \tag{9}$$

The aggregate states of the economy evolve with a function, G, that is assumed to be known by the household.

$$S_{t+1} = G(S_t) \tag{10}$$

3.3 Technology

The production function for the market sector good is given as follows:

$$Y_t = f(K_{mt}, H_{mt}) \text{ where } H_{mt} = H_{ft} + H_{it} \tag{11}$$

Formal sector production uses aggregate market capital and aggregate market labor supply, where aggregate market labor supply is the sum of aggregate formal labor and aggregate informal labor. Additionally, capital evolves according to the following equation, where δ represents depreciation and X_{mt} is investment in market capital.

$$K_{mt+1} = (1-\delta)K_{mt} + X_{mt} \tag{12}$$

3.4 Government

Government policy is defined as a series of sequences, $\{\tau_{ct}, \tau_{pt}, \tau_{dt}, T_t^j(\cdot), B_t, G_t\}$ which represent various fiscal policy elements. τ_{ct} denotes a tax rate on consumption. τ_{pt} represents a tax on accounting profits of the firm. τ_{dt} is a tax on dividends paid by the firm.

In order to define the budget constraint of the government, profits and firm dividends must be defined. Accounting profits of the firm, Π_t, and the dividend distributions of these firms, Δ_t, are given by the following equations:

$$\Pi_t = Y_t - w_t\left(H_{ft} + H_{it}\right) - \delta K_{mt} \tag{13}$$

$$\Delta_t = (1-\tau_{pt})\,\Pi_t - K_{mt+1} + K_{mt} \tag{14}$$

Additionally, $T_t^{j,\varepsilon}(\cdot)$ represents the net tax function from the household problem which combines the payroll tax, retirement transfers, and common transfers. B_t denotes government debt, and G_t represents government consumption of a pure public good.

The government budget constraint is defined as:

$$B_{t+1} + \tau_{ct}\,(C_{mt} + D_t) + \tau_{pt}\Pi_t + \tau_{dt}\Delta_t + \sum_{j,\varepsilon} \mu_t^{j,\varepsilon} \left[(\tau_{ht} + \tau_{sst})\, w_t \varepsilon h_{ft} - \psi_j^R\,(\bar{y}_t) - \psi^c \right] = (1+i_t)B_t + G_t \tag{15}$$

On the revenue side of the government budget constraint are issuance of new debt, B_{t+1}, and collection of taxes. These taxes are the consumption tax on market consumption and durable spending, the profit tax on accounting profits of the firm, the dividend distribution tax on the firm's distributed profits, and the outcome of the net tax function when aggregated over the heterogeneous households alive in any period t. The net tax function is the combination of three elements: the income from taxes levied on formal sector income $(\tau_{ht} + \tau_{sst})\, w_t \varepsilon h_{ft}$, the retirement transfer $\psi_j^R\,(\bar{y}_t)$, and the lump-sum transfer ψ^c. The common transfer consists will be the sum of per-capita spending on social programs, ψ^s, and a lump-sum term which will adjust to balance the government budget, $\overline{\psi}$.

$$\psi^c = \psi^s + \overline{\psi} \tag{16}$$

The budget constraint requires that revenue must be equal to government spending. Total government spending is the sum of interest paid on the debt from the previous period, $(1+i_t)\,B_t$ and government spending on a pure public good, G_t.

I assume that government debt and government spending are a percentage of output. Specifically,

$$B_t = \phi_B Y_t \tag{17}$$

$$G_t = \phi_G Y_t \tag{18}$$

3.5 Equilibrium

An equilibrium in this economy is given by government policies, prices, and allocations such that:[9]

1. Given the government policies, interest rate, and wage rate, the value functions and allocations solve the household's maximization problem given the state variables

2. Given the government policies, interest rate, and wage rate, the firm optimizes

[9]Detailed equilibrium definition is given in Section 1 of the Technical Appendix.

3. The government budget constraint holds in each period

4. All markets clear

4 Social Security in Chile

4.1 Before the 1981 Reform

The Chilean Social Security reform of 1981 replaced a pay-as-you-go system with a retirement age of 65 for men and 60 for women. This old system (called the INP system[10]) was comprised of many different pension institutions. Each of these institutions, known as *Cajas de Prevision,* covered the pensions for a subset of the population. Because each of the *Cajas de Prevision* was independent, the pensions were dependent on the employer. Each institution had its own contribution and indexation rates, benefit levels, and requirements for retirement. However, 94 percent of the population was covered under one of three main systems for salaried workers (white-collar), manual laborers (blue-collar), and government employees.[11] Other smaller funds had fewer than 1,000 members each. The agents were required to contribute to the system, through a payroll tax, for 20 years before they were eligible for pension benefits.[12]

Although each pension institution had different a indexation rate for calculating benefits, all institutions calculated benefits as a percentage of average earnings. Average earnings were calculated over the five years prior to retirement. This was constant over all funds; retirees could receive different percentages of this average depending on the institution. Due to the reform, the system was heavily simplified by introducing a single method of retirement funding for everyone.[13]

4.2 After the 1981 Reform

The new system, called the AFP system[14], began in May 1981. The INP system was immediately closed to new entrants, and all workers who entered the workforce after this date were automatically enrolled in the new AFP system. Workers who had already made contributions to the INP system were given five years to decide whether they would switch to the AFP program. In order to induce workers from the old system to switch to the new system, workers were offered two things. First,

[10] INP=*Instituto de Normalizacion Previsional*

[11] In 1980, 8.2 percent of workers worked in the public sector. This gives an estimate of what percentage of the population would have been covered under the government plan. Therefore, this paper models the transition for the remaining 91.8 percent of workers in the private sector.

[12] Agents were not required to contribute for 20 consecutive years. Rather agents must contribute for a total of 80 quarters prior to retirement in order to receive the Social Security benefits.

[13] Government and military workers have their own pension system and are exempt from enrolling in the AFP system. In 1980, public sector employees represented only 8.2 percent of the working age population

[14] AFP=*Administradoras de Fondos de Pensiones*

workers were offered a one time 17 percent increase in net income. Second, those who switched were given a recognition bond to represent the contributions they had made to the old INP system. These inducements encouraged 90 percent of the workers covered under the old system to switch to the reformed system by 1986.[15]

After the reform occurred in 1981, the rules change. The payroll tax is eliminated, but the workers are now required to contribute 10 percent of monthly earnings up to a ceiling.[16] These contributions are tax-deferred and difficult to draw from before retirement.[17] [18]

Individuals can access their retirement savings funds at age 65 for men and age 60 for women.[19] Non-contributory retirement income is available either through a welfare pension that is independent of contribution history or through a minimum pension guarantee that is available only to workers who contributed sufficiently but whose funds were not able to fund a higher pension. All workers over age 65 are eligible for a welfare pension, called PASIS. The PASIS pension is around one-third of the minimum wages. If an agent has made more than 20 years of contributions, he is eligible for the minimum pension guarantee (MPG). This pension is about twice the PASIS pension.

5 Parameters

I will use data and prior literature to set three categories of parameters. First, the details of the pension reform policy and aggregate data on government revenue and spending is used to set government policy parameters and fiscal policy time series. Second, survey data is used to estimate the parameters governing home production and market labor supply decisions. Finally, other model

[15]Workers were also offered a one time 17 percent increase in net income if they chose to switch. However, high inflation during this time raises questions on whether this caused any real increase in worker income. For this reason, I choose not to model this wage increase.

[16]The ceiling for monthly contributions is 66 Unidades de Fomento (UF). Unidades de Fomento is a Chilean unit of account constantly adjusted to inflation so that the value of the UF remains constant or nearly constant during times of low inflation. As of 2015, 66 UF is equivalent to nearly $2500. Agents also have the option to contribute up to an additional 48 UF tax-deferred if they choose.

[17]There are very strict restrictions on withdrawing funds from the account before retirement. These restrictions are more restrictive than those on US 401K plans.

[18]In addition to the mandatory savings, Chilean workers are required to contribute 7 percent of monthly earnings for health insurance, 3 percent of monthly earnings for survivor and disability insurance, and administrative fees. The worker can choose to invest his funds in one of the AFP firms who manage and invest the contributions. The Chilean government imposes a lower and upper limit on the returns an AFP must pay its members. If a fund over-performs, excess returns are placed in a profitability reserve. If the fund then under-performs in future years, reserves are used to make up the difference between the actual return and the minimum return guaranteed by the state. If the AFP cannot meet the requirements with its reserves, it is liquidated, the government makes up the difference between the return and the minimum guarantee, and all contributors transfer their funds to another AFP. These regulations have led historical returns to cluster at the mean level.

[19]The law permits early retirement if the worker has accumulated an amount greater than 110 percent of the minimum pension guaranteed by the government. The pension must be greater than 50 percent of the average of taxable income over the last ten years.

Table 1: Contribution Rates, τ_{ss}, by Type of Employment

Effective Date and Type of Worker	% paid by –		
	Employee	Employer	Total
Old System			
Servicio de Seguro Social (SSS)	7.25	15.95	23.2
Caja de Empleados Particulares (EMPART)	16.67	10.83	27.5
New System			
	10.0	0.0	10.0

parameters will be internally calibrated to aggregate data or set based on prior literature.

5.1 Government Policy Parameters and Fiscal Series

Prior to 1981, pension benefits were dependent on employment. Different types of workers faced different rules in regards to contribution rates and indexation rates. The two largest funds were those covering manual laborers and salaried workers. Based on this, I choose to model the details of the pension programs for two groups: manual laborers and salaried workers. The program for manual laborers is known as Servicio de Seguro Social (SSS), and the program for salaried workers is called Caja de Empleados Particulares (EMPART). In this work, manual laborers are covered under SSS while employees and managers are assumed to receive a salary and are covered by EMPART.[20] In this paper I use three productivity types. These groups are defined as manual laborers, employees, and managers.

Contribution Rates

Prior to the reform, each of the two main systems had differing contribution rates for both employees and employers. Employees paid a percentage of earnings and employers contributed a percentage of the payroll bill to the pension fund. These contribution rates, τ_{ss}, are shown in Table 1. Prior to the reform, blue-collar employees pay 7.25 percent of income to pension funds; employers contribute 15.95 percent of payroll. Under the program for white-collar workers, employees

[20]The data does not contain a question for which program a worker is covered by. I set these groups based on their occupation. While not a perfect translation, workers who identify as obreros will be considered manual laborers, those who respond empleados are considered employees, and those who answer empleadores are defined as managers.

contribute 16.67 percent and employers contribute 10.83 percent. I assume that the employer contributions are passed through to workers and are combined into the payroll tax of the agent. After the reform, contributions for the old-age portion of the program are eliminated. Contributions for health, survivor, and disability insurance remain. These contributions are roughly 10 percent of earnings.[21]

After the reform workers are required to save 10 percent of formal income into their private accounts. I model this as only impacting the decisions of households if they would optimally choose to save below this level. Households who save below 10 percent are increased to this mandated threshold while those households who optimally choose savings above this point are unaffected.[22]

Retirement Transfers

The form of the Social Security transfers received by the retired households will be dependent on the time period in question and whether the cohort was in the labor force at the time of the reform. This work assumes that all agents immediately switch to the individual account system.[23] Therefore, the government transfers will be dependent only on the time period and the birth-year cohort of the household. Note that for any worker who is not of retirement age, $\psi^R = 0$. Consider the transfers for retired workers in three different cases:

$$\psi^R = \begin{cases} \zeta^{\varepsilon}\bar{y}_t & \text{Cohorts who entered the workforce and are retired prior to the reform} \\ \frac{1}{J-R}\left[0.8\bar{y}_t\left(\frac{t^*-t_0}{35}\right)\nu_G\nu_A(1.04)^{R-t^*}\right] & \text{Cohorts who entered the workforce and are not retired prior to the reform} \\ \max\left\{0, \underline{c} - \left(\frac{R-1}{J-R}\right)*(0.1\bar{y}_t)\right\} & \text{Cohorts who entered the workforce after the reform} \end{cases} \tag{19}$$

Case 1: Cohorts who entered the workforce and are retired prior to the reform

Those workers who were retired prior to the reform are grandfathered in to the PAYG system. Therefore, the retirement transfers for this group are given by the formula from PAYG:

$$\zeta^{\varepsilon}\bar{y}_t$$

Under the pay-as-you-go Social Security system, agents are entitled to some percentage ζ^{ε}, known as the indexation rate, of working-age income. This working-age income is calculated as the

[21]The split of these contribution is 7 percent for health insurance and 3 percent for survivor's and disability insurance as well as administrative fees.

[22]In equilibrium, all households optimally pick savings above the 10 percent threshold. Therefore, this forced saving does not distort individual decisions.

[23]This is a reasonable assumption as 77 percent of workers covered until the PAYG system had chosen to switch to the new system by 1983; 90 percent of workers had chosen to switch by 1986. The case in which no one switches is shown in the the Technical Appendix Section 15.

average income over the five years prior to retirement.[24] Additionally, the indexation rate varies by profession, or skill in the model. SSS entitles manual laborer households to receive up to 70 percent of pensionable wages during retirement.[25] EMPART gives employees and managers 100 percent of pensionable wages during retirement.[26]

$$\zeta^{\varepsilon} = \begin{cases} 0.70 & , SSS \\ 1.00 & , EMPART \end{cases}$$

Case 2: Cohorts who entered the workforce and are not retired prior to the reform

$$\frac{1}{J-R}\left[0.8\bar{y}\left(\frac{t^*-t_0}{35}\right)\nu_G\nu_A(1.04)^{R-t^*}\right] \tag{20}$$

Households who entered the workforce prior to the reform but are not yet retired in 1981 receive transfers that represent the recognition bond. The value of this bond is given by the formula above. t^* represents the time period in which the reform occurred (1981), and t_0 represents the year a particular agent entered the workforce. This recognition bond represents the Social Security payouts the agent should receive for the contributions that had already been made. This formula is calculated from four elements: 80 percent of pensionable salaries[27], a correction for years of contributions, a correction for age and gender, and interest for the time between when the reform occurs and the household retires.

It is assumed that 35 years is the number of contribution needed to receive a normal pension. Therefore, the calculation of 80 percent of the average earnings for the twelve months prior to June 1979 is multiplied by the ratio of the years contributed to 35. This fraction is capped at 1.

The value of the recognition bond is then also corrected for both age and gender. ν_G corrects for gender. This value is 10.35 for men and 11.36 for women. I use a value of 11. ν_A varies based on both the age and gender of the agent.[28] It varies between 1 and 1.11 for men and 1 and 1.31 for

[24]Rather than using average income for the 5 years prior to retirement, I use an average over total working life in order to calculate benefits. I do this in order to simplify the transfers through the transition. By using this, I can use the same state variable to calculate transfer under all three cases.

[25]Under SSS, agents receive 50 percent of pensionable wages after 10 years of contributions to the program and 1 percent for each year of contributions over 10 years. This is capped at 70 percent of pensionable wages. Under this system, pensionable salary is calculated as the average of salary for the 5 years prior to retirement. This value is not indexed to inflation.

[26]Under EMPART, pensionable wages are calculated as the average of the wages for the five years prior to retirement where the most recent two years are indexed to inflation.

[27]In the calculation of the recognition bond, pensionable salaries are calculated based on all earnings received prior to April 1979.

[28]This correction is set so that men who enter the new system at age 61 or older and women who enter at age 42 or older receive additional benefit.

women.[29] I will use a value of 1.15 for the family.[30]

The recognition bond received a 4 percent real return. Therefore, interest on the bond is compounded based on the years between the reform and the time period that the agent retires. This interest is added to the amount the agent receives.

This calculation gives the total sum of money received by the worker as a representation of the previous contributions to the pay-as-you-go system. I assume that an equal amount is paid out to the retiree in each period of retirement. Therefore, this total is divided by the number of years spent in retirement, $J-R$.

Case 3: Agents who entered the workforce after the reform

All agents who entered the workforce after the reform occurred are immediately enrolled in the new system. Under this system, retirement consumption is funded through individual savings. The government, however, guarantees a minimum pension if accumulated savings are not sufficient. If agents accumulate sufficient assets, transfers in this case are 0. This policy is top-up in construction; if savings are not sufficient to fund a higher pension, government transfers are equal to the difference between the savings of the agent and the minimum guaranteed by the government. The minimum pension guarantee is around two-thirds the minimum wage.[31]

$$\max\left\{0, \underline{c} - \left(\frac{R-1}{J-R}\right) * (0.1\overline{y}_t)\right\} \tag{21}$$

The second term in the max function represents the amount that would be received if savings cannot fund a sufficient pension. $\underline{c}$ represents the lower bound the government set on retirement consumption. $\left(\frac{R-1}{J-R}\right) * (0.1\overline{y}_t)$ represents the retirement savings of the household split equally between the years of retirement. I assume all agents save exactly the 10 percent of wages required by law when calculating this amount. This 10 percent of taxable income is multiplied by the number of years spent working, $R-1$, and divided by the years of retirement, $J-R$.

The lower bound of consumption, $\underline{c}$, is set based upon the government policy. I will set this value as a percentage of the average wage.[32] In particular, the minimum pension guarantee is set to be 25 percent of the average wage for workers between the ages of 65 and 70, 27 percent of the average wage for workers between the ages of 70 and 75, and 29 percent of the average wage for workers over the age of 75.

Fiscal Variables

[29] In 1980, there were no pension benefits for married couples. Therefore, I model the pension of an agent rather than the pension of a household.

[30] Future versions of the paper will contain sensitivity on how the value of this parameter changes results.

[31] In 1980, minimum wage was around 48,000 Chilean pesos.

[32] James, Estelle, and Iglesias (2007) find that the minimum pension guarantee (MPG) provided by the government after the 1981 reform is between 25 and 29 percent of the average wage.

Additionally, time series for government debt, government spending on defense, aggregate spending on social programs, and other taxes are calculated from the data.[33] Future values for these variables are calculated in two ways. first, those between the data and 2020 are fit using a time trend from the 10 years prior. The series, as a percentage of GNP, are assumed to be constant after 2020.

Each of these fiscal series are used to identify different parameters used in the model. The series of government debt and defense spending are used to identify the parameters ϕ_B and ϕ_G which tell what percentage of GNP is in debt and government spending, respectively. Consumption tax rates, general labor income tax rates, and firm tax rates are used to set τ_{ct}, τ_{ht}, and the profit and dividend taxes, τ_{pt} and τ_{dt}. Finally, the series of per-capita spending on social programs represents a lump-sum transfer from the government to households. This data is used to discipline the transfer ψ^s.

5.2 Home Production and Market Labor Supply Parameters

I choose CES functions to represent the relationships for the home production and market labor supply parameters, $h(\cdot)$, $\Gamma(\cdot)$, and $g(\cdot)$. Specifically,

$$c_t = h(c_{mt}, c_{ht}) = \left\{ a_1 c_{mt}^{b_1} + (1-a_1) c_{ht}^{b_1} \right\}^{1/b_1} \tag{22}$$

$$h_{mt} = \Gamma\left(h_{ft}, h_{it}\right) = \left\{ a_2 h_{ft}^{b_2} + (1-a_2) h_{it}^{b_2} \right\}^{1/b_2} \tag{23}$$

$$c_{ht} = g(d_t, h_{ht}) = \left\{ a_3 d_t^{b_3} + (1-a_3) h_{ht}^{b_3} \right\}^{1/b_3} \tag{24}$$

5.2.1 Data and Sample

Data for this estimation comes from two sources. First is Encuesta Nacional Sobre el Uso del Tiempo (ENUT) – a time use survey that contains a representative sample of the Chilean population. The 2015 survey is used in the analysis. The second data source used is the Encuesta de Protección Social[34] (EPS). This is a longitudinal study which contains a representative sample of the national population. The 2004, 2006, and 2009 waves are used in the estimation.[35] The data from the first

[33] More discussion on the time series for these government policy variables is included in the Section 4 of the Technical Appendix.

[34] Esta investigación utilizó información de la Encuesta de Protección Social. El autor agradece a la Subsecretaría de Previsión social, propietaria intelectual de la Encuesta, la autorización para usar la Base de Datos Innominada. Todos los resultados del estudio son de responsabilidad del autor y en nada comprometen a dicha Subsecretaría.

This research used information from the Social Protection Survey. The author thanks the Subsecretary of Social Prevision, the intellectual owner of the Survey, for the authorization to use the anonymous database. All the results of the study are the responsibility of the author and not of the aforementioned Subsecretary.

[35] The 2002 waves of the EPS is representative of only those individuals and household that are affiliated with the pension system. As of the 2004 waves, the survey was corrected to be representative of the population as a whole. I

survey, ENUT, is used in order to estimate how the hours of home work vary across observable characteristics which are present in both data sets. The results are then used to impute values of home work for individuals present in the EPS. The EPS data with imputed home work is then used to estimate the parameters $a_1, b_1, a_2, b_2, a_3, b_3$.

ENUT is a two-part survey. The first part is a household questionnaire containing demographic and socioeconomic information for the individual and the household. The second part of the survey is a time use questionnaire in which the respondent answers the amount of time spent on various activities in the last day. They are surveyed on one week day and one weekend day. My sample contains only individuals who responded to both the household questionnaire and the time use questionnaire. 21,960 individuals responded to both questionnaires. The final sample used is the subset of these respondents who are between the age of 25 and 65 who reported that nothing out of the ordinary occurred in the last week. The final sample contains 13,614 individual. This comes out to 62 percent of the the total sample.

The estimation sample from the EPS is constructed as a combination of the household responses from the 2004, 2006, and 2009 waves of the survey.[36] A sample from each cross-section is first constructed. The final sample is created as a panel of households observed in at least two consecutive cross-sections. The three waves of the survey contain 14,856; 14,836; and 10,347 households respectively. The final sample for each year cross-section contains the responses for households in which the head of the household is working age[37], works at least 30 hours per week or at least 40 weeks per year, and does not receive a welfare pension from the government. This assumption is made as data on income support programs and welfare pensions and their interaction with the labor supply is not included. The final sample also includes all households with non-zero spending on non-durable and durable consumption. The final samples for three waves contain 8,313 observations, 6,750 observations, and 5,318 observations, respectively. These final samples for each year are pooled together for the estimation.

5.2.2 Estimation and Results

The following regression equations are derived from the first order conditions of structural model. This procedure builds upon the methodology used in the literature related to home production.[38] The extension here includes the derivation of an equation relating formal labor supply to informal

choose to use the nationally representative 2004, 2006, and 2009 waves as I want to consider the impact of informal laborers who are not necessarily affiliated with the pension system.

[36]Results from the estimation of the parameters of cross-sections from each year are also included in Section 8.1.2 of the Technical Appendix.

[37]By excluding agents who are not working age, I also remove agents who receive minimum pensions from the government. This is done because data on this pension transfer and its impact on labor supply is not included in the analysis.

[38]Papers in this literature include Rupert, Rogerson, and Wright (1994) and Fang and Zhu (2012).

labor supply. The results of estimating these equations gives an understanding of the how households substitute between various decisions. At the same time, estimation of these equations gives a relation between the data and the parameters of the structural model. These equations are derived from three marginal conditions of the structural model: the relationship between the marginal utility of formal labor and informal labor, the relationship between the marginal utility from home hours and durable spending, and the relationship between the marginal utility gained from market consumption and durable spending.[39] Households substitute between decisions based on relative prices and the substitutability of other decisions.

$$\ln\left[\frac{h_f}{h_i}\right] = \beta_0 + \beta_1 \ln\left(1-\tau_h\right) + \varepsilon_1 \tag{25}$$

where $\beta_0 = \frac{1}{b_2-1}\ln\left[\frac{1-a_2}{a_2}\right]$ and $\beta_1 = \frac{1}{b_2-1}$

$$\ln\left[\frac{h_h}{d}\right] = \beta_2 + \beta_3 \ln\left[\frac{\left(1-\tau_h\right)w\varepsilon}{\left(1+\tau_c\right)}\right] + \beta_4 \ln\left[1+\frac{1-a_2}{a_2}\left(\frac{h_i}{h_f}\right)^{b_2}\right] + \varepsilon_2 \tag{26}$$

where $\beta_2 = \frac{1}{b_3-1}\ln\left[\frac{a_3}{1-a_3}\right] - \frac{1}{b_2(b_3-1)}\ln[a_2]$, $\beta_3 = \frac{1}{b_3-1}$, and $\beta_4 = \frac{b_2-1}{b_2(b_3-1)}$

$$\ln\left[\frac{c_m}{d}\right] = \beta_5 + \beta_6 \ln\left[1+\frac{1-a_3}{a_3}\left(\frac{h_h}{d}\right)^{b_3}\right] + \varepsilon_3 \tag{27}$$

where $\beta_5 = \frac{1}{b_1-1}\ln\left[\frac{1-a_1}{a_1}\right] + \frac{b_1}{b_3(b_1-1)}\ln[a_2]$ and $\beta_6 = \frac{b_2-b_3}{b_3(b_1-1)}$

A few issues must be discussed in the estimation procedure. First, the log-linear structure of the regressions limits the estimation to observations without corner solutions. These corner solutions can occur in both labor supply and consumption decisions. The number of corner solution in consumption (durable and non-durable) and home work hours are minimized by the way in which the data is constructed. First, zero spending on consumption is minimized by aggregating the data to the household level and including housing spending in the measure of durable consumption. Also, because hours of home work is imputed based on the observables available there are no corner solutions in home work hours. For these reasons, I am not concerned with bias caused by the omission of corner solutions in these equations. However, only 25.9 percent of households in 2004, 22.8 percent in 2006, and 16.8 percent of households in 2009 have positive number of annual hours in both the formal and informal sectors. Therefore, there is reason to be concerned about bias caused by the exclusion of the corners in this first regression.

In the baseline estimation, I choose to present the estimates for the regression with only households which work positive hours in both sectors. These households represent the marginal household

[39] Derivation of these regression equations is described in Section 5 of the Technical Appendix.

which is most likely to make adjustments to their sectoral (formal and informal) intensive margin labor supply in response to policy changes. Therefore, by using these households in the estimation, the parameters represent the substitutability for those households most likely to adjust their decisions in response to the reform.[40]

Another issue of the estimation that must be considered is whether the independent variables are correlated with the error term. For example, it is reasonable to believe that the labor income tax rate or the wage rate is correlated with the amount of work in the formal sector but other demographic features such as age or education level. I deal with this issue is two ways: by adding controls for household level effects that may be contributing and using instrumental variables. In the regression involving the substitutability of formality and informality, I control for age, industry, region, and lagged formal hours. In the regressions involving home production, I follow home production literature and use an instrumental variables approach. The instruments used are: age of the head of household, age of the head of household squared, education of the head of household, age of the spouse, age of the spouse squared, education of the spouse, a dummy for whether the household resides in Santiago, and lagged values of formal work, durable spending, and market consumption.[41] These instruments based upon the instruments used by Rupert, Rogerson, and Wright (1994).[42]

Table 2 shows the structural parameters constructed from these regression results. Formal and informal hours have roughly equal weight in market hours and the two types of work are highly substitutable–but not perfectly substitutable.[43] Home production is produced using mostly home hours while total consumption is weighted to market consumption. The elasticities of substitution between durable spending and home hours in home production and market consumption and home consumption in total consumption show that these inputs are much less substitutable than formal and informal hours are in market hours. [44] The standard errors for estimates on the parameters for total consumption and market hours are low, indicating precise estimate for the parameters. Standard errors for the home production function, however, are quite large.[45].

[40]The households who participate in only one sector or the other are acting as if the sectors are perfectly substitutable. Therefore, when the estimation is augmented to include these households, the estimates for the substitutability of formality and informality are higher (closer to 1). The results of this version of the estimation are in Section 8.1.3 of the Technical Appendix.

[41]By including the age of spouse and education of spouse as instruments in the IV regression, the sample excludes households consisting of a single member or households with only one parent. 69 percent of population in 2004 was in a married or co-habitating relationship.

[42]Due to differences in the data and modeling, these are not the exact instruments used in Rupert, Rogerson, and Wright (1994). They use age of husband, age of husband squared, age of wife, age of wife squared, the wife's education, lagged consumption, lagged wife's home work, and dummies for whether living in a SMSA, whether covered by a union, and whether living in the South in order to estimate the home production elasticity.

[43]The elasticity of substitution in these equations is given by $\varepsilon = \frac{1}{1-b_i}$. A value of $b_i = 1$ is associated with perfect substitutes, $b_i = 0$ is Cobb-Douglas, and $b_i = -\infty$ is associated with perfect complements.

[44]I performed the same estimation procedure on data for the United States. In this exercise, I find estimates in the ranges of the estimates found by other researchers. Details on this test is in Section 8.4 of the Technical Appendix.

[45]These large standard errors are likely due to how durable spending is constructed in this data set. More discussion

Table 2: Estimated Parameter Values

Function	Estimate (SE)		Elasticity of Substitution*
$\left\{a_1 c_m^{b_1} + (1-a_1) c_h^{b_1}\right\}^{1/b_1}$	$a_1 =$ 0.538 (0.039)	$b_1 =$ 0.039 (0.005)	$\eta_1 = 1.041$
$\left\{a_2 h_f^{b_2} + (1-a_2) h_i^{b_2}\right\}^{1/b_2}$	$a_2 =$ 0.447 (0.039)	$b_2 =$ 0.869 (0.030)	$\eta_2 = 7.634$
$\left\{a_3 d^{b_3} + (1-a_3) h_h^{b_3}\right\}^{1/b_3}$	$a_3 =$ 0.070 (0.044)	$b_3 =$ 0.035 (0.182)	$\eta_3 = 1.036$

*The elasticity of substitution shown is that which is implied by the estimation of the b parameters using the equation $\eta_i = \frac{1}{1-b_i}, i = 1,2,3$

5.3 Other Parameters

The remaining parameters are either set outside the model based on previous literature and data or internally calibrated to match macroeconomic aggregates. These parameters are shown in Table 3.

5.3.1 Parameters Set Outside the Model

Coefficient of Relative Risk Aversion

The utility function is represented by a CRRA function.

$$U(c,l) = \frac{\left(c^{\gamma} l^{1-\gamma}\right)^{1-\sigma} - 1}{1-\sigma}$$

In order to set a value for the coefficient of relative risk aversion, I look to other papers which use a utility function that is non-separable between consumption and leisure as well as papers in the home production literature. In these literatures, σ is usually set between 1.5 and 4[46]. I set $\sigma = 2$ in the analysis that follows.

Production Parameters

I choose a Cobb-Douglas function for the market production function:

$$Y_t = (K_{mt})^{\alpha} \left(H_{ft} + H_{it}\right)^{1-\alpha}$$

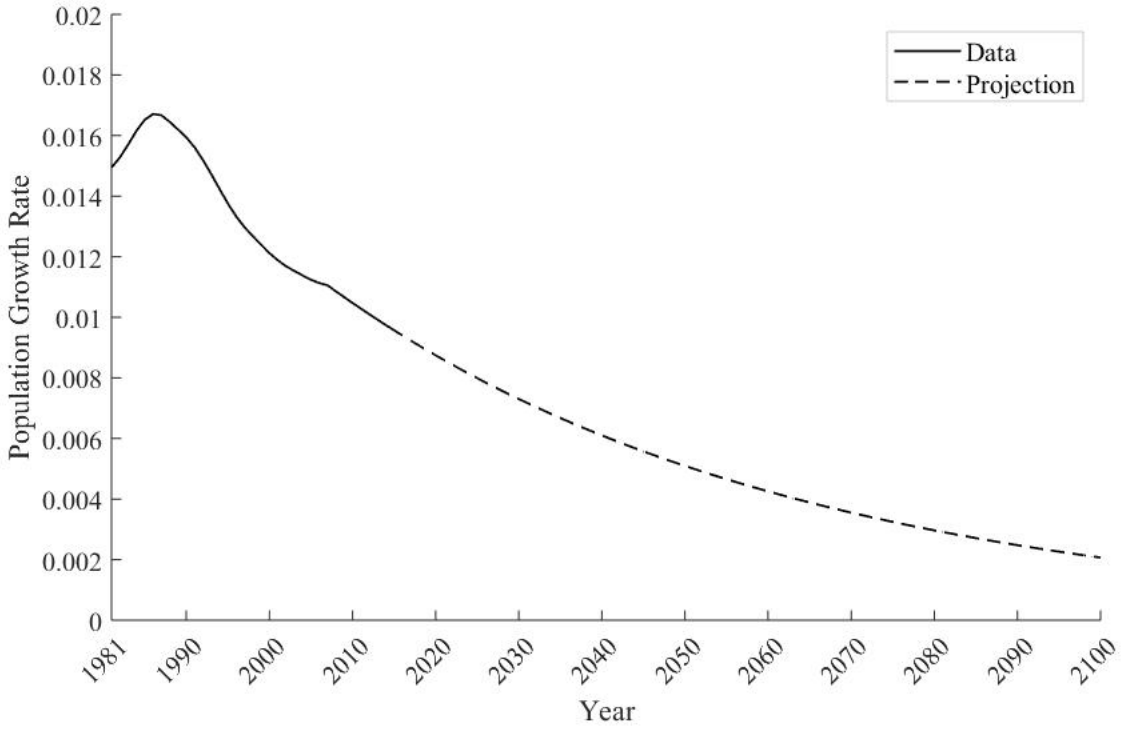
of this is in Section 8.2.3 of the Technical Appendix.

[46] Auerbach et. al. (1999), for example, uses a value of $\sigma = 4$ while Dotsey, Li, and Yang (2015) sets $\sigma = 1.5$.

Table 3: Other Parameters

Parameter	Description	Value	Target	Source
β	Discount rate	0.901	$\frac{K}{Y} = 1.667$	National Accounts
γ	Weight of consumption in utility	0.484	Annual hours worked per worker $= 2572$	OECD
ε	Productivity	$\{0.5, 1.45, 4.5\}$	Manuel laborers: 21% Employees: 52% Managers: 27%	EOD 1980
α	Weight of capital in production	0.33		
δ	Depreciation	0.05		
σ	Risk aversion	2		
J	Retirement Age	40	Retirement age of 65	
T	End of Life Age	55	Exit the model at age 80	

Figure 1: Population Growth Rate (1981-2100)



The weight of capital in market production, α, and the depreciation rate of capital, δ, are also set outside the model. In accordance to other literature, I set $\alpha = 0.33$ and $\delta = 0.05$ in the analysis.[47]

Demographic Parameters

The growth rate of the population, g_t,is set so as to match the growth rate of the Chilean population. From the World Bank's World Development Indicators, I can calculate the growth rate of the population from 1981 to 2016. For the years after 2016, I predict the values using a linear trend from the years prior. This population growth rate ranges from a high of 1.7% in the late 1980s to a low of 0.9% in 2016. This I assume that the decline in the population growth rate continues. This population growth rate is shown in Figure 1.[48]

5.3.2 Internally Calibrated

In the final stage of the estimation, three parameters are internally calibrated to match macroeconomic aggregates in 1980. The discount factor, β, the weight of consumption in utility, γ, and the

[47]More discussion of the choice for the depreciation rate is in the construction of the capital stock series.

[48]In Section 16 of the Technical Appendix, I consider a case in which the growth of the labor force is used rather than the growth of the population.

productivity term by type, ε, are set so as to match the capital-output ratio of the economy, the aggregate hours worked, and the fraction of total labor income received by each of the types.

The aggregate data used to calculate the target moments come from three sources. First of these sources is historical Chilean National Accounts. The capital-to-output ratio is calculated from this source. National account data provides time series for investment and GDP that are used in this calculation. A time series for the capital stock is constructed using this data.[49] The calculation returns a ratio of average capital-to-output of 1.667 for the years of 1960-1980.

The second data source, OECD aggregates, is used for the measure of annual hours worked per worker. Data shows that annual hours worked per worker in Chile was 2,572 hours in 1980. I assume discretionary time per week is 100 hours. Therefore, the fraction of time spent working is 0.495.

Finally, productivity terms in the model are chosen in order to match the fraction of labor income received by each of the types in the model. As described above, these types are meant to represent manual laborers, employees, and managers. The employment survey Encuesta de Ocupación y Desocupación en El Gran Santiago (EOD) is used to calculate the percentage of labor income received by each type.[50] Manual laborers make up 49 percent of the population and receive 21 percent of labor income, Employees represent 44 percent of the population and receive 52 percent of labor income, managers are 7 percent of the population and receive 27 percent of labor income. The model reproduces these fractions when $\varepsilon = \{\varepsilon_1, \varepsilon_2, \varepsilon_3\} = \{0.5, 1.45, 4.5\}$.

5.4 Model Fit

This section describes how the model fits the aggregate and micro data along various dimensions. The fit of the model to the aggregate moments is shown in Table 4. The model can reproduce the targeted moment well. In addition to the targeted moments, I include the capital-to-output ratio and annual hours worked per worker from the year 2004 to assess how the model matches the evolution of these variables over time. The model does a good job of fitting these aggregate moments, although only the value for 1980 is used in the calibration.[51]

In addition to these aggregate moments, I also look at the performance of the model in reference to the formality decision, savings decision, and relative wages. First, Table 4 also shows the comparison of average hours worked formally per household to average hours worked informally per household. I show that the model produces a ratio of 3.1. This indicated that roughly 30 percent of hours worked are informal. This ratio in the data in 3.2. The fact that this ratio is nearly the

[49] Details on the construction of the capital stock series is discussed in Section 4.1 of the Technical Appendix.

[50] EOD is an employment survey for the Greater Santiago area. Demographic information from the 1982 Chilean census indicate the Santiago is representative of the national population. Therefore, the results from study of EOD are used as representative of the country. More information is contained in Section 4.3 of the Technical Appendix.

[51] Time series for these variables are included in Section 9 of the Technical Appendix.

same in the data and the model is somewhat by construction, as this micro-data was used in the estimation of the parameters of the CES function governing this decision. However, this ratio is an aggregate moment while the cross-section is used in estimation. This result indicates that the model can reproduce the size of the informal sector in Chile.

It is important to note that a limitation of the model and analysis is that while I can match the aggregate ratio of formal hours to informal hours per household, there are distributional differences across productivity types that I cannot match. Specifically, higher productivity type workers are more likely to spend more time working formally relative to informally. Therefore, the data shows this ratio to be 5.4 for employees and 1.5 for managers. The model, however, predicts this ratio to be 3.1 for all types.

When studying how the predictions of the model match the data on the savings of households, I compare the impact across productivity types and across age. First, consider the differential impact of the savings on two different groups of productivity types: employees and managers.[52] I look at the ratio of the savings of the managers to the savings of the manual laborers and employees; this is shown in Table 4. This ratio is 2.3 in the data and 3.9 in the model. Therefore, while the model predicts more dispersion in the savings across productivity types than in the data, the model does a fairly good job of matching the data. This shows that while savings of all types increase due to the reform, this increase is larger for those with higher productivity; this is also true in the data.

Second, I look at the age-profile of savings in both the model and the data. This comparison is shown in Figure 2. The figure demonstrates that the model can reproduce the hump-shaped age profile of savings and the level of these savings relative to mean savings in the economy. One shortcoming is that the model under predicts the savings of young households. This result is most likely the result of the assumption that households enter the labor force at age 25 with no assets. The data, however, indicates that young households often have some savings. Additionally, the model under predicts the savings at the peak of the age profile. Despite these, the model does a good job of replicating this key feature of the micro-data.[53]

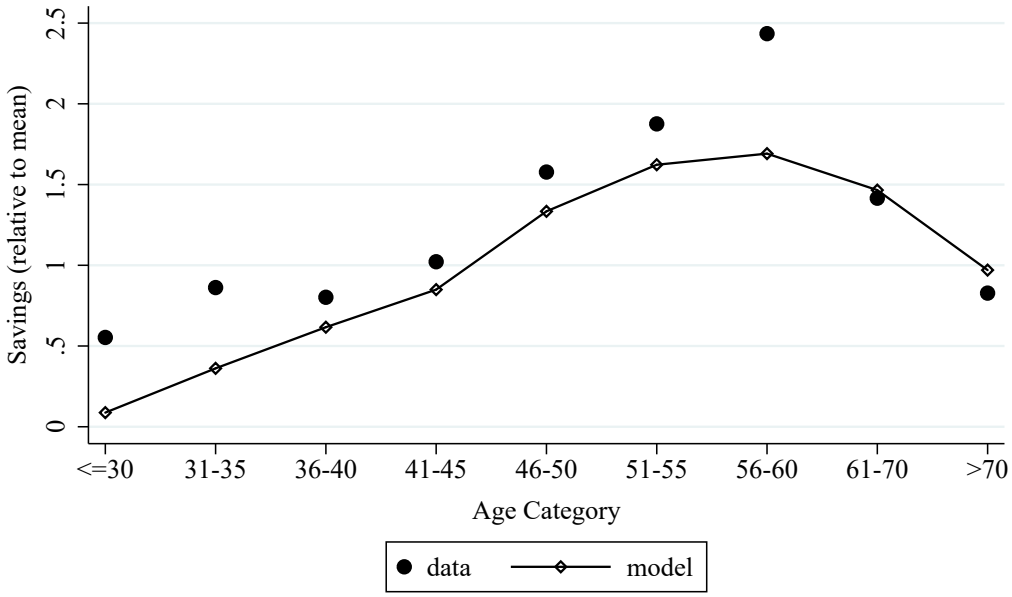
As a final test of the model's ability to fit the data, I consider a comparison the relative productivity terms, ε, with the relative hourly wage for households in 1980.[54] The final rows of Table 4 show that the model replicates these patterns fairly well. I match that there is a much larger gap between average hourly wages for the highest productivity type (managers) and the lowest productivity type (employees). Additionally, I match that this gap is much larger than the gap between

[52]These two groups are chosen rather than the three used in the baseline model due to data limitations. The post-reform data does not separate the manual laborers and the employees. I believe that similarities in the wording indicates that employees are a better comparison than the combination of the two groups.

[53]Additional discussion of the micro-data and the distributional fit of the model is considered in Section 10 of the Technical Appendix.

[54]The hourly wage is constructed as the average of the ratio of total labor income to hours worked for each occupation group.

Figure 2: Savings by Age: Model and Data



NOTE: Data shows the average savings for each age category relative to the mean over all ages.
Model shows how savings evolve throughout the lifetime, relative to the average savings over the lifetime
Both data and model are shown using aggregate savings across employment types for 2004

consecutive productivity types–managers and employees versus employees versus manual laborers. However, the calibration of the productivity term using total labor income earned predicts a larger spread between hourly wages of managers and employees than in the data; the ratio between wages is 9.0 in the model and 7.1 in the data. Additionally, the model predicts the gap between employees and manual laborers wages is larger than the data (ratio of 2.9 versus 1.8) and that the gap between managers and employers is smaller than in the data (ratio of 3.1 versus 4.0).

These tests indicate that the model can reproduce, fairly well, multiple features present in both aggregate and micro-data. In the next section, I turn to discuss the policy experiment associated with the 1981 reform.

6 Transitional Results

In order to assess the impact of the 1981 Chilean reform, I perform an experiment in which I compare the transition path of the economy under two scenarios. First, I consider an economy in which the pre-1981 pay-as-you-go Social Security system continues unchanged. In order to consider this case, I make an assumption that the government would have been able to continue to pay the pensions of retirees at the same rates without changing the payroll tax. However, I do not assume that the PAYG

Table 4: Model Fit

Targeted Moments		Data	Model
Capital output ratio		1.667	1.664
Aggregate hours worked		0.495	0.495
Fraction of GNP spent on social programs		0.144	0.144
Fraction of labor income earned by manual laborers		0.210	0.217
Fraction of labor income earned by employees		0.520	0.522
Fraction of labor income earned by managers		0.270	0.262
Untargeted Moments			
Capital output ratio (2004)		1.626	1.768
Aggregate hours worked (2004)		0.429	0.483
$\frac{\text{avg formal hours per HH}}{\text{avg informal hours per HH}}$ (2004)	overall	3.2	3.1
	employees	1.5	—
	managers	5.4	—
$\frac{\text{avg savings of managers}}{\text{avg savings of employees}}$(2004)		2.3	3.9
relative hourly wages (1980)	$\frac{\text{managers}}{\text{manual laborers}}$	7.1	9.0
	$\frac{\text{managers}}{\text{employees}}$	4.0	3.1
	$\frac{\text{employees}}{\text{manual laborers}}$	1.8	2.9

system is sustainable. Rather, I assume that general government revenue would need to be used to compensate for any deficits in the Social Security program. Second, I consider an economy in which the reform occurs as it did historically.

In both simulations, fiscal series–including debt, government spending on social programs, defense spending, consumption taxation, general labor income taxation, and firm taxation–follow the time series from the historical data.[55] It is assumed that a per-capita lump sum transfer, $\overline{\psi}$,is adjusted in order to balance the government budget. There are portions of the government budget throughout the transition which are not included due to missing historical data. This transfer can be understood as representing these missing portions of the government budget.[56] I compare the results of continuing the PAYG system with the results of the change to the mandatory savings program that occurred in Chile.

The aggregates throughout the transition path and the welfare impact of the policy change are reported. In both cases, the initial state is given by the steady state distributions of household asset holdings and household average annual taxable income as well as the level of government debt and spending in 1980. In the transition paths, historical data is used as inputs for the years 1981 to 2010. These inputs are: government debt; tax rates on consumption, labor income, and corporations; defense spending; and the population growth rate. I assume $t = 0$ is the year 1981, the year in which the Chilean reform occurred. I calculate the welfare impact on households of all ages and productivity levels that are in the labor force or retired at the time at the reform and for all new generations that enter the workforce after the reform. I assume that the policy change is unexpected, and that households operate under perfect foresight.

6.1 Continue PAYG

First, I simulate the demographic transition path for an economy in which the PAYG Social Security system continued.

Table 5 shows the evolution of aggregates throughout the transition. Under this transition path, output decreases roughly 15 percent with a similar drop in capital stock. Total hours drop over 10 percent. This drop is almost entirely caused by decreases in market hours (formal and informal hours) as hours spent in home production increase 2 percent. Consumption increases by around 9 percent–market consumption increases by 12 percent while home production increases by 3 percent. The increase in home consumption is caused by increases in both durable spending–which increases 12 percent–and hours spend in home production. Investment decreases by around 25 percent.

[55] Alternate specifications in which these series are different between the cases are considered in Section 13 of the Technical Appendix.

[56] This term can additionally represent the implicit transfer caused because I use marginal labor tax rates rather than average rates. More on this implicit transfer is discussed in McGrattan and Prescott (2017). This element is relatively small in this context due to the smaller labor tax base present in the Chilean economy.

Table 5: Aggregates, Prices, and Government Budget through the Transition

Continue PAYG Program

	1980	1981-2000	2001-2020	2021-2050	2051-2080	2081-2115	Steady State*
Output	1.000	0.920	0.954	0.899	0.869	0.852	0.846
Capital Stock	1.000	0.932	0.917	0.866	0.848	0.833	0.836
Hours	1.000	0.953	0.968	0.931	0.912	0.900	0.894
Formal Hours	1.000	0.927	0.955	0.898	0.867	0.847	0.836
Informal Hours	1.000	0.947	0.979	0.927	0.897	0.877	0.867
Home Hours	1.000	1.009	0.994	1.003	1.012	1.016	1.019
Consumption	1.000	1.012	1.035	1.066	1.076	1.083	1.087
Market Consumption	1.000	1.013	1.054	1.093	1.105	1.112	1.116
Durable Spending	1.000	1.013	1.054	1.093	1.105	1.112	1.116
Home Consumption	1.000	1.009	0.998	1.008	1.017	1.022	1.026
Investment	1.000	1.120	1.011	.866	0.786	0.744	0.735
Interest Rate	1.000	1.003	0.999	0.998	0.998	0.997	0.995
Wage	1.000	0.985	0.988	0.991	0.992	0.995	1.002
Per-capita Transfer	1.000	0.740	0.850	0.658	0.577	0.520	0.498
Consumption Tax	0.075	0.073	0.046	0.034	0.036	0.037	0.037
Labor Tax	0.378	0.371	0.366	0.360	0.359	0.358	0.357
Corporate Tax	0.082	0.078	0.085	0.088	0.090	0.091	0.091
Retirement Transfer	0.077	0.099	0.118	0.175	0.202	0.221	0.229
PAYG Pension	0.077	0.099	0.118	0.175	0.202	0.221	0.229
Recognition Bond	—	—	—	—	—	—	—
MPG	—	—	—	—	—	—	—
Per-capita transfer	0.364	0.280	0.324	0.266	0.242	0.222	0.214
Debt	0.252	0.361	0.056	0.035	0.035	0.035	0.035
Government Spending	0.043	0.041	0.024	0.019	0.019	0.019	0.019

Note: Values for aggregates and prices are reported relative to the pre-reform balanced growth path.
Values for government revenue and spending variables are reported as a percentage of GNP.

* The steady state value is the average of these values for the last 9 years of the transition 2116-2124

Throughout the demographic transition simulated here, the percentage of GNP spent on financing pensions–which are entirely PAYG pensions in this scenario–increases from 7.7 percent to 22.9 percent. This increase is caused by the aging population and the decrease in output. Aging populations cause the costs of pensions to increase. Therefore, the government must spend more to pay for the PAYG pensions. While the costs are increasing, this number is also larger due to the falling output. As GNP has decreased, this causes the percentage of GNP spent on pensions to increase. The rising costs of pensions puts pressure on the government budget constraint and causes the per-capita transfer used to balance the budget to decrease. Throughout the transition, this per-capita transfer decreases to less than half the level it was prior to the reform.

6.2 Reform Occurs

In order to set up the welfare comparison, I also simulate the economy with the reform. Table 6 shows how the aggregates evolve in this simulation. Output decreases, but by only around 5 percent. Capital stock increases by 15 percent. Therefore, the decrease in output is driven by a drop in market hours worked. The drop in market hours worked is caused by a 30 percent drop in formal hours; informal hours increase massively–to roughly 5 times their value from before the reform. This large increase is due to the fact that formal hours were low prior to reform. Although they increase drastically, informal hours still represent around 20 to 30 percent of total market hours after the reform. Therefore, the large drop in formal hours overwhelms the increase in informal hours and causes a decrease in market hours. Additionally, home production hours drop roughly 20 percent.

The drop in market hours reflects the importance of eliminating the retirement transfer. As the wage increases 5 percent throughout the transition, the relative price of home production relative to market work increases. Market work, however, does not increase. This is a result of the change in the pension system. Prior to the reform, market work had two benefits: the wage received and the pension that a worker could receive for their formal work.[57] After the reform, the second benefit of market work disappears. Therefore, the drop in market hours represents that while the higher wage may push workers into the market sector, the elimination of the pension also leads to a drop in market hours worked.

While market work–the sum of formal and informal work–drops, there is a large increase in informal hours. The trade-off between formality and informality is determined by two elements: the relative price–in this case the formal sector labor income taxation–between the sectors and the preference parameters which estimate the imperfect substitutability between the sectors in the utility of the household. The labor tax wedge, $1 - \tau_{ht}$, governs the relative marginal benefit of the formal

[57] While the pension does not show up in the first-order conditions of the worker, average taxable income is internalized as an individual state of the worker. Therefore, this still impacts the worker's decisions.

sector relative to the informal sector.[58] As the tax rate decreases through the reform, the relative marginal benefit of formality increases. Therefore, workers can earn the same take home pay in the formal sector with fewer hours. This encourages substitution towards the informal sector and a fall in the ratio of formal work to informal work, $\frac{h_f}{h_i}$.

Total consumption increases by 10 percent in the long-run after the reform. This increase is made up of a 23 percent increase in market consumption and a 17 percent decrease in home production. Additionally, investment increases 3 percent.

The transition is associated with an increase in up-front costs as the government must finance the pensions of current retirees with lower labor tax revenue as well as a decrease in future costs as the government gets out from under the burden of the PAYG pensions. This is seen in the pension costs and per-capita transfers throughout the transition. Pension payments increase from 7.7 percent to 9.5 percent and 10.2 percent of GNP in the years of the transition. However, they decrease to 1.1 percent of GNP in the long-run as the government is only providing the minimum pension guarantee. Therefore, transfers drop initially but the government can provide higher transfers in the future due to low pension costs.[59]

6.2.1 Long-Run Welfare Impact

Figure 3 shows the welfare gains from the reform. The welfare gains are measured as a percentage of remaining lifetime total consumption for cohorts working or retired at the time of the reform. Welfare change is measured as a percentage of lifetime total consumption for cohorts that entered the labor force after the reform.

This figure shows large long-run gains from the reform. These gains are nearly 10 percent of lifetime consumption for the manual laborers; the gains are nearly 15 percent of lifetime consumption for employees and managers. These long run gains are driven by two factors. First, the reform removes the distortion caused by the PAYG payroll tax. Second, the reform is associated with a capital deepening as the Social Security system no longer crowds out private savings. In order to isolate the impact of the removal of distortions, I simulate the model as a small open economy rather than a closed economy. Table 7 shows the results. When I consider a small open economy, aggregate long-run welfare gains hold nearly constant at 14 percent of lifetime consumption. However, capital deepening has heterogeneous welfare impacts on different productivity type workers. For manual laborers the gains increase from 12 percent to 14 percent. For employee and managers gains

[58]The relative marginal benefit of formality to informality in period t is given by $\frac{(1-\tau_{ht})w_t\varepsilon}{w_t\varepsilon}$. As wages are the same in both sectors and productivity constant, this marginal benefit simplifies to $(1-\tau_{ht})$

[59]Even in the long-run steady state, transfers are below their pre-steady state levels. However, these transfers are higher than those in the long-run steady state in which PAYG continues. The low long-run transfers are a result of the other fiscal series which are exogenously fed into the model.

Table 6: Aggregates, Prices, and Government Budget through the Transition

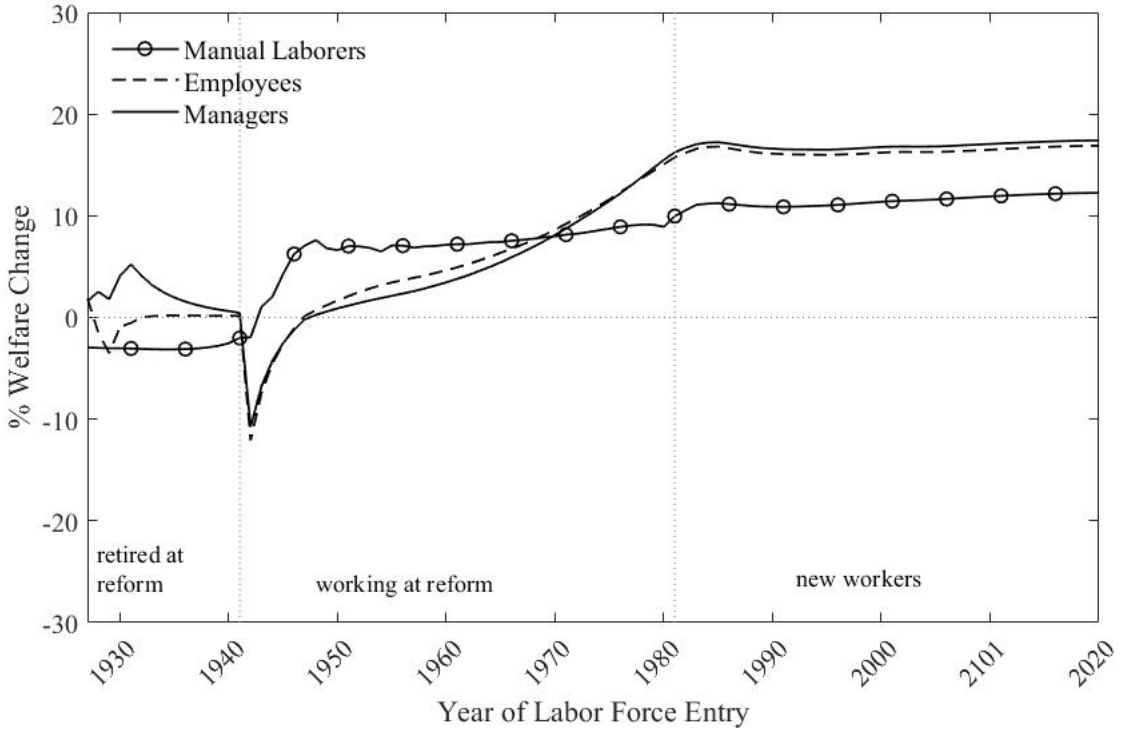
Transition from PAYG to Current Chilean Policy

	1980	1981-2000	2001-2020	2021-2050	2051-2080	2081-2115	Steady State*
Output	1.000	0.929	0.968	0.975	0.964	0.955	0.953
Capital Stock	1.000	0.961	1.042	1.125	1.095	1.112	1.151
Hours	1.000	0.930	0.928	0.889	0.875	0.861	0.854
Formal Hours	1.000	0.769	0.780	0.769	0.757	0.744	0.735
Informal Hours	1.000	5.489	5.568	5.487	5.404	5.310	5.248
Home Hours	1.000	0.958	0.923	0.828	0.812	0.804	0.804
Consumption	1.000	1.164	1.189	1.123	1.103	1.095	1.097
Market Consumption	1.000	1.255	1.307	1.254	1.232	1.224	1.227
Durable Spending	1.000	1.254	1.305	1.251	1.230	1.221	1.224
Home Consumption	1.000	0.973	0.943	0.850	0.833	0.826	0.826
Investment	1.000	1.192	1.299	1.136	1.026	1.018	1.031
Interest Rate	1.000	0.996	0.986	0.978	0.977	0.974	0.971
Wage	1.000	1.006	1.025	1.037	1.038	1.042	1.047
Per-capita Transfer	1.000	0.407	0.508	0.722	0.749	0.739	0.737
Consumption Tax	0.075	0.090	0.057	0.036	0.036	0.036	0.036
Labor Tax	0.378	0.211	0.211	0.216	0.218	0.219	0.216
Corporate Tax	0.082	0.077	0.077	0.085	0.088	0.089	0.089
Retirement Transfer	0.077	0.095	0.102	0.022	0.010	0.011	0.011
PAYG Pension	0.077	0.034	0.000	0.000	0.000	0.000	0.000
Recognition Bond	—	0.060	0102	0.015	0.000	0.000	0.000
MPG	—	0.000	0.000	0.007	0.010	0.011	0.011
Per-capita transfer	0.364	0.154	0.191	0.269	0.283	0.282	0.282
Debt	0.252	0.361	0.056	0.035	0.035	0.035	0.035
Government Spending	0.043	0.041	0.024	0.019	0.019	0.019	0.019

Note: Values for aggregates and prices are reported relative to the pre-reform balanced growth path.
Values for government revenue and spending variables are reported as a percentage of GNP.

* The steady state value is the average of these values for the last 9 years of the transition 2116-2124

Figure 3: Welfare Impact by Cohort



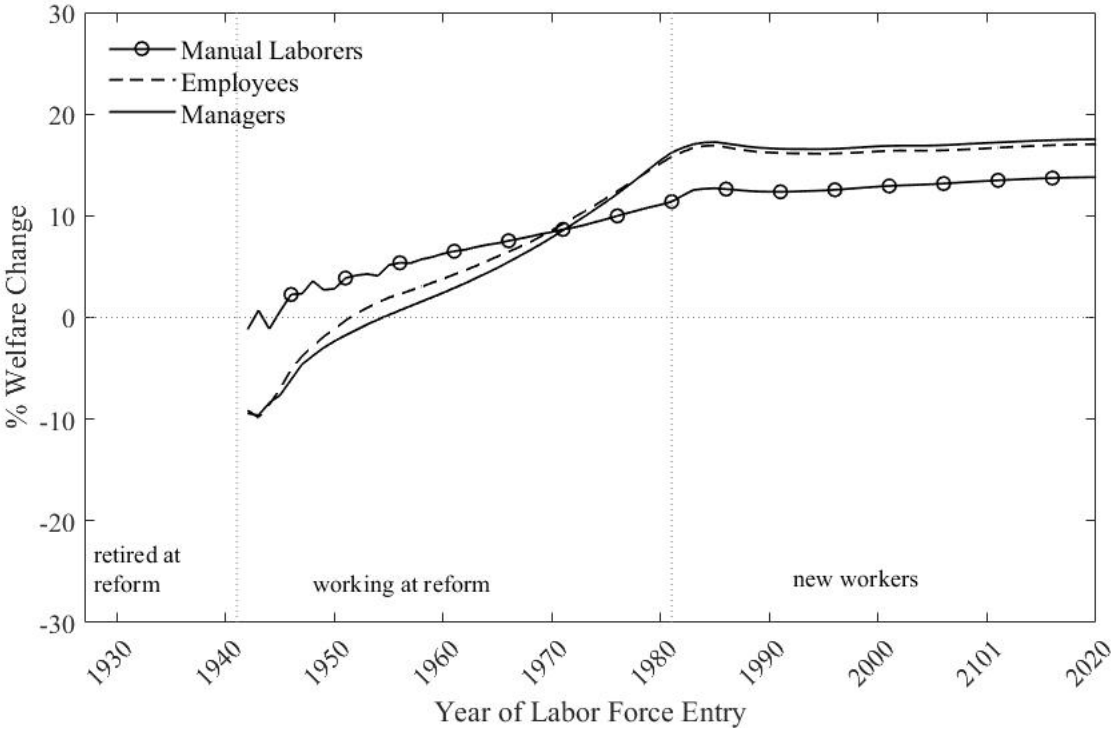
decrease from roughly 17 percent to 15 percent and 8 percent for the two groups, respectively.[60] Therefore, most of the gains are the result of the removal of the distortionary tax associated with the PAYG system, but capital deepening also plays an important role, especially for the gains of employees and managers.

An interesting feature of the long-run welfare gains is when during the life-cycle are these gains realized. In order to study this, I separate the welfare gains by whether they are accrued during the household's working years or during the household's retirement years. These results are shown in Figure 4 with Figure 4a showing the gains accrued during working years and Figure 4b showing the gains during retirement. As shown, the long-run gains are realized during working years. This indicates that lower distortions and higher wages largely drive welfare gains. However, there are welfare losses during retirement indicating that retirees receive less income during retirement due to policy change and lower interest rates associated with the reform. However, the large welfare gains during the working years lead to welfare gains overall.

[60]This heterogeneous impact is driven by how differences in the prices, the interest rate and the wage rate, impact the types differently. The small open economy is associated with a higher wage and lower interest rate than the baseline. Therefore, manual laborers, whose income comes more from labor income benefit from the higher wage. However, employees and managers who have a high fraction of income coming through capital returns, are hurt by the lower interest rate.

Figure 4: Welfare Gains by Cohort: Working Years and Retirement Years

(a) Working Years



(b) Retirement Years

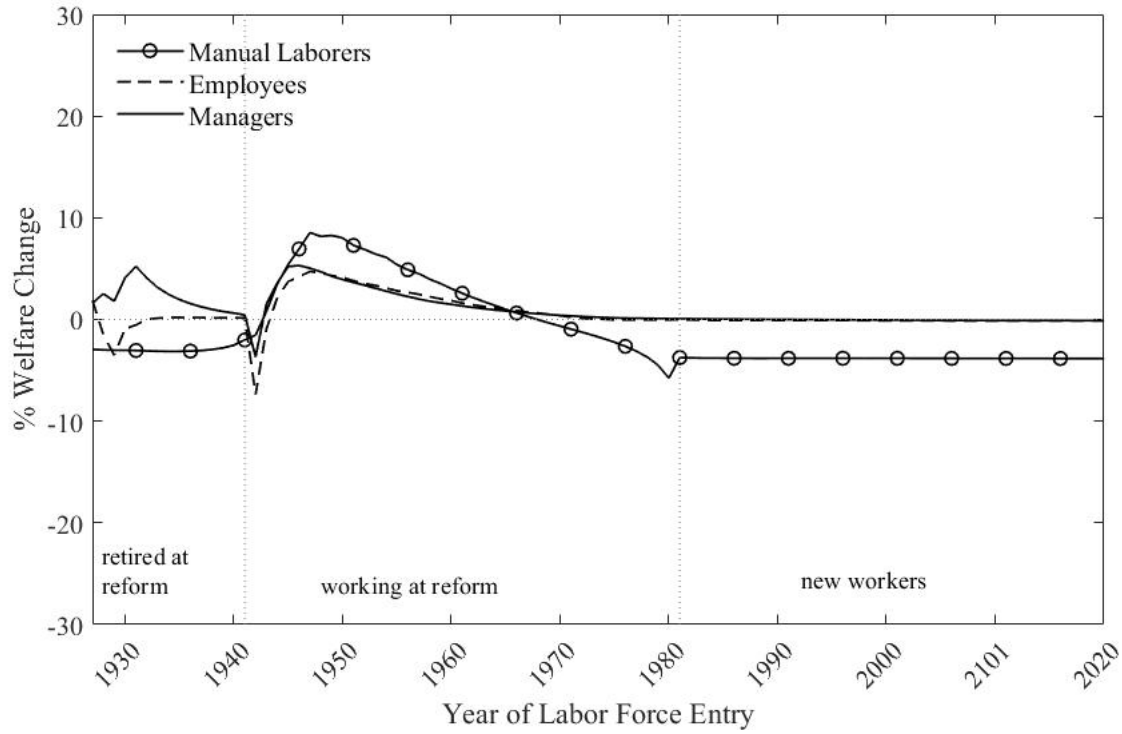


Table 7: Impact of Capital Deepening on Long-Run Welfare Gains

	Baseline	Small Open Economy
Total	14.7	14.2
Manual Laborers	12.3	14.4
Employees	16.9	14.9
Managers	17.6	8.0

6.2.2 Transitional Welfare Impact

Generations that live through the transition between the systems, particularly those who are retired or nearing retirement at the time of reform experience welfare losses. Two groups experience the largest welfare losses: those generations of manual laborers who retired at the time of reform and employees and managers who are within 5 years of retirement at the time of reform.

Manual Laborers

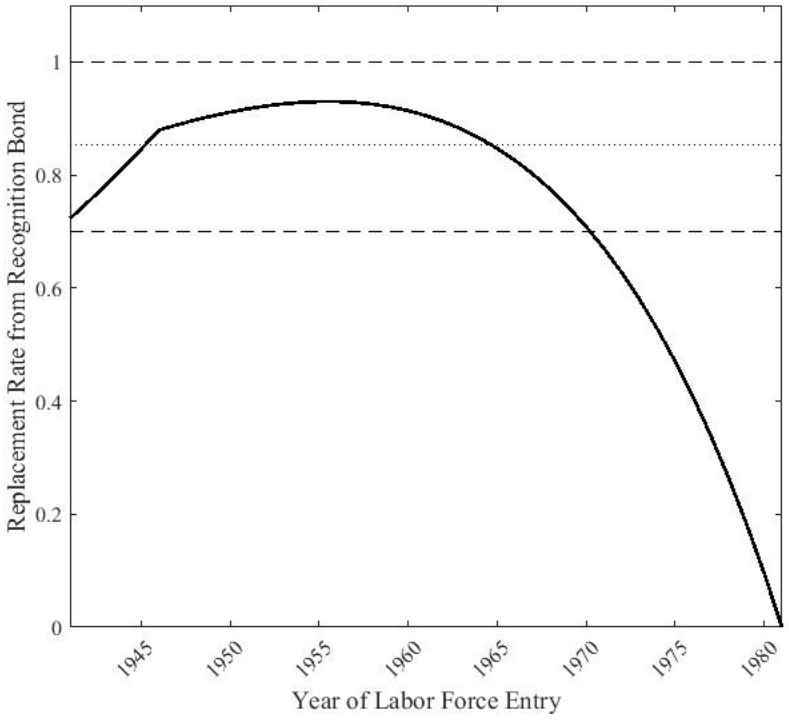
Manual laborers who are already retired at the time of the reform experience welfare losses of around 5 percent of remaining lifetime consumption. These losses are driven by the drop in the per-capita transfers throughout the transition. These worker who are already retired are grand-fathered into the pay-as-you-go program and receive the same pension under both cases. However, when the reform occurs the per-capita transfers must drop during the first years of the transition. Therefore, these households lose income from the transfer without receiving any benefit of elimination of distortions, wage gains, or higher pensions. The welfare impact is most negative for manual laborers are the per-capita transfer represents the largest fraction of income for this group relative to the others productivity types.

Employees and Managers

Higher productivity workers who are nearing retirement at the time of the reform experience large losses due to the structure of the transitional policy. In particular, these groups are hurt by the way in which the value of the recognition bond received to represent prior contributions to PAYG was calculated. Recall the formula for the per-period payout from the recognition bond:

$$\frac{1}{J-R}\left[0.8\bar{y}_t\left(\frac{t^*-t_0}{35}\right)\nu_G\nu_A(1.04)^{R-t^*}\right] \tag{28}$$

Figure 5: Implied Replacement Rate from the Recognition Bond Policy



where t^* represented the year of the reform (1981) and t_0 was the year a particular household entered the workforce. Important for comparison is that this formula allows the payout to be written as a percentage of the average taxable earnings, $\bar{y}_t$, just as the PAYG pension was.

$$\frac{1}{J-R}\left[0.8\left(\frac{t^*-t_0}{35}\right)\nu_G\nu_A(1.04)^{R-t^*}\right]\bar{y}_t = IRR * \bar{y}_t \tag{29}$$

where I will refer to *IRR* as the implied replacement rate for the recognition bond policy. A few features of this implied replacement rate are: it is dependent on the cohort of the individual, independent of general equilibrium effects on the interest rate as the bond paid a fixed real interest rate of 4 percent, and nearly independent of wage effects as the cohorts discussed here are close to retirement at the time of the reform. Figure 5 shows this implied replacement rate for cohorts where dashed lines at 0.7 and 1.00 represent the replacement rate that blue-collar and white-collar workers would have received under PAYG, respectively. The dotted line shows the average payed out in the PAYG system. It is obvious from this graph that for all cohorts of employees and managers who live through the transition the recognition bond pays less than they would have received under PAYG. Those cohorts closest to retirement do not have time to accumulate additional savings to buffer against this falling income. Therefore, these cohorts experience large welfare losses.

Overall, these results are caused by different effects depending on the cohort in question. For the future cohorts, welfare gains are driven by a combination of the removal of the distortionary tax and the capital deepening caused by increased savings. For transitional generations, the welfare losses are caused by the transitional details of the reform.[61] The oldest generations of manual laborers are hurt due to falling tax revenue and thus falling transfers. Employees and managers close to retirement are hurt due to the transitional policy paying less than they would have received under PAYG.

7 Impact of Informality and Home Production

7.1 Calibration

In order to study cases without the options of informality and home production, I must update the calibration of the model to match the same macroeconomic aggregates discussed in Section 5.3.2. Without the options of home production and informality, the calibration will result in different parameter values. Table 8 shows the parameter values for these calibrations; Table 9 shows the fit of these calibrations.

The key difference between these calibrations is the result of the weight of consumption in utility, γ. The value for this parameter varies significantly across the cases considered. These values must be different in order to match the aggregate market hours, formal and informal hours, worked in the economy. Consider, first, the economy without home production and informality. In order to match the fraction of time spent working, this parameter must increase moderately to 0.604. The impact of home production and informality independently, however, are much different. Specifically, excluding only informality (and including home production) requires an increase in this parameter while excluding only home production (and including informality) requires γ to decrease. In order to match the fraction of time spent working of 0.495, this value must be 0.769 in an economy where the only outside option is home production and 0.278 in an economy with only informality.

The differences in this parameter imply differences in labor supply elasticity across these economies. As the parameter γ increases, so does labor supply elasticity. Including home production increases the labor supply elasticity as workers are given an outside option to working formally. Adding only informality, however, decreases labor supply elasticity. Since the household's freedom to move between the sectors is limited by the imperfect substitutability between the sectors, the inclusion of this option decreases elasticity. Finally, when both options are included, the labor supply elasticity is slightly smaller than the case of formality only.

[61] Because this is a deterministic model, there is not an insurance motive for Social Security. Including this motive would add additional transitional welfare impacts. These impacts are show in Conesa and Krueger (1999), Nishiyama

Table 8: Calibrated Parameters

Informality and Home Production Experiments

Parameter	Baseline	Formality + Home Production	Formality + Informality	Only Formality
β	0.901	0.906	0.898	0.915
γ	0.484	0.769	0.278	0.604
$\{\varepsilon_1, \varepsilon_2, \varepsilon_3\}$	$\{0.5, 1.45, 4.5\}$	$\{1.0, 2.75, 6.25\}$	$\{0.45, 1.4, 4.55\}$	$\{0.45, 1.4, 4.55\}$

Table 9: Targeted Moments

Informality and Home Production Experiments

Moments	Data	Formality + Home Production	Formality + Informality	Only Formality
Capital to output ratio	1.667	1.675	1.665	1.665
Aggregate hours worked	0.495	0.496	0.495	0.495
Fraction of GNP spent on social programs	0.144	0.143	0.145	0.144
Fraction of labor income earned by manual laborers	0.210	0.228	0.207	0.204
Fraction of labor income earned by employees	0.520	0.562	0.527	0.523
Fraction of labor income earned by managers	0.270	0.210	0.266	0.273

Table 10: Impact of Home Production and Informality on Long-Run Welfare Gains

	Baseline		Formality + Home Production		Formality + Informality		Formality Only
	welfare	% change	welfare	% change	welfare	% change	welfare
Total	1.0	10.3	1.2	34.7	0.8	-11.8	0.9
Manual Laborers	0.9	2.0	1.1	27.2	0.7	-13.5	0.8
Employees	1.1	17.1	1.4	41.1	0.9	-10.8	1.0
Managers	1.1	18.7	1.4	40.9	0.9	-8.2	1.0

Note: % changes are measured relative to the case with only formality

7.2 Results

The inclusion of home production and informality changes the impacts of the reform to Social Security. As market consumption is the only form of consumption that is present across all economies studied, welfare must be measured as a percentage of lifetime market consumption rather than as a percentage of lifetime total consumption as was used in the baseline results.[62] Table 10 shows how the long-run welfare impact of the Chilean policy change is impacted by the inclusion of home production, informality, and both options together.

The key results demonstrate that including home production increases the long-run welfare impact of the reform while including informality decreases the long-run impact of reform. Quantitatively, I find that the positive impact of home production is slightly stronger; this leads to welfare gains in the baseline (including both home production and informality) being roughly 10 percent larger than the welfare gains in an economy which features only formality. These results can be understood through two main channels: the elasticity channel and the market wage channel. In this framework, including home production impacts welfare through only the elasticity channel[63] while informality impacts welfare through both the elasticity and the market wage channel.[64] A summary of the direction of these mechanisms in the cases of home production and informality is shown in Table 11.

Elasticity Channel

and Smetters (2007), Huggett and Parra (2010), and Imrohoroglu and Kitao (2012), among others.

[62]This results in welfare numbers (around 1 percent) much smaller than in the baseline. This is the result of the low substitutability between market and home consumption in the Chilean economy.

[63]In a framework with labor supply risk, Social Security also has an insurance motive. Including home production in this alternative framework works through an additional channel of reducing this insurance motive of Social Security as workers can use home production to partially insure against income risk.

[64]Aggregates throughout the transition path are shown in Section 18 of the Technical Appendix

Table 11: Impact of Mechanisms on Welfare

	Elasticity Channel	Market Wage Channel
Home Production	↑	—
Informality	↓	↑

The elasticity channel focuses on the link between the labor supply elasticity of the model and the distortionary nature of the labor income tax. As discussed, each of these economies is associated with a different labor supply elasticity. Specifically, adding home production increases the elasticity of the labor supply while adding informality decreases the labor supply elasticity. Increases in the labor supply elasticity render the payroll tax in the pay-as-you-go Social Security system more distortionary. Therefore, gains from the removing this payroll tax through the reform increase long-run welfare gains.

This force works in different directions when home production and informality are included independently. Because of the higher labor supply elasticity induced by adding home production, the payroll tax in more distortionary in the economy with formality and home production than in the economy with only formality. Therefore, welfare gains from privatizing Social Security are higher in the economy with formality and home production. Including only informality, however, reduces the labor supply elasticity lower. Therefore, the economy with formality and informality is less elastic than the economy with formality only. Therefore, when informality is included, the payroll tax is less distortionary and the long-run welfare impact is lower.

Market Wage Channel

The inclusion of informality is distinct from the inclusion of home production due to how informality can impact welfare through the market wage channel. This channel focuses on how informality provides workers with an outside option to formal work which is still within the market sector. Therefore, workers can use informality to avoid distortionary taxation while continuing to receive a market wage.

In both the formal and informal sectors workers are paid a market wage for time working. However, in the formal sector, workers must pay taxes on income earned. Throughout the transition between pay-as-you-go Social Security and the privatized system, capital deepens as the pension system no longer crowds out private savings. This increase in capital stock induces lower interest rates and higher wages. This higher wage causes workers to substitute into market work. Including informality, however, means workers flow into informality rather than formality. Workers can

receive higher wages without facing distortionary taxation that remains in the formal sector.

The overall welfare impact is a quantitative question. I find that including home production increases welfare gains from reform by roughly 30 percent and including informality decreases welfare gains from reform by around 10 percent. The increase in gains from home production is a result of the elasticity channel while the decrease in welfare gains by adding informality indicates the elasticity channel is quantitatively stronger than the market wage channel.

8 Conclusion

In conclusion, this work supports the literature on Social Security privatization by showing large long-run welfare gains from the reform. However, as with the literature, these long-run gains are financed by losses for those generations that live through the transition between the programs. These gains and losses are different depending on the type of employment the worker had before the reform. Specifically, long-run gains are roughly 15 percent for employees and managers while they are nearly 10 percent for manual laborers. In the transition two groups experience losses of 10 percent. Manual laborers who are already retired at the time of reform experience losses as the government must continue to pay PAYG pensions to current retirees while receiving less tax revenue due to the removal of the Social Security payroll tax. White-collar workers within five years of retirement experience large losses as the transitional policy used in the Chilean reform pays out less than these workers would have received from the PAYG program.

My model also allows me to analyze how home production and informality impact these welfare gains. Both home production and informality increase long-run welfare gains. The option to work at home increases the elasticity of labor supply and causes the payroll tax to be more distortionary. Therefore, there are larger welfare gains from removing the payroll tax as part of the reform. In addition to this, informality has two effect which work against each other. First, informality decreases the elasticity of labor supply. This causes the pay-as-you-go payroll tax to be less distortionary, and, therefore, decreases the welfare gains from reform. Second, informality allows workers to take advantage of wage growth that occurs throughout the transition without facing remaining taxation. This wage effect causes higher welfare gains in an economy in which informality is an option. Quantitatively, the downward pressure on welfare gains through the elasticity channel is stronger and leads to smaller long-run welfare gains from reform when we consider an economy with informality as compared to an economy with only formality.

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