# PENSION REFORM, INFORMAL MARKETS, AND LONG-TERM INCOME AND WELFARE

Klaus Schmidt-Hebbel

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Klaus Schmidt-Hebbel
Manager of the Economic Research Unit
Central Bank of Chile

## Resumen

Es sabido que un sistema de pensiones de reparto reduce los niveles de ahorro, ingreso y bienestar de generaciones futuras en una economía de un solo sector porque implica una transferencia de ingresos hacia las primeras generaciones de pensionados bajo el sistema de reparto. ¿Es posible el resultado opuesto en una economía de dos sectores productivos, uno formal y otro informal? Sí, como lo muestran las simulaciones realizadas en éste trabajo para una economía representativa, reflejada por la solución de equilibrio de estado estacionario de un modelo de generaciones traslapadas de dos períodos y dos sectores productivos. Un sistema de reparto puede elevar el ahorro, el ingreso y el bienestar de largo plazo en una economía de dos sectores cuando el sector formal (obligado a pagar contribuciones al sistema de reparto) es más intensivo en capital que el sector informal (que no paga contribuciones), aumentando los salarios y reduciendo la tasa de interés. ¿Es empíricamente probable este resultado? No, como sugiere una revisión de las características empíricas de los sistemas de pensiones y estructuras de producción formal-informal en el mundo. Por lo tanto el reemplazo de un sistema de pensiones de reparto por otro de capitalización es probable que contribuya positivamente a generar mayores niveles de ahorro, ingreso y bienestar en el largo plazo, aún en una economía de dos sectores.

## Abstract

It is well known that a pay-as-you-go (PAYG) pension system lowers saving, income, and welfare of future cohorts in a one-sector economy because it entails a transfer to the first cohorts of PAYG pensioners. Is the opposite result possible in a two-sector (formal-informal production) economy? Yes, as shown by the simulations for a representative economy reported in this paper, based on the stady-state solution of a two-sector two-period overlapping-generations model. A PAYG system can raise long-term saving, income, and welfare in a two-sector economy if the formal sector (forced to pay mandatory PAYG taxes) is more capital intensive than the non-taxed informal sector, causing higher wages and lower interest rates. Is this outcome empirically likely? No, as suggested by reviewing the stylized features of real world pension systems and formal-informal market structures. Therefore replacing PAYG by a fully-funded pension system is still more likely than not to raise long-term saving, income, and welfare levels.

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## 1. Introduction

Pension system reforms are spreading around the globe, ranging from Latin America (Chile 1981, Mexico 1991 and 1995, Peru 1993, Argentina 1994, Colombia 1994, and Uruguay 1995) to OECD countries (Switzerland 1985, Australia 1991) and to Eastern Europe (Latvia 1995). Many more countries -- including economies as diverse as Bolivia, Hungary, and Sweden -- are currently discussing major reform initiatives.[1] The next few years will witness exponential growth of pension reform. It is likely that 25 major country-wide pension reforms will have been initiated by the year 2000.

The new brand of mandatory pension systems typically comprises two components or "pillars". The first comprises fully-funded old-age savings based on individual pension accounts, with investments channeled to various public and private long-term instruments often selected and managed by the private sector; the second pillar is a complementary state-run distributive transfer program in support of the old-age poor. Such a pension regime involves a radical departure from the still dominating conventional pension paradigm in three dimensions: (i) substitution of a pay-as-you-go (PAYG) scheme by a fully-funded (FF) arrangement for (at least part) of old-age saving, (ii) more explicit separation of the distributive component from the non-distributive pillar, and (iii) (frequently) private management of collection of contributions, investment of pension fund savings, and/or payment of pension benefits.[2]

These pension reforms attempt to address various shortcomings that tend to be associated with conventional state-managed PAYG schemes: unsustainable public pension debt paths reflected in exploding social security deficits, distorted labor markets, under-developed capital markets, low saving and growth rates, and political-economy drawbacks of public pension plans. Assessing such claims requires using an analytical framework that is able to compare the potential consequences of different pension regimes.

The seminal contributions by Samuelson (1958) and Diamond (1965) have introduced the two-cohort overlapping-generations (OLG) model for a closed economy with exogenous long-term growth to analyze the main public finance, accumulation, and intergenerational welfare dimensions of public debt in general and old-age security arrangements in particular. A major extension of Diamond's two-cohort OLG model is Auerbach and Kotlikoff's (1987) many-generations dynamic OLG model, which provides a realistic number of interacting cohorts and has been successfully applied to assess quantitative outcomes of different pension systems.[3] From this literature it is well known that a pay-as-you-go (PAYG) pension system lowers saving, income, and welfare of future cohorts in a one-sector economy because it entails a transfer to the first cohorts of PAYG pensioners.

Corsetti (1994) develops an innovative endogenous-growth model for a two-sector OLG economy to compare the steady-state income growth and welfare effects of PAYG and FF pension systems in a two-sector economy that distinguishes between a more efficient formal

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[1] Demirgüç-Kunt and Schwarz (1996) take stock of all recent and ongoing pension reforms throughout the world, distinguishing between major reforms (in the sense discussed here), major reverse reforms (adoption of PAYG systems), and minor changes to pension systems.

[2] For a comprehensive analysis of pension arrangements throughout the world, their problems and possible solutions see World Bank (1994) and James and Palacios (1996).

[3] The Diamond-Auerbach-Kotlikoff framework is particularly useful in showing impact, transition and steady-state effects of mandatory pension systems and reforms. Applications to Mexico (Arrau 1990), Chile (Arrau 1991), and representative economies (Arrau and Schmidt-Hebbel 1993, Valdés Prieto 1994, Cifuentes and Valdés-Prieto 1996) have been used to assess the dynamic and macroeconomic effects of pension reforms involving substitution of PAYG systems by FF schemes.

sector that complies with social security legislation and a less-efficient informal sector that is not bound by such legislation. Using an "AK" technology in the sense of Romer (1986) where capital (used only in the formal sector) has an external effect on labor productivity and is the ultimate productive resource, Corsetti analyzes conditions under which a PAYG-FF reform raises the rate of capital accumulation and output growth allowing for reform-induced changes in the structure of production. In general, because of conflicting income and substitution effects, the change in consumption and growth cannot be determined unambiguously. However, illustrative simulations suggest that the long-run positive effect of a PAYG-FF pension reform on growth may be sizable.

Loayza (1996) estimates the size of the informal sector for a sample of Latin American countries based on a latent-variable model for the share of the informal sector in GDP. The latter unobserved variable is linked to both multiple causes (including the negative effect of contributions to social security) and multiple indicators (including the positive effect on the share of non-farm workers not covered by social security). His cross-country regression results evidence a significant negative effect of the size of the informal sector on long-term GDP growth. This result supports the notion -- formalized by Loayza in an endogenous-growth model where output follows an AK technology augmented by a public-services externality that is larger in formal-sector production -- that informality lowers aggregate growth by reducing aggregate public services and crowding out the formal sector.

A question not addressed by the previous literature is the following. Which are the signs of the steady-state income and welfare effects of a PAYG-FF pension reform in a two-sector economy where differences in capital/labor intensities of production in the formal and informal sectors can go either way and where it is not assumed from the outset that the formal sector is more efficient than the informal sector? This paper focuses on this issue. It shows that the difference in factor intensities between the formal and informal sectors is crucial in deriving the steady-state effects of pension reform on all relevant macroeconomic and welfare variables.

The general-equilibrium OLG model derived in this paper for an economy with exogenous steady-state growth and the simulations carried out for its stationary equilibrium reflect three channels at work when a PAYG system is adopted in a two-sector economy. The first channel is the conventional intergenerational transfer toward the first PAYG pensioners, the second comprises an intergenerational transfer whose sign depends on sector differences in factor intensities, and the third is a Pareto efficiency loss from distorted inter-sector factor reallocation that is suffered by all cohorts. The standard pension reform model for a one-sector economy emphasizes only the first and unambiguous channel. The two-sector setup presented here adds the second and third channels and shows that, because of the ambiguous sign of the second channel, adoption of a PAYG system has ambiguous effects on long-term values of all relevant variables. Likewise a PAYG-FF reform -- substituting FF for an existing PAYG system -- is shown to have ambiguous effects on long-term saving, income, and welfare, that depend crucially on sector differences in factor intensities.

Section 2 of the paper presents the two-sector two-period OLG model for a closed economy. Section 3 reports simulation results for the steady-state solution of the model parameterized for a representative economy, comparing the long-term values of macroeconomic and welfare variables attained under different pension systems and formal-informal sector technologies. Suggestive international evidence on the features of pension systems and formal/informal production structures is reviewed in section 4 to draw inferences about the likely long-term effects of pension reform in real-world economies. A final section concludes.

## 2. The Model

The framework presented in this section is a two-period general-equilibrium model for two overlapping generations (OLG) for a closed economy in the tradition of the neoclassical models developed by Samuelson (1958) and Diamond (1965) and extended by Auerbach and Kotlikoff (1987) to analyze the features and consequences of different pension regimes. The model developed here differs from the previous literature by allowing for two sectors of production that produce the same good but differ in technology and their participation in the PAYG pension system. A similar model was developed by Corsetti (1994) for an economy with endogenous growth based on an "AK" technology, where capital has a positive externality on labor productivity and the formal sector is assumed to be more productive than the informal sector.

In this section I introduce an exogenous-growth OLG model for a two-sector closed economy where steady-state growth is exogenous. As opposed to Corsetti's model, the formal and informal sectors are treated symmetrically in regard to factor productivity and factor externalities are excluded. This allows to focus on a feature of formal and informal markets -- the difference in factor intensities -- that will be shown to be crucial in determining the net effect of pension reform on steady-state levels of macroeconomic and welfare variables. The model allows for varying degrees of PAYG contribution-benefit links, and flexible intra and inter-temporal preferences and production technologies.

Next I present the general set-up of the model. The 18 equations that represent the model solution are summarized in the appendix. The steady-state equilibrium solution of these equations is used in the simulations reported in section 3 below.

FF and PAYG Pension Systems

A mandatory FF pension system is modeled here as equivalent to no mandatory system at all, i.e., a case of entirely voluntary retirement saving.[4] Hence the mandatory PAYG contribution rate (d) is zero in a FF regime.

Now consider a PAYG system. The young-age cohort of people works in the first period (denoted by subscript t) and saves for the second period (denoted by subscript t+1). If they are employed in the formal production sector (denoted sector 1) they pay a fraction (d) of their gross wage (w) as a mandatory contribution to a PAYG system. If they are employed in the informal production sector (denoted sector 2) they are either exempted from paying or evade payment of PAYG contributions, implying that net and gross informal-sector wages are identical (wn). Workers do not necessarily link their current PAYG contributions to future PAYG benefits. Therefore their expected gross rate of return of current PAYG contributions (v) takes any value between zero and the maximum gross rate of return of a PAYG system in steady state (the gross rate of GDP growth). The difference between the latter and v is distributed as a lump-sum payment to all workers. This payment can also be rationalized as

[4] This assumes that contribution rates mandated by a FF system do not exceed the saving rates that would be observed under voluntary saving. This assumption reflects a benchmark that may not be realistic. In fact, an important rationale for adopting mandatory FF pension systems is the presumably large incidence of myopia, reflected in high discount rates and low retirement savings across many population groups. Under these conditions people are forced to save for retirement by a FF system in excess of what they would save voluntarily.

the distributive component of PAYG benefits, i.e., an amount that is paid in accordance to criteria other than pension contributions.[5]

Equalization of net wages in the informal and formal sectors under a PAYG system implies:

$$(1) \qquad wn_t = w_t \left[ 1 - d_t \left( 1 - \frac{v}{1+r_{t+1}} \right) \right]$$

where r is the rate of interest. The right-hand side of this equation reflects the net wage as perceived by a formal-sector worker. It deducts the net contribution to the PAYG system -- i.e., the net PAYG tax comprised by the gross contribution (d) less the present value of future benefits -- from the gross wage paid by the formal-sector firm.

The PAYG pension system collects contributions from workers employed in the formal sector and pays out pension benefits to retirees. Neither does it accumulate reserves nor does it incur into losses. Pension benefit payments are split into the gross return on pension contributions during the preceding period and a lump-sum pension or redistributive pension benefit (z). The latter lump-sum pension is equal to the difference between contributions and contribution-related benefit payments:

$$(2) \qquad z_{t+1} = d_{t+1} w_{t+1} l_{1t+1} - d_t w_t l_{1t} \left[ \frac{v}{(1+n)(1+\gamma)} \right]$$

where l is employment and subscript i (i= 1,2) denotes production sector.

Note that preceding-period (t) PAYG contributions are deflated by the gross rate of growth of efficiency labor units, equal to the product of the gross rate of population growth (1+n) and the gross rate of Harrod-neutral technical progress (1+γ). The latter product is also equal to the economy's exogenous steady-state gross rate of GDP growth. The reason for this deflation is that all stock and flow variables in this model are written in terms of labor efficiency units.

Utility Maximization

Each cohort maximizes the present value of utility as given by the following two-period intertemporal constant relative risk aversion and intratemporal CES function over current consumption, future consumption, and leisure (c, cf, and o ≡ 1-l, respectively):

[5] Explicit modeling of a redistributive component of PAYG benefits would require introducing consumer-worker heterogeneity by disaggregating cohorts according to differences in discount rates, PAYG contributions, incidence of borrowing constraints, and/or endowments and income levels. Examples of pension reform models that address explicitly consumer heterogeneity are Valdés-Prieto (1994) for a representative economy, Cifuentes and Valdés-Prieto (1996) for Colombia, Hungary, and the Philippines, and Kotlikoff, Smetters, and Walliser (1996) for the U.S.

(3) $V(c_t, o_t, cf_{t+1}, 1) =$

$$= \frac{1}{1-\theta}\left[\mu c_t^{\lambda} + (1-\mu)o_t^{\lambda}\right]^{\frac{1-\theta}{\lambda}} + \frac{1}{1+\rho}\,\frac{1}{1-\theta}\left[\mu\, cf_{t+1}^{\lambda} + (1-\mu)\right]^{\frac{1-\theta}{\lambda}}$$

with current-consumption weight parameter $\mu$, an intertemporal elasticity of substitution $1/\theta$, and an intratemporal elasticity of substitution $1/(1-\lambda)$.

Utility maximization is subject to a standard intertemporal budget constraint that equates the present value of consumption spending to wage income and the present value of net non-wage income (m):

$$(4) \qquad c_t + \left(\frac{1}{1+r_{t+1}}\right) cf_{t+1} = wn_t\, l_t + m_t$$

where net non-wage income is defined as bequests received from parents net of the present value of bequests inherited to children plus the present value of the lump-sum payment from the PAYG pension system:

$$(5) \qquad m_t = b_t - \left(\frac{(1+n)(1+\gamma)}{1+r_{t+1}}\right)\left[b_{t+1} - z_{t+1}\right]$$

Profit Maximization

Representative formal and informal-sector firms face a standard static net profit maximization problem under conditions of constant returns to scale and perfect conditions in goods and factor markets. Output in each sector is produced by a CES technology. Goods produced by formal and informal-sector firms are indistinguishable, hence their common price is set to be the model's numeraire. Net profits in each sector are simply given by:

$$(6a) \qquad \varepsilon 1\left[\alpha\,(k_{1t})^{\frac{\sigma 1-1}{\sigma 1}} + (1-\alpha)(l_{1t})^{\frac{\sigma 1-1}{\sigma 1}}\right]^{\frac{-\sigma 1}{1-\sigma 1}} - \left[r_t(1+\delta)+\delta\right]k_{1t} - w_t\, l_{1t}$$

$$(6b) \qquad \varepsilon 2\left[\beta\,(k_{2t})^{\frac{\sigma 2-1}{\sigma 2}} + (1-\beta)(l_{2t})^{\frac{\sigma 2-1}{\sigma 2}}\right]^{\frac{-\sigma 2}{1-\sigma 2}} - \left[r_t(1+\delta)+\delta\right]k_{2t} - wn_t\, l_{2t}$$

with aggregate productivity parameters $\varepsilon 1$ and $\varepsilon 2$, capital weight parameters $\alpha$ and $\beta$, and capital/labor elasticities of substitution $\sigma 1$ and $\sigma 2$. The cost of capital is given by the rate of interest and the rate of capital depreciation $\delta$. While technology is symmetrical in both sectors, labor-market conditions are not in a PAYG system. The formal-sector firm pays a gross wage that exceeds the net wage paid by the informal-sector firm by the value defined in equation (1).

Saving and Investment

The supply of saving is determined by the excess of income over consumption during young age:

$$(7) \qquad s_t = (1 - d_t)\, w_t\, l_{1t} + wn_t\, l_{2t} + b_t - c_t$$

The investment-saving equilibrium (or, equivalently, the economy's goods market equilibrium, is given by:

$$(8) \qquad (1+n)\,(1+\gamma)\,(1+\delta)\,k_{t+1} = s_t$$

## 3. Simulation Results

In this section I apply the steady-state equilibrium solution of the complete model summarized in the appendix to simulate the impact of different pension systems on aggregate levels of production factors, output, and welfare, and the allocation of to the factors to the formal and informal sectors of production.[6]

How do pension systems affect the intertemporal allocation of resources and hence aggregate levels of employment, capital, and welfare? How do pension systems affect the intratemporal factor allocation among formal and informal markets, and hence the relative size of the latter sectors? And, most important, how does the interaction between inter and intratemporal resource allocation affect the economy's aggregate levels of resource inputs, output and welfare, as well as its structure of formal-informal production?

The first question has received wide attention in the literature, the second only scantily. The third question is new -- we want to find out if the well-known effects of a pension system in a one-sector economy are altered when introducing a dual production structure. Our answer is yes.

The simulation results compare steady-state equilibria of FF and PAYG pension systems. I typically consider various PAYG cases that differ by their level of intergenerational distribution (reflected by the PAYG contribution rate) and by their level of intragenerational redistribution (reflected by the valuation of future benefits by active pension contributors). PAYG contribution rates paid by the workers employed in the formal sector vary between a low 10% and a prohibitive 90% of gross wages.[7] Considering a wide range of PAYG contribution rates has the advantage of illustrating non-monotonicities and corner solutions that are not apparent at the lower end of the distribution of contribution rates. Two polar cases of implicit intra-generational redistribution by the PAYG system are considered here: zero redistribution (equivalent to an expected gross rate of return on PAYG contributions equal to the economy's steady-state growth rate) and 100% redistribution (equivalent to an expected gross rate of return on PAYG contributions equal to zero).

Parameter values for the base case simulations have been chosen to satisfy empirical relevance and consistency across simulations. Table 3.1 summarizes coefficient values for base-case simulations.

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[6] The simulation program and simulation results in Gauss are available on request.

[7] Social-security contribution rates range from zero to 60% of gross wages in the world (see World Bank 1994 and Demirgüç-Kunt and Schwarz 1996).

**Table 3.1**
**SIMULATION MODEL: COEFFICIENT VALUES**

| | | |
|---|---|---|
| **Preference Parameters** | | |
| Intratemporal consumption substitution parameter: $\lambda$ (implies a 0.99 intratemporal elasticity of substitution) | | -0.01 |
| Intratemporal consumption parameter: $\mu$ | | 0.70 |
| Intertemporal consumption substitution parameter: $\theta$ (implies a 1.01 intertemporal elasticity of substitution) | | 0.99 |
| Annual intertemporal preference parameter: $\rho$ | | 0.02 |
| Bequests: b | | 0 |
| **Technology Parameters** | | |
| Annual capital depreciation rate: $\delta$ | | 0.03 |
| (i) One-sector economy | | |
| Capital parameter: $\alpha$ | | 0.38 |
| Capital/labor elasticity of substitution: $\sigma$ | | 1.05 |
| (ii) Two-sector economy | | |
| Productivity parameters in sectors 1 and 2: $\varepsilon 1$, $\varepsilon 2$ | | 1.0, 1.0 |
| | Sector 1 is K intensive | Sector 1 is L intensive |
| Capital parameters in sectors 1 and 2: $\alpha$, $\beta$ | 0.30, 0.50 | 0.50, 0.30 |
| Capital/labor elasticities of substitution in sectors 1 and 2: $\sigma 1$, $\sigma 2$ | 0.87, 1.34 | 1.30, 0.84 |
| **Other Parameters** | | |
| Annual population growth rate: n | | 0.01 |
| Annual rate of Harrod-neutral technical progress: $\gamma$ | | 0.01 |
| Annual expected gross rate of return of PAYG system (v) under: | | |
| zero intragenerational distribution or lump-sum PAYG benefit: $(1+n)(1+\gamma)$ | | 1.0201 |
| full intragenerational distribution or lump-sum PAYG benefit: | | 0 |
| Number of active (labor) and passive (retirement) years | | 25 |

Preference and technology parameters have been chosen to correspond to simple functional forms that ease interpretation of base-case simulation results. Utility parameters correspond approximately to Cobb-Douglas intratemporal preferences (with a 0.99 intratemporal elasticity of substitution for CES preferences) and approximately to logarithmic intertemporal preferences (a 1.01 intertemporal elasticity of substitution for constant relative risk-aversion preferences).

Production parameters have been chosen to satisfy five criteria. First, in the one-sector economy they correspond approximately to a Cobb-Douglas technology (the capital-labor elasticity of substitution is 1.05). Second, in the one-sector economy the combination of the latter elasticity of substitution and the value selected for the capital parameter (0.40) imply a 34% share of capital in production under the simulations for a FF pension system reported below. Third, production parameters for the two-sector economy are set to obtain significant sector differentiation (i.e., significant concavity of the production frontier) in order to reduce occurrence of corner solutions (i.e., specialization of production in one sector). Fourth, two alternative technology combinations are considered for the two-sector economy. In one case the formal sector is more capital intensive than the informal sector, while the opposite is assumed in the second case. The latter distinction will be crucial for the results reported in this paper. Finally, the weighted averages of sector capital parameters and sector elasticities of substitution in the two-sector economy are roughly equal to the corresponding values set for the one-sector economy. Capital parameters are 0.30 and 0.50, and elasticities of substitution are 0.87 and 1.34 (when the formal sector is capital-intensive) and 1.30 and 0.84 (when the formal sector is labor-intensive). The latter combinations of parameters allow to obtain capital shares in production of 43% in the formal sector and 23% in the informal sector (when the formal sector is capital intensive), and 26% and 46%, respectively (when the formal sector is labor intensive).

The overall combination of parameters allows to satisfy dynamic efficiency: the endogenous interest rate is higher than the exogenous stationary GDP growth rate in all simulations reported below.

One final feature to note is the time dimension of the simulation model. In order to assure consistency between the two-period character of the OLG model and a realistic time frame for life-cycle consumption-saving decisions, I chose 25 years to be the length of both working and retirement life. This implies that all model variables and parameters with an annual time dimension have been compounded to 25 years.

### 3.1 Dynamic general equilibrium in a one-sector economy

I start by comparing the steady-state macroeconomic and welfare effects of a FF pension system with those of various PAYG regimes in a one-sector economy. It is well known that adopting a PAYG regime involves an income transfer from future generations to the first cohorts that have retired under PAYG without paying their full pension contributions. Future generations living in the new PAYG steady-state equilibrium suffer an income and welfare loss (as compared to all cohorts living in a FF system) and hence consume, save, and invest less.

The simulation results reported in Table 3.2 compare the stationary performance of a mandatory FF pension regime to those of various PAYG pension regimes. The first column reports the values of endogenous macroeconomic and welfare variables under a FF system (equivalent to entirely voluntary saving, with a zero rate of PAYG contribution d). The following columns summarize the results for various PAYG systems that differ by the rate of mandatory PAYG contributions (from d=0.1 in column 2 to d=0.9 in column 5). The upper

panel summarizes results for a PAYG system with zero intragenerational redistribution, where pension contributors expect a gross rate of return of PAYG contributions equal to one plus steady-state GDP growth (v=1.0201 per year). The lower-panel results are for a PAYG system with 100% intragenerational distribution (v=0), where the whole PAYG contribution is equivalent to a pure tax on labor.

We start by discussing the simulation results in the upper panel. The income loss imposed by PAYG on future generations reduces their demand for current and future consumption (i.e. saving) and leisure. Less saving reduces the supply of capital, lowering the capital stock from 0.0136 under FF to 0.0101 under a 10% PAYG contribution rate and to 0.0002 under a 90% PAYG contribution rate. The interest rate increases accordingly, from 4.0% under FF to 4.7% (under d=0.1) and to 16.1% (under d=0.9). Total labor employment remains almost unchanged. Both net and gross wages fall under a PAYG regime. Relative factor prices (the ratio of the interest rate to gross wages) rise with PAYG, in proportion to the decline in relative factor endowments (the ratio of capital to labor).

PAYG reduces total consumption and tilts the consumption profile toward the future in response to the higher interest rate: the ratio of future to current consumption increases from 1.6 under FF to 1.9 under d=0.1 and to 25.8 when d=0.9.[8]

The difference between gross and net wages grows with the pure tax on formal-sector labor, that is, the PAYG contribution net of the discounted value of expected future PAYG benefits. The size of PAYG contributions relative to GDP also grows monotonically with the rate of contribution: from 6.7% when d=0.1 to 63.9% when d=0.9. Overall GDP and welfare levels decline monotonically and exponentially with the size of the PAYG regime.[9] The GDP and welfare gains of a reform that substitutes FF for an initial PAYG regime are 10.5% and 6.8%, respectively when d=0.1, and rise to extremely high levels -- 302% and 511% -- when PAYG contribution rates are extreme (d=0.9).[10] [11]

[8] Recall that current and future consumption are separated by a 25-year period.

[9] Reported welfare gains and losses are based on wealth-equivalent compensatory variations in indirect utility, derived as in Auerbach and Kotlikoff (1987).

[10] These gains are higher than those obtained in most pension simulation studies based on 55 overlapping cohorts that follow the simulation framework developed by Auerbach and Kotlikoff (1987) (see Corsetti and Schmidt-Hebbel 1996 for a comparative review). The reason is that the latter studies typically consider 40 active and 15 retirement years, requiring lower amounts of retirement saving (and hence lower effects of PAYG regimes) than those here where active and passive lives are of equal length.

[11] These gains are reaped when the implicit PAYG debt is wiped out. This means that the cost of the reform transition deficit is borne by transition cohorts, benefiting future steady-state cohorts accordingly.

TABLE 3.2
DYNAMIC GENERAL EQUILIBRIUM FOR DIFFERENT PENSION SYSTEMS
IN A ONE-SECTOR ECONOMY

| | FF | PAYG | | | |
|---|---|---|---|---|---|
| **PAYG w/o Intrag. Distr.** | | **d=10%** | **d=30%** | **d=50%** | **d=90%** |
| Consumption Young | 0.076 | 0.066 | 0.046 | 0.028 | 0.003 |
| Consumption Old | 0.125 | 0.127 | 0.126 | 0.120 | 0.071 |
| Consumption Old/Young | 1.636 | 1.920 | 2.760 | 4.302 | 26.185 |
| GDP | 0.185 | 0.168 | 0.136 | 0.107 | 0.046 |
| Capital | 0.0136 | 0.0101 | 0.0053 | 0.0025 | 0.0002 |
| Labor | 0.792 | 0.792 | 0.793 | 0.794 | 0.798 |
| Capital/Labor | 0.0172 | 0.0127 | 0.0067 | 0.0031 | 0.0002 |
| Interest Rate | 4.0% | 4.7% | 6.2% | 8.1% | 16.1% |
| Gross Wage | 0.156 | 0.141 | 0.115 | 0.092 | 0.041 |
| Net Wage | 0.156 | 0.135 | 0.093 | 0.057 | 0.006 |
| PAYG Revenue / GDP | — | 6.7% | 20.2% | 34.1% | 63.9% |
| PAYG-FF GDP Gain | — | 10.5% | 36.7% | 73.9% | 302.2% |
| PAYG-FF Welfare Gain | — | 6.8% | 27.9% | 66.4% | 510.8% |
| **PAYG with Intrag. Distrib.** | | **d=10%** | **d=30%** | **d=50%** | **d=90%** |
| Consumption Old/Young | 1.636 | 1.920 | 2.757 | 4.306 | 25.346 |
| GDP | 0.185 | 0.166 | 0.131 | 0.102 | 0.043 |
| Capital | 0.0136 | 0.0100 | 0.0051 | 0.0024 | 0.0001 |
| Labor | 0.792 | 0.783 | 0.768 | 0.758 | 0.745 |
| Capital/Labor | 0.0172 | 0.0128 | 0.0066 | 0.0032 | 0.0001 |
| Interest Rate | 4.0% | 4.7% | 6.2% | 8.1% | 16.1% |
| Gross Wage | 0.156 | 0.141 | 0.115 | 0.092 | 0.041 |
| Net Wage | 0.156 | 0.127 | 0.081 | 0.046 | 0.004 |
| PAYG LS Pension/Cons.Old | — | 14.5% | 35.7% | 50.0% | 68.6% |
| PAYG Revenue / GDP | — | 6.7% | 20.2% | 34.1% | 63.9% |
| PAYG-FF GDP Gain | — | 11.9% | 41.2% | 82.3% | 331.1% |
| PAYG-FF Welfare Gain | — | 6.9% | 28.1% | 67.0% | 515.8% |

TABLE 3.3
STATIC PRODUCTION EQUILIBRIA FOR DIFFERENT PENSION SYSTEMS
IN A TWO-SECTOR ECONOMY

| | FF | PAYG | | | |
|---|---|---|---|---|---|
| **Formal Sec. K-intensive** | | **d=10%** | **d=30%** | **d=50%** | **d=90%** |
| (K=0.0123, L=0.7923,K/L=0.0155) | | | | | |
| GDP | 0.172 | 0.172 | 0.170 | 0.168 | 0.167 |
| GDP Share Sector 1 | 62.3% | 47.5% | 23.3% | 5.6% | 0% |
| Capital/Labor Sector 1 | 0.021 | 0.024 | 0.030 | 0.035 | 0.044 |
| Capital/Labor Sector 2 | 0.008 | 0.010 | 0.012 | 0.015 | 0.016 |
| Interest Rate | 4.3% | 4.0% | 3.5% | 3.2% | 3.1% |
| Gross Wage | 0.140 | 0.149 | 0.165 | 0.177 | 0.199 |
| Net Wage | 0.140 | 0.144 | 0.150 | 0.155 | 0.157 |
| PAYG Revenue / GDP | — | 2.7% | 4.1% | 1.7% | 0% |
| PAYG-FF GDP Gain | — | 0.2% | 1.3% | 2.5% | 2.9% |
| **Formal Sec. L-intensive** | | **d=10%** | **d=30%** | **d=50%** | |
| (K=0.0118, L=0.7923,K/L=0.6149) | | | | | |
| GDP | 0.160 | 0.159 | 0.155 | 0.153 | |
| GDP Share Sector 1 | 64.7% | 50.7% | 11.6% | 0% | |
| Capital/Labor Sector 1 | 0.011 | 0.009 | 0.006 | 0.010 | |
| Capital/Labor Sector 2 | 0.026 | 0.023 | 0.016 | 0.015 | |
| Interest Rate | 3.9% | 4.2% | 4.9% | 5.1% | |
| Gross Wage | 0.135 | 0.131 | 0.123 | 0.134 | |
| Net Wage | 0.135 | 0.126 | 0.104 | 0.099 | |
| PAYG Revenue / GDP | — | 3.8% | 2.7% | 0% | |
| PAYG-FF GDP Gain | — | 0.2% | 3.0% | 4.5% | |

TABLE 3.4
DYNAMIC GENERAL EQUILIBRIUM FOR DIFFERENT PENSION SYSTEMS
IN A TWO-SECTOR ECONOMY (FORMAL SECTOR IS CAPITAL-INTENSIVE)

| | FF | PAYG | | | | |
|---|---|---|---|---|---|---|
| **PAYG w/o Intrag. Distr.** | | **d=5%** | **d=10%** | **d=30%** | **d=50%** | **d=90%** |
| Consumption Young | 0.069 | 0.069 | 0.070 | 0.074 | 0.076 | 0.079 |
| Consumption Old | 0.121 | 0.118 | 0.115 | 0.108 | 0.103 | 0.099 |
| Consumption Old/Young | 1.762 | 1.699 | 1.640 | 1.464 | 1.354 | 1.250 |
| GDP | 0.172 | 0.170 | 0.169 | 0.168 | 0.170 | 0.173 |
| GDP Share Sector 1 | 62.3% | 52.1% | 43.6% | 20.5% | 8.6% | 0% |
| Capital | 0.0123 | 0.0120 | 0.0118 | 0.0120 | 0.0127 | 0.0141 |
| Labor | 0.792 | 0.792 | 0.792 | 0.792 | 0.792 | 0.792 |
| Capital/Labor | 0.0155 | 0.0151 | 0.0149 | 0.0151 | 0.0160 | 0.0178 |
| Capital/Labor Sector 1 | 0.021 | 0.023 | 0.024 | 0.030 | 0.035 | — |
| Capital/Labor Sector 2 | 0.008 | 0.009 | 0.010 | 0.012 | 0.015 | 0.018 |
| Interest Rate | 4.3% | 4.1% | 4.0% | 3.5% | 3.2% | 2.9% |
| Gross Wage | 0.140 | 0.145 | 0.149 | 0.165 | 0.177 | 0.194 |
| Net Wage | 0.140 | 0.142 | 0.144 | 0.150 | 0.155 | 0.161 |
| PAYG Revenue / GDP | — | 1.5% | 2.5% | 3.6% | 2.5% | 0% |
| PAYG-FF GDP Gain | — | 0.87% | 1.49% | 2.20% | 1.39% | -0.70% |
| PAYG-FF Welfare Gain | — | 0.06% | 0.09% | -0.01% | -0.28% | -0.75% |
| | | | | | | |
| **PAYG with Intrag. Distrib.** | | **d=5%** | **d=10%** | **d=30%** | | |
| Consumption Old/Young | 1.762 | 1.602 | 1.439 | 1.250 | | |
| GDP | 0.1719 | 0.1717 | 0.1720 | 0.1731 | | |
| GDP Share Sector 1 | 62.3% | 44.3% | 25.2% | 0.0% | | |
| Capital | 0.0123 | 0.0124 | 0.0129 | 0.0141 | | |
| Labor | 0.792 | 0.790 | 0.790 | 0.792 | | |
| Capital/Labor | 0.0155 | 0.0157 | 0.0163 | 0.0178 | | |
| Interest Rate | 0.043 | 0.039 | 0.035 | 0.029 | | |
| Gross Wage | 0.140 | 0.152 | 0.168 | 0.230 | | |
| Net Wage | 0.140 | 0.145 | 0.151 | 0.161 | | |
| PAYG LS Pension/Cons.Old | — | 3.1% | 3.8% | 0.0% | | |
| PAYG Revenue / GDP | — | 1.3% | 1.5% | 0.0% | | |
| PAYG-FF GDP Gain | — | 0.08% | -0.04% | -0.71% | | |
| PAYG-FF Welfare Gain | — | -0.86% | -1.21% | -0.75% | | |

TABLE 3.5
DYNAMIC GENERAL EQUILIBRIUM FOR DIFFERENT PENSION SYSTEMS
IN A TWO-SECTOR ECONOMY (FORMAL SECTOR IS LABOR-INTENSIVE)

| | FF | PAYG | | | | |
|---|---|---|---|---|---|---|
| **PAYG w/o Intrag. Distr.** | | **d=10%** | **d=30%** | **d=50%** | **d=65%** | **d=90%** |
| Consumption Young | 0.066 | 0.062 | 0.051 | 0.035 | 0.023 | 0.032 |
| Consumption Old | 0.106 | 0.106 | 0.105 | 0.109 | 0.110 | 0.098 |
| Consumption Old/Young | 1.610 | 1.710 | 2.083 | 3.162 | 4.821 | 3.059 |
| GDP | 0.160 | 0.150 | 0.127 | 0.107 | 0.093 | 0.103 |
| GDP Share Sector 1 | 64.7% | 72.7% | 99.0% | 100% | 100% | 0% |
| Capital | 0.0118 | 0.0097 | 0.0050 | 0.0023 | 0.0011 | 0.0054 |
| Labor | 0.792 | 0.793 | 0.793 | 0.794 | 0.794 | 0.794 |
| Capital/Labor | 0.015 | 0.012 | 0.006 | 0.003 | 0.001 | 0.007 |
| Capital/Labor Sector 1 | 0.011 | 0.009 | 0.006 | 0.003 | 0.001 | — |
| Capital/Labor Sector 2 | 0.026 | 0.023 | 0.016 | — | — | 0.007 |
| Interest Rate | 3.9% | 4.2% | 5.0% | 6.8% | 8.6% | 6.9% |
| Gross Wage | 0.135 | 0.131 | 0.122 | 0.107 | 0.096 | 0.161 |
| Net Wage | 0.135 | 0.126 | 0.103 | 0.071 | 0.047 | 0.062 |
| PAYG Revenue / GDP | — | 5.4% | 22.7% | 39.7% | 53.4% | 0% |
| PAYG-FF GDP Gain | — | 6.7% | 25.9% | 49.9% | 72.3% | 55.2% |
| PAYG-FF Welfare Gain | — | 3.6% | 14.4% | 36.4% | 66.6% | 50.9% |
| **PAYG with Intrag. Distrib.** | | **d=10%** | **d=30%** | **d=50%** | | |
| Consumption Old/Young | 1.610 | 1.890 | 2.622 | 3.242 | | |
| GDP | 0.160 | 0.146 | 0.121 | 0.103 | | |
| GDP Share Sector 1 | 64.7% | 56.8% | 35.9% | 0% | | |
| Capital | 0.0118 | 0.0093 | 0.0062 | 0.0054 | | |
| Labor | 0.792 | 0.787 | 0.783 | 0.794 | | |
| Capital/Labor | 0.015 | 0.012 | 0.008 | 0.007 | | |
| Interest Rate | 3.9% | 4.6% | 6.0% | 6.9% | | |
| Gross Wage | 0.135 | 0.126 | 0.113 | 0.123 | | |
| Net Wage | 0.135 | 0.114 | 0.079 | 0.062 | | |
| PAYG LS Pension / Cons. Old | — | 9.5% | 15.7% | 0% | | |
| PAYG Revenue / GDP | — | 4.3% | 8.4% | 0% | | |
| PAYG-FF GDP Gain | — | 9.3% | 32.5% | 55.2% | | |
| PAYG-FF Welfare Gain | — | 5.9% | 25.6% | 50.9% | | |

TABLE 3.6
CHANGE IN TECHNOLOGY I: HIGHER FORMAL SECTOR PRODUCTIVITY ($\varepsilon 1=1.1$)
(FORMAL SECTOR IS CAPITAL INTENSIVE;
PAYG WITHOUT INTRAGENERATIONAL DISTRIBUTION)

| | FF | PAYG | | |
|---|---|---|---|---|
| **PAYG w/o Intrag. Distr.** | | **d=10%** | **d=50%** | **d=90%** |
| Consumption Old/Young | 2.351 | 2.306 | 1.627 | 1.396 |
| GDP | 0.179 | 0.174 | 0.166 | 0.168 |
| GDP Share Sector 1 | 95.8% | 74.1% | 25.7% | 8.2% |
| Capital | 0.0112 | 0.0105 | 0.0104 | 0.0119 |
| Labor | 0.793 | 0.792 | 0.792 | 0.792 |
| Capital/Labor | 0.0141 | 0.0133 | 0.0131 | 0.0150 |
| Interest Rate | 5.5% | 5.1% | 4.0% | 3.3% |
| Net Wage | 0.127 | 0.131 | 0.144 | 0.153 |
| PAYG Revenue / GDP | — | 4.2% | 7.4% | 4.3% |
| PAYG-FF GDP Gain | — | 3.1% | 8.0% | 6.7% |
| PAYG-FF Welfare Gain | — | 0.6% | 1.4% | 1.2% |

Now consider the lower-panel simulation results in Table 3.2 when intragenerational distribution of PAYG is 100%. Here workers do not see any link between their PAYG contributions and future pension benefits. Hence the full difference between gross and net wages is a pure tax on labor. When d=0.1 and intragenerational distribution of PAYG is zero (v=1.0201), the pure tax on labor of PAYG amounts to 4.3% (upper panel results). The latter figure rises to 10% when intragenerational distribution of PAYG is 100% (v=0; lower panel results). In the latter case workers are paid a lump-sum pension benefit that grows from 14.5% of future consumption when d=0.1 to 68.6% of future consumption when d=0.9. Hence the absence of any link between PAYG contributions and expected benefits worsens the macro and welfare effects of a PAYG system -- but this deterioration is only of second-order magnitude. For instance, when d=0.1, the GDP gain of a PAYG-FF reform reaches now 11.9%, a figure that is only slightly larger than the 10.5% gain reported in the upper-panel case. The reason for this low marginal effect of full intra-generational distribution of a PAYG is that the pension benefits anticipated under a non-redistributive PAYG system are small anyhow: the wedge between pension benefit growth and the discount rate grows exponentially during the 25-year horizon that separates active life from retirement.

The main conclusion of both sets of results in Table 3.2 is consistent with the standard literature for a one-sector economy under dynamic general-equilibrium optimization: the steady-state effects of PAYG are unambiguous and negative, and grow monotonically with both the rate of PAYG contribution and the level of intragenerational PAYG distribution.

### 3.2 Static production equilibria in a two-sector economy

Now let's abstract from the intertemporal dimensions of pension regimes and focus only on the intratemporal intersector resource allocation aspects of a sector-specific tax on labor (equivalent to the PAYG pension contribution) in a two-sector economy. Total factor endowments are determined exogenously, at those values that are obtained endogenously for the dynamic general equilibrium simulation under a FF regime in a two-sector economy (in section 3.3 below), to ensure comparability between the latter results and those presented here. Sector 1 (the formal sector) complies with mandatory pension legislation while sector 2 (the informal sector) is not required to comply with or evades compliance of pension legislation. The relative price of goods produced by the formal and informal sectors is equal to 1 -- consumers do not distinguish between goods of different sector origin.

The simulation results in Table 3.3 compare the production equilibrium in a FF regime (corresponding to the first-best production equilibrium attained in a non-distorted economy) in column 1 to various production equilibria in an economy with a sector-specific labor tax (corresponding to the PAYG contribution in the formal sector) that differ by the tax rate (from d=0.1 in column 2 to d=0.9 in column 5). We consider only the case of a PAYG system with zero intragenerational redistribution (v=1.0201). The upper-panel (lower-panel) results reflect the case when sector 1 is relatively more capital (labor) intensive.

In both cases the PAYG tax paid by labor employed in the formal sector leads to lower formal-sector and higher informal-sector output, made possible by a sector reallocation of both factors of production. Aggregate output declines under PAYG until the formal sector -- increasingly burdened by the tax on labor -- is closed down and the economy specializes fully in informal-sector production. As labor can evade the PAYG tax by moving from the formal to the informal sector, PAYG tax revenue as a share of GDP exhibits a Laffer-curve behavior, reaching a maximum of 4.1% at d=0.3 (3.8% at d=0.1) when sector-1 is capital (labor) intensive.

Having underscored the common features shown by both cases, now let's focus on the very important differences in factor price responses under different sector combinations of factor intensities. As factor intensities differ among sectors, the relative price of the factor in which the formal sector is more intensive drops, leading to a higher production intensity in the latter factor in both sectors. In the case of a capital-intensive formal sector (upper panel), this sector releases relatively more capital and less labor than what the informal sector is willing to absorb at current factor prices, which leads to a lower interest rate and higher gross and net wages. This reflects operation of the Stolper-Samuelson theorem: factor prices are determined only by relative goods prices (that are held constant at 1.0) and taxes on factors and goods.

The interest rate declines from 4.3% under FF to 3.1% under d=0.9, when the economy fully specializes production in the informal sector. Net wages increase from 0.140 under FF to 0.157 under d=0.9. Gross wages increase correspondingly but cease to be paid when formal-sector production stops. In both sectors of production capital-labor intensities increase in response to the declining ratio of the interest rate to wages. The capital/labor ratio of the informal sector more than doubles when increasing from its low initial level under FF to reach the economy's capital/labor ratio when all production is concentrated in the informal sector. The PAYG labor tax imposes a Pareto welfare loss on every cohort due to the misallocation of production factors. A PAYG-FF reform reverses that loss, allowing to reap a reform gain in terms of GDP increase that ranges from 0.2% under d=0.1 to 2.9% under d=0.9.

When the formal sector is relatively more labor-intensive than the informal sector the opposite response of relative factor prices is observed (lower panel results). Factor shedding by the formal sector in response to the PAYG labor tax leads now to a higher interest rate and a lower wage, causing a decline in capital/labor ratios in both sectors. Full production specialization in the informal sector is reached much earlier now (at d=0.5) because the formal sector is hurt more strongly when the tax falls on the factor in which its production is relatively more intensive. At that point the Pareto welfare loss caused by PAYG -- as measured by the decline in GDP that could be reverted by adopting a FF pension system -- is 4.5%.

These results are a simple illustration of the general-equilibrium properties of international trade models under static optimization in the Heckscher-Ohlin-Samuelson tradition (Samuelson 1948, Jones 1965). At given relative goods prices and factor endowments, the static effect of a sector-specific labor (PAYG) tax on relative factor prices depends on the relative factor intensities of production in each sector. This ambiguous result stands in contrast to the unambiguous results of a PAYG regime on steady-state factor prices in a dynamic one-sector economy that was discussed in section 3.1 above.

### 3.3 Dynamic general equilibria in a two-sector economy

Now we combine the dynamic general equilibrium set-up of section 3.1 with the two-sector static production equilibrium of section 3.2. The results reported in Tables 3.4 and 3.5 are for the cases when the formal sector is relatively more capital intensive and more labor intensive, respectively, analogous to the differences in factor intensities reported in the upper and lower panels of Table 3.3. The results in the upper and lower panels of Tables 3.4 and 3.5 correspond to a PAYG system with zero intragenerational redistribution (v=1.0201) and 100% intragenerational PAYG distribution (v=0), respectively, comparable to the corresponding cases in the upper and lower panels of Table 3.2.

We start by pointing out the main result. Imposing a PAYG tax on labor in the formal sector implies two channels of intergenerational distribution that can be of opposite sign. The

first effect is the unambiguous positive transfer from future cohorts to the first cohorts retired under the PAYG system, that implies an unambiguous decline in steady-state saving, capital, income, and welfare.

But PAYG taxation also encourages an intersectoral resource shift to avoid labor taxation in the formal sector. This resource reallocation causes a second intergenerational distribution effect whose sign depends on relative factor intensities of production in each sector and the associated change in factor prices. When the formal sector is labor intensive, resource reallocation toward the informal sector implies a higher interest rate and a lower wage, hence redistributing income from workers to pensioners. This reinforces the first channel of intergenerational distribution.

However, when the formal sector is capital intensive, resource reallocation implies a lower interest rate and a higher wage, shifting income away from initial cohorts and toward future cohorts. At increasing levels of PAYG tax rates and continuing resource reallocation towards the informal sector, the PAYG tax base -- based on formal-sector production -- shrinks and hence the PAYG system taxes itself gradually out of existence. Hence the first (conventional) channel of intergenerational distribution first increases to a maximum, subsequently declines and eventually ceases completely. Once production in the formal sector stops fully, only the second channel of intergenerational distribution -- that benefits future cohorts -- is effective.

However, even at full specialization of production in the informal sector the effect of the now defunct PAYG system but still binding PAYG tax on labor in the disappeared formal sector has an ambiguous effect on steady-state saving, capital, labor, output, and welfare levels. The reason is that the gains reaped by future steady-state cohorts from the second channel of intergenerational distribution may be offset by the efficiency losses that arise from complete specialization of production in the informal sector. Therefore, when the formal sector is capital intensive, the steady-state effects of a PAYG pension system are ambiguous, depending on the level of the PAYG tax rate and on technology and preference parameter values, as shown by the simulation results reported below.

There are two important points to note when comparing the results for the dynamic general equilibrium in a two-sector economy (reported in the upper panels of Tables 3.4 and 3.5) to the results for the static production equilibrium (reported in the upper and lower panels of Table 3.3). First, at any given PAYG tax rate, factor prices and factor intensities of production under dynamic general equilibrium are equal to those observed under static production equilibrium. As in the static production equilibrium, this result reflects operation of the Stolper-Samuelson theorem: factor prices are determined only by relative goods prices (that are held constant at 1.0) and taxes on factors and goods. Second, although factor endowments are endogenous to the PAYG labor tax in the dynamic two-sector equilibrium (as opposed to the static production equilibrium when capital and labor are fixed), changing factor endowments do not affect factor prices. This result reflects operation of the Rybczynski theorem: factor endowments determine how much is produced in each sector but they affect neither factor prices nor factor intensities of production.

Now let's turn to the results in the upper panel of Table 3.4 when the formal sector is capital intensive and intragenerational distribution is zero. As opposed to the one-sector dynamic general equilibrium, when the wage declines strongly and labor increases slightly in response to an increasing PAYG tax (upper panel, Table 3.2), in the two-sector dynamic general equilibrium (upper panel, Table 4) the wage increases and labor employment does not change.

Saving and the aggregate capital stock follow a non-monotonic behavior in response to rising PAYG taxation. When d increases from zero to 0.1, equilibrium capital declines from 0.0123 to 0.0118. However, further increases in d raise equilibrium capital again, until a maximum level of 0.0141 attained at d=0.9 when the economy specializes fully in the production of the informal sector. At that point the capital stock (and saving) is **15% higher** under the still binding (but non-existent) PAYG regime than under the FF pension system. As opposed to the one-sector economy, high PAYG tax rates imposed on a capital-intensive formal sector could raise aggregate saving and capital levels.

Overall output follows a similar non-monotonic behavior in response to rising PAYG contribution rates. GDP declines until d=0.3 and subsequently increases to grow again. At full production specialization in the informal sector (attained at d=0.9), switching back to a FF pension system **reduces** GDP by 0.7%. Welfare levels of future steady-state cohorts follows a similar non-monotonic pattern. A pension reform that substitutes FF for an initial PAYG pension system implies a 0.09% welfare gain at d=0.1 and a **0.75% loss** at d=0.9.

The non-monotonic behavior exhibited by capital, output and welfare is the result of the two opposing intergenerational distribution channels and the production efficiency loss set in motion by the PAYG system in an economy where the formal sector is capital intensive. At low to moderate levels of PAYG tax rates (in the 0 - 0.3 range), the redistribution from future steady-state cohorts to initial pensioner cohorts effected by the PAYG regime dominates the combination of redistribution in favor of future cohorts (due to changing factor prices as a result of resource reallocation) and the production loss from inefficient factor reallocation. However, at higher PAYG tax rates the first redistribution channel diminishes while both the second distribution channel and the production efficiency loss keep growing until full specialization in informal-sector production is achieved.

A few additional results are worth pointing out. First, the welfare and output changes caused by PAYG in a two-sector economy are only a small fraction of the losses observed in the one-sector economy. This reflects both production substitution toward the informal sector and the presence of the second channel of intergenerational redistribution that benefits future cohorts when the formal sector is capital intensive. Second, as opposed to the dynamic equilibrium in the one-sector economy, the ratio of old-age to young-age consumption declines with PAYG, in response to the falling interest rate. Third, the size of the PAYG system (reflected by the share of PAYG revenue in GDP) follows a Laffer-type pattern. As in the static two-sector production equilibrium it peaks at d=0.3 and declines subsequently. Finally, factor prices and factor intensities in each production sector are identical to those observed in the static production equilibrium as long as production is not specialized (a result of the Stolper-Samuelson theorem noted above). However, once production is specialized in the informal sector at d=0.9, the relative price of goods ceases to exist, implying that factor prices and factor intensities differ between the static production equilibrium and the dynamic general equilibrium.

The lower-panel results in Table 3.4 illustrate the case of 100% intragenerational distribution (v=0). They are qualitatively similar to those in the upper panel; the now larger pure tax component of PAYG intensifies the effects of PAYG shown above. The share of formal-sector production falls from 62.3% in the FF regime to 25.2% at d=0.1 when v=0, a much lower share than the 43.6% reached at d=0.1 when v=1.0201. Complete production specialization is already attained at d=0.3. At that point, all variables (except the gross wage) attain the values reached in the upper-panel case of complete specialization at d=0.9. As above, both output and welfare show a non-monotonic behavior. However, as opposed to the

upper-panel case, aggregate capital increases monotonically while aggregate labor shows a non-monotonic response to the PAYG tax.[12]

Both the upper and lower-panel results of Table 3.4 report net steady-state output and welfare losses when a FF pension regime substitutes an existing PAYG system. However, more generally, when the formal sector is capital-intensive, the sign of the net steady-state effects is ambiguous due to the opposite signs of the intergenerational transfer and Pareto efficiency effects at work. This point will be illustrated below when reporting the results of a pension reform when formal-sector production is more efficient.

Next I show in table 3.5 the results for the case when the formal sector is labor intensive (analogous to the results in the lower panel of Table 3.3 for the static production equilibrium). As opposed to the case when the formal sector is capital intensive (Table 3.4), the PAYG tax raises the interest rate and reduces the wage. But higher interest rates and lower wages as a result of higher PAYG tax rates are precisely the dynamic general equilibrium results in a one-sector economy. Hence output and welfare also decline monotonically with PAYG taxation in a two-sector economy when the formal sector is labor intensive -- as opposed to the case when the formal sector is capital intensive.

A second result that distinguishes this case from the one reported in Table 3.4 is that the formal sector may initially shrink or expand -- although eventually PAYG taxation will lead to its demise. This possible non-monotonic behavior of resource reallocation is matched by possible non-monotonicities in aggregate capital and labor levels. Both possibilities are illustrated by the upper and lower panel results in table 3.5.

Factor prices reflect unchanged goods prices and rising PAYG tax rates (as predicted by Stolper-Samuelson) unless production specialization is complete, as shown by comparing results in Tables 3.5 and 3.3. However, when intragenerational distribution is zero, and given the parameterization of the model reflected by the upper-panel results in Table 3.5, formal-sector production **expands** initially. In the range of low to moderately high PAYG taxes (from d=0.1 to 0.5), the production disincentive of PAYG taxation suffered by the formal sector is more than offset by the production incentive stemming from declining aggregate capital/labor ratios (as predicted by the Rybczynski theorem). Hence the GDP share of the formal sector increases from 64.7% under the FF system to 100% at d=0.5. When d is increased further from 0.5 to 0.65, full production specialization in the formal sector continues. Within that range, the conventional PAYG transfer from future cohorts to first pensioners is at work as the economy operates effectively as a one-sector economy.

At d=0.65, the GDP share of PAYG revenue -- that reflects the size of the conventional intergenerational transfer to the first PAYG pensioners -- reaches a massive 53.4% of GDP. When d is increased beyond 0.65, however, formal-sector production gets increasingly non-competitive in comparison to the informal sector that -- although still not producing at d=0.65 -- is ready to take over production from the formal sector. This occurs at d=0.85, when the economy switches from one production corner solution to the other and production specialization in the informal sector wipes out the PAYG pension system. Reflecting this change in the pattern of specialization, all variables (except labor) shift in the opposite direction they had taken in the range of d=0 to 0.65.

It is worth pointing out that the PAYG transfer to the first pensioners attains a maximum value at d=0.65, the maximum PAYG rate at which production is still specialized in

[12] This illustrates that monotonicity and non-monotonicity in the response of endogenous variables to PAYG taxation simply reflect the model's parameter combinations.

the formal sector. However, at d=0.85 (full specialization in informal-sector production), the conventional PAYG transfer is zero but income transfers from future cohorts to the first cohorts or pensioners arising from a higher interest rate and a lower wage -- due entirely to intersector factor reallocation -- attain a maximum.

GDP and welfare shrink monotonically with PAYG contribution rates as long as there is formal-sector production. At any positive PAYG contribution rate the potential gains of a PAYG-FF reform are very large in comparison to those reaped when the formal sector is capital-intensive (Table 3.4). This is not surprising because both the two channels of intragenerational distribution and the Pareto efficiency losses in production hurt future cohorts when the formal sector is labor-intensive.

Next we consider the lower-panel results in Table 3.5 that illustrate the case of 100% intragenerational distribution (v=0). The results are similar to those in the upper panel; the now larger pure-tax component of PAYG contributions magnifies the effects of PAYG shown above. One difference is that all variables (less labor) exhibit now a monotonic behavior as the formal sector starts shrinking from the beginning until full informal-sector specialization is attained at d=0.5. The Laffer-curve maximum for the PAYG tax is reached at d=0.3, at a ratio of PAYG revenue to GDP of 8.4%.

Finally I report in Table 3.6 a variation of the dynamic general equilibrium results for a two-sector economy where the formal-sector is capital intensive (the case shown in the upper panel of Table 3.4). The difference with the latter case is that now formal-sector production is 10% more productive than informal production ($\varepsilon 1 = 1.1$; $\varepsilon 2 = 1.0$). This productivity difference raises the Pareto gain derived from shifting resources from informal to formal production, increasing the likelihood of positive output and welfare gains is increased. This outcome is reflected by the simulation results which show positive gains for the entire range of contribution rates, even though the aggregate capital stock is still higher than under a FF system at d=0.9. We conclude that the sign of the net output and welfare gains of pension reform when the formal sector is relatively more capital-intensive is very sensitive to the structure of the underlying economy.

### 3.4 Summing Up

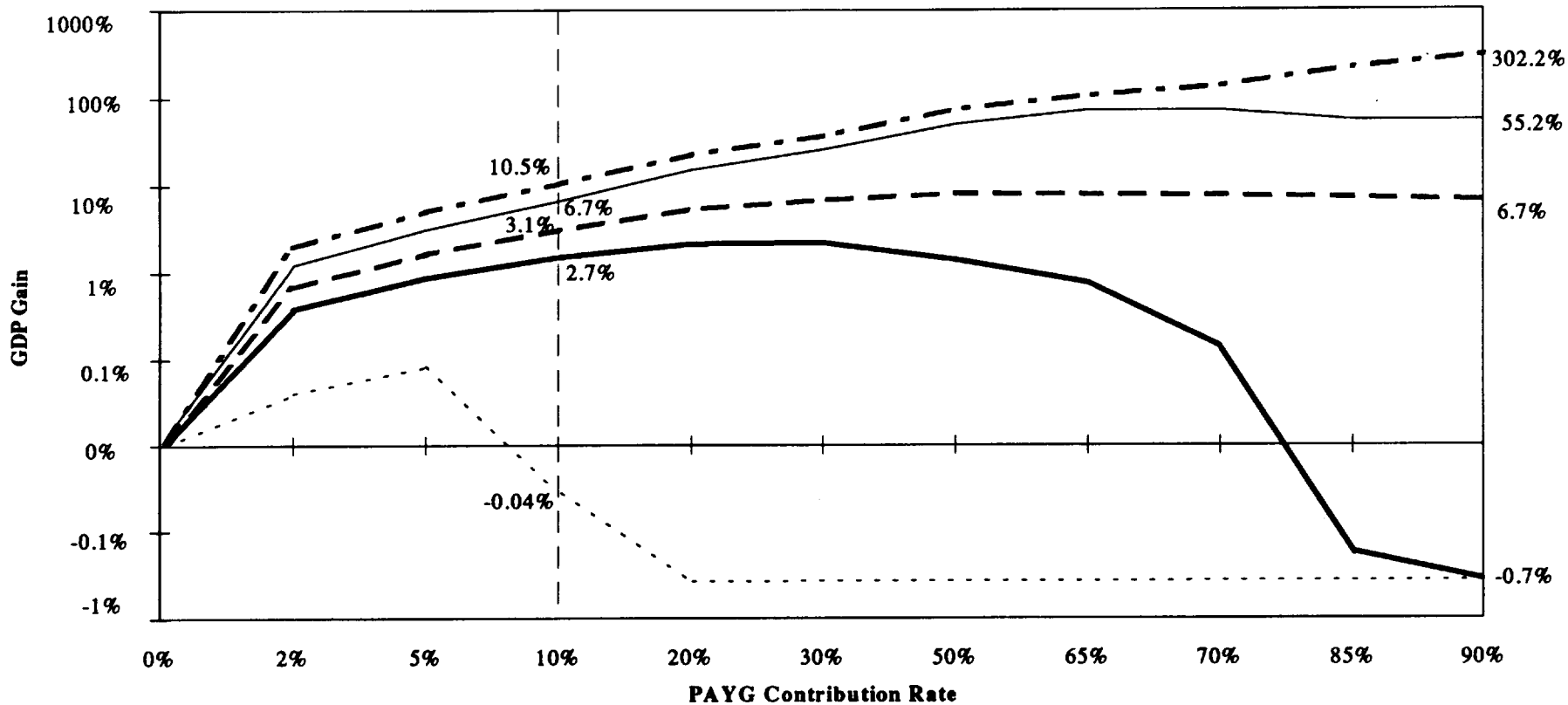
Figure 1 depicts the steady-state GDP gains of a PAYG-FF reform at different PAYG contribution rates, under dynamic general equilibrium for five different economies, consistent with the results reported in Tables 3.2-3.6. At the high end of the distribution of stationary output gains ranks the one-sector economy, with very large output gains of 10.5% at d=0.1 and 302.2% at d=0.9. These results seem to be highly misleading for a two-sector economy with an informal sector that can evade or is exempted from mandatory PAYG contributions. When the two-sector economy features a more labor-intensive formal sector, the GDP gains are still unambiguously positive and quantitatively large, ranging from 6.7% at d=0.1 to 55.2% at d=0.9.

However, when the formal sector is relatively more capital-intensive, the reform-induced GDP gains have ambiguous sign and are quantitatively rather modest. When intragenerational distribution is absent and there is no productivity differential between both sectors, the GDP gain is +2.7% at d=0.1 and turns into -0.7% at d=0.9. Under full intragenerational distribution and no sector productivity differential, pension reform implies small GDP losses at contribution rates equal or higher than 10%. Finally, under zero intragenerational distribution but at a modest 10% sector productivity difference, only positive GDP gains are reaped from pension reform, ranging from 3.1% at d=0.1 to 6.7% at d=0.9.

Figure 1

Steady State GDP Gains of PAYG - FF Reforms under Dynamic General Equilibrium for Various Economies

(Zero Intragenerational Distribution unless noted otherwise)




— · — One-Sector Economy, Capital-intensive Formal Sector (Table 3.2, upper panel)

——— Two-Sector Economy Capital-intensive Formal Sector (Table 3.4, upper panel)

· · · · · Two-Sector Economy, Capital-intensive Formal Sector, PAYG wtih 100% Intragenerational Distribution (Table 3.4, lower panel)

——— Two-Sector Economy, Labor-intensive Formal Sector (Table 3.5, upper panel)

— — — Two-Sector Economy, Capital-intensive and more productive Formal Sector (Table 3.6)

**Table 3.7**

**STEADY-STATE EFFECTS OF A PAYG-FF REFORM ON INCOME AND WELFARE IN A TWO-SECTOR ECONOMY**

| | Formal Sector is Capital Intensive | | Formal Sector is Labor Intensive | |
|---|---|---|---|---|
| | PAYG Contribution Rate: | | PAYG Contribution Rate: | |
| | At highest PAYG revenue | At specialization of production in informal sector | At highest PAYG revenue | At specialization of production in informal sector |
| Steady-State Intergenerational Transfer and Pareto gains of a PAYG-FF reform in a Two-Sector Economy | | | | |
| 1. Transfer from transition cohorts to future cohorts from paying off implicit PAYG debt | Positive and highest | Zero | Positive and highest | Zero |
| 2. Transfer from first reform cohorts to future cohorts through changes in factor prices due to factor reallocation toward formal sector | Negative | Negative and highest | Positive | Positive and highest |
| 3. Pareto efficiency gain due to factor reallocation toward formal sector | Positive | Positive and highest | Positive | Positive and highest |
| Net Income and Welfare Gains from a PAYG-FF Reform financed by Transition Cohorts | Uncertain | Uncertain | Positive | Positive |

This result is important as it suggests that even a small difference in productive efficiency in favor of the formal sector can raise significantly the likelihood of a positive GDP (and welfare) gain resulting from a PAYG-FF pension reform.

In Table 3.7 I summarize the three steady-state effects of pension reform on income and welfare in a two-sector economy and their combined net effect, that were illustrated numerically by the simulation results discussed above. Both the reversal of the conventional intergenerational transfer suffered by steady-state cohorts due to PAYG (if the implicit PAYG debt is eliminated during the reform transition) and the reversal of the allocative efficiency loss in a two-sector economy are made possible by a PAYG-FF reform. However, the sign of the reversal of the intergenerational transfer due to the effect of intersector factor reallocation on factor prices is ambiguous because it depends on sector differences in factor intensities. When the formal sector is more capital-intensive, the lower wage and the higher interest rate caused by PAYG-FF reform benefits the first reform cohorts at the expense of future cohorts. Therefore the net combined effect of a PAYG-FF pension reform on steady-state output and welfare levels is ambiguous when the formal sector is capital-intensive. This ambiguity vanishes in the case of a labor-intensive formal sector, implying positive gains for future generations.

## 4. Some Suggestive Empirical Evidence

The simulations reported in the preceding section showed that the effects of pension systems on steady-state capital, employment, output, and welfare hinge on the features of the PAYG system, the size and structure of formal and informal production sectors, and the interaction between production structure and pension reform. The simulations compared the steady-state levels attained by relevant macroeconomic and welfare variables under various PAYG systems to the ones observed under a FF regime. They also reported the GDP and welfare gains reaped by a PAYG-FF pension reform -- defined as replacing PAYG by FF -- that is financed by a mix of tax hikes and public expenditure cuts borne by transition cohorts, wiping out the implicit PAYG debt of the public sector.

We concluded in the preceding section that the net effect of a pension reform on steady-state variables in a closed two-sector economy is ambiguous, depending on relative factor intensities in both sectors of production. In addition to the latter condition, the sign and size of the net effect depends on pension system features of the initial PAYG and the new FF regime system such as the degree of intra-generational distribution. Other structural features of real-world economies -- not addressed by the stylized model used above -- are also certainly important in determining the long-term consequences of pension reforms.

In order to assess how likely a PAYG-FF pension reform is to raise or lower an economy's stationary levels of saving, income, and welfare, next I revise selectively some empirical evidence on the features of pension regimes, formal-informal market structures, and other relevant aspects of real-world economies. This evidence is largely drawn from Latin America, where most major pension reforms have been carried out to date.

### How large are formal and informal sectors?

The relative sizes of formal and informal sectors and their responsiveness to changes in taxes and regulations (such as contributions to a mandatory PAYG system) are essential in drawing inferences about potential inter-sector resource reallocation and factor-price effects caused by a pension reform. How is informality measured? That depends on how it is defined.

Three alternative measures are provided next, referred to pension system coverage, employment structure, and output shares.

When measured by the share of public-pension system contributors in the labor force, formal-sector size grows with income, demographic maturity, and pension system maturity (World Bank 1994). By major world regions, the share of public-pension system contributors varies between 6.4% in Sub-Saharan Africa to 93.9% in OECD countries (Table 4.1).

An alternative measure of the relative size of the informal sector, based on the structure of non-farm employment, is estimated by ILO or most Latin American countries since 1980. This measure -- likely to be highly correlated with the share of workers that do not contribute to mandatory (public and private) pension systems -- is based on the status of workers and the size of firms where they work (Table 4.2). The data reflects two features about total informality, which can be understood as the sum of open informal-sector employment (reported in the third column of Table 4.2) plus a fraction of small-firm employment (in the second column). First, informal-sector employment is large in Latin America, on average comprising one quarter to one half of the region's labor force (a figure similar to the 38.3% of public pension coverage reported for Latin America in Table 4.1). Second, and still more important, the informal-sector share of employment is growing steadily in all Latin American countries except Chile since 1980.[13] This may be no coincidence: Chile is the only country with a growing FF pension system since 1981 -- the other Latin American that have reformed partially their PAYG pension schemes (Argentina, Peru, Colombia, and Mexico) have done so only in recent years. Hence pension reform may contribute significantly to employment formalization -- as reflected in expanding pension system coverage -- in countries where initial informality is large.

The implication that adopting a FF pension system may have a significant effect on formal-informal sector shares of employment is confirmed by data on the share of total pension system contributors in Chile's labor force (Table 4.3). A large increase in pension system coverage has taken place in Chile, growing from 45.5% in 1980 to 60.1% in 1991-95. Most pension system contributors -- 54.0% of the labor force -- were contributing to the fully-funded privately-managed pension funds during 1991-95.

A third measure of informality is reflected by output shares. ILO estimates of informal sector shares are about 10% and 7% of GDP in Costa Rica and Panama during the 1980s, respectively (Castiglia, Martinez, and Mezzera 1995). At the opposite end of the distribution of informal-sector shares is Loayza (1996), who reports large estimates for the two latter countries and for 12 other Latin American countries (Table 4.4). The figures range from 19% of official GDP in Chile to 66% in Bolivia, with a mean share of the informal-sector estimated at 39%. However, even in industrial countries the size of the informal economy can be surprisingly large; in Italy the irregular sector is estimated to produce 16% of value added in 1990 (Rey 1993, as quoted by Corsetti 1994).

We conclude that informal sectors are relatively large in most countries in the world but may shrink after introducing FF systems, in response to lower net labor taxes in the formal sector that encourage resource reallocation toward the formal sector.

[13] This information is not obvious from the average regional data reported here but is reflected by the 12 country data reported in the original sources.

**Table 4.1**
**Ratio of Public Pension Scheme Contributors to the Labor Force in Major World Regions, Late 1980s to Early 1990s (Unweighted Averages, %)**

| | | | |
|---|---|---|---|
| OECD Countries: | 93.9 | | |
| Latin America and Caribbean: | 38.3 | Asia: | 23.5 |
| Middle East and North Africa: | 41.3 | Sub-Saharan Africa: | 6.4 |

Source: World Bank (1994), Table A.4.

**Table 4.2**
**Formal-Informal Non-Farm Employment Structure in Latin America and Chile, 1980-1994 (%)**

| | Formal Sector | Small Firms | Informal Sector |
|---|---|---|---|
| Latin America | | | |
| 1980 | 59.8 | 14.6 | 25.6 |
| 1985 | 53.1 | 16.6 | 30.4 |
| 1990-1992 | 47.2 | 20.8 | 32.0 |
| 1993-1994 | 44.9 | 22.2 | 33.0 |
| Chile | | | |
| 1980 | 49.6 | 14.3 | 36.1 |
| 1985 | 46.7 | 19.1 | 34.2 |
| 1990-1992 | 50.2 | 19.0 | 30.8 |
| 1993-1994 | 49.6 | 20.6 | 29.8 |

Note: formal-sector workers are dependent workers employed by public-sector and large private-sector firms; the informal sector is comprised by independent workers and household employees.

Source: ILO (1996), Table 1-B, and Uthoff (1994), Table 1 (based on ILO estimates).

**Table 4.3**
**Labor Force and Pension System Participation Rates in Chile, 1970-1995 (%)**

| | Total Labor Force Participation | Male Labor Force Participation | Total Pension Contributors / Labor Force | Private Pension Contributors / Labor Force |
|---|---|---|---|---|
| 1970 | 45.6 | n.d. | n.d. | 0 |
| 1976-80 | n.d. | 70.2 | n.d. | 0 |
| 1980 | n.d. | 70.3 | 45.5 | 0 |
| 1981-85 | 47.2 | 69.9 | 46.6 | 33.8 |
| 1986-90 | 51.8 | 74.5 | 57.2 | 48.0 |
| 1991-95 | 53.7 | 75.9 | 60.1 | 54.0 |

Source: Superintendency of Private pension Funds and Central bank of Chile.

**Table 4.4**
**Estimated Share of Informal Sector in GDP in Latin American Countries, 1990 (%)**

| | | | | | |
|---|---|---|---|---|---|
| Chile | 18.2 | Ecuador | 31.2 | Guatemala | 50.4 |
| Argentina | 21.8 | Colombia | 35.1 | Peru | 57.9 |
| Costa Rica | 23.3 | Uruguay | 35.2 | Panama | 62.1 |
| Mexico | 27.1 | Brazil | 37.8 | Bolivia | 65.6 |
| Venezuela | 30.8 | Honduras | 46.7 | | |

Note: estimates reported by Loayza (1996), Table 1, based on a latent-variable model.

**Table 4.5**
**Capital/Labor Ratios and Employment Shares in Informal and Formal Sectors: Lima (Peru), 1984**

| | Informal Sector | Formal Sector |
|---|---|---|
| Capital/Labor Ratio (US$/worker) | 1,000 | 30,000 |
| Sector Share of Employment (%) | 30.2 | 69.8 |

Source: Castiglia, Martinez, and Mezzera (1995).

Is the formal sector more capital-intensive than the informal sector?

Addressing this question is also essential in drawing inferences about the likely effects of a pension reform. Casual evidence suggests strongly that formal-sector production is more capital-intensive than informal-sector production. At one extreme of the distribution of firms according to factor intensities are the large and highly capital-intensive formal-sector enterprises in manufacturing, mining or utilities; at the other extreme are the urban street vendors and the rural small landholders that work with little or no capital and often represent the core of the informal economy. This casual observation is confirmed by firm-level data on capital-labor ratios for Peru and Uruguay (Castiglia, Martinez, and Mezzera 1995). In the case of Peru, an average formal-sector worker works with US$ 30,000 of capital, a figure that shrinks to $1,000 in the informal economy (Table 4.5).

The implication of this evidence is that factor reallocation from the labor-intensive formal sector to the capital-intensive formal sector in response to a PAYG-FF pension reform tends to reduce wages and increase interest rates, therefore benefiting retired cohorts and hurting all future generations. This opens up the prospect that PAYG-FF pension reforms reduce saving, income, and welfare levels of future generations.

How large is the efficiency gain derived from shifting production from the informal to the formal sector?

A PAYG-FF pension reform reverts the Pareto loss due to the distorted production structure caused by the net PAYG tax on factor use. In the absence of detailed firm-level data it is not possible to make a quantitative assessment of this efficiency gain. However, the simulation results reported above suggest that small differences in productive efficiency between formal and informal sectors can lead to significant changes in the estimates of output and welfare gain caused by pension reform. Casual evidence suggests that this efficiency gain accruing to all generations may be very large as managerial and technical skills seem to be disproportionately concentrated in formal production sectors of any economy. Significant further Pareto-improving efficiency gains due to pension reform -- but not considered in the model applied in this paper -- could be reaped from capital-market deepening and improvements due to the adoption of a FF pension system managed by the private sector, as argued by the recent literature on pension reforms (World Bank 1994, Arrau, Valdés-Prieto and Schmidt-Hebbel 1993, Corsetti 1994, Holzmann 1996).

Which other structural features are important when considering the likely effects of a pension reform?

At least two: the form of financing chosen for covering the public-sector transition deficit associated to pension reform and the degree of financial openness of the reforming economy.

First, how are pension transition deficits financed? Addressing this question is essential to draw inferences about the long-term effects of pension reform. When the transition deficit is financed by swapping the implicit initial PAYG debt for other public-sector assets and liabilities, the long-term reform effects derived from the first channel are only of second-order importance.[14] First-order transfer effects toward future cohorts arise only when transition generations bear the cost of paying off all (or at least part) of the implicit PAYG debt.

[14] Second-order effects are derived from debt servicing of the higher net explicit public debt (that substitutes the implicit PAYG debt) and from differences in the distortionary nature of PAYG taxation

It is hard to assess how real-world pension reforms are financed because the latter coexist with many other changes affecting public finances and deficits. Because of the fungibility of money it is not possible to infer clearly from public deficit data how transition pension deficits are financed in reforming countries. However, most pension reform are intended to be financed at least in part by reducing non-pension deficits through tax hikes or expenditure cuts. Hence one might argue that part of the reform is financed by transition generations who contribute to paying off part of the initial implicit PAYG debt, implying a resource transfer toward future generations.

Second, how open are reforming economies? In a price-taking economy that is fully integrated into world financial markets, a PAYG-FF pension reform affects long-term saving and net foreign-asset holdings but does not alter capital levels as domestic interest rates are given by international markets. Therefore the more open is an economy, the smaller is the intergenerational transfer caused by the change in factor prices due to factor reallocation toward the formal sector.

Since the original Feldstein-Horioka (1980) study, a large body of empirical evidence tends to support the notion that financial integration into world markets is less than perfect in industrial economies and even weaker in developing economies. Therefore it is likely that pension reform could have an impact on domestic factor as a result of production reallocation toward the formal sector.

Putting the evidence together

How likely is a pension reform to reduce long-term saving, income, and welfare levels due to the strong weight of an income transfer toward initial cohorts caused by higher interest rates and lower wages in response to a shift in production from a labor-intensive informal sector to a capital-intensive formal sector? Probably not very much. On one hand informal sectors tend to be large under PAYG regimes, they shrink in response to pension reform, and they are significantly more labor intensive -- all these factors point out toward a possible resource transfer to initial cohorts. However, on the other hand, the latter effect seems to be empirically offset by the combination of the transfer toward future cohorts stemming from at least partial financing of pension transition deficits by reform transition cohorts and the potential efficiency gains from shifting resources toward the formal sector, augmented by possible efficiency gains in capital markets and pension system management.

## 5. Conclusions

It is well known that a pay-as-you-go (PAYG) pension system lowers saving, income, and welfare of future cohorts in a one-sector economy because it entails a transfer to the first cohorts of PAYG pensioners. Is the opposite result possible in a two-sector (formal-informal production) economy? Yes, as shown by the simulations for a representative economy reported in this paper, based on the steady-state solution of a two-sector two-period overlapping-generations model. A PAYG system can raise long-term saving, income, and welfare in a two-sector economy if the formal sector (forced to pay mandatory PAYG taxes) is more capital-intensive than the non-taxed informal sector, causing higher wages and lower interest rates. Is this outcome empirically likely? No, as suggested by reviewing the stylized features of real-world pension systems and formal-informal market structures. Therefore replacing PAYG by a

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and the net additional taxes required for the latter debt servicing (see Arrau and Schmidt-Hebbel 1993 and Corsetti and Schmidt-Hebbel 1996 for a discussion).

fully-funded pension system is still more likely than not to raise long-term saving, income, and welfare levels.

Further work is warranted to give stronger support to this conclusion. Fruitful extensions of the model developed in this paper may include imperfect substitutability between formal and informal goods on the demand side, and heterogeneity of labor employed by formal and informal-sector firms. Further analytical and quantitative insights may be reaped from a model that allows for a realistic number of overlapping generations, and for simulating both the transition path and the stationary equilibrium in response to pension reforms. Finally, more empirical evidence on the technological differences between formal and informal production and their responsiveness to changes in regulatory, tax, and pension regimes is required to better understand the consequences of PAYG-FF pension reforms.

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## APPENDIX: SUMMARY OF MODEL EQUATIONS

This appendix lists the complete set of model equations derived from consumer utility and firm profit maximization as stated in section 2, where variables have been defined.

Implicit equations for young and old-age age consumption:

$$(1a)\quad c_t = \left[1+\left(\frac{1-\mu}{\mu}\right)^{\frac{1}{1-\lambda}} wn_t^{-\frac{\lambda}{1-\lambda}}\right]^{\frac{1-\theta-\lambda}{\lambda\theta}} \left(\frac{1+r_{t+1}}{1+\rho}\right)^{-\frac{1}{\theta}} \left[1+\left(\frac{1-\mu}{\mu}\right)\left(\frac{1}{cf_{t+1}}\right)^{\lambda}\right]^{\frac{1-\theta-\lambda}{-\lambda\theta}} cf_{t+1}$$

$$(1b)\quad cf_{t+1} = wn_t\,(1+r_{t+1}) - \left(1+wn_t^{-\frac{\lambda}{1-\lambda}}\left(\frac{1-\mu}{\mu}\right)^{\frac{1}{1-\lambda}}\right)(1+r_{t+1})\,c_t + m_t\,(1+r_{t+1})$$

Aggregate labor supply:

$$(2)\quad l_t = 1 - \left(\frac{(1-\mu)}{\mu} wn_t^{-1}\right)^{\frac{1}{1-\lambda}} c_t$$

Saving when young:

$$(3)\quad s_t = (1-d_t)\,w_t\,l_{1t} + wn_t\,l_{2t} + b_t - c_t$$

Formal-sector labor demand:

$$(4)\quad l_{1t} = (\alpha)^{\frac{\sigma 1}{\sigma 1-1}}\left[\left(\frac{w_t}{\varepsilon 1\,(1-\alpha)}\right)^{\sigma 1-1} - (1-\alpha)\right]^{\frac{\sigma 1}{1-\sigma 1}} k_{1t}$$

Informal-sector labor demand:

$$(5)\quad l_{2t} = (\beta)^{\frac{\sigma 2}{\sigma 2-1}}\left[\left(\frac{wn_t}{\varepsilon 2\,(1-\beta)}\right)^{\sigma 2-1} - (1-\beta)\right]^{\frac{\sigma 2}{1-\sigma 2}} k_{2t}$$

Labor market equilibrium:

$$(6)\quad l_{1t} + l_{2t} = l_t$$

Formal-sector capital demand:

(7) $$k_{1t} = (1-\alpha)^{\frac{\sigma 1}{\sigma 1-1}} \left[ \left( \frac{r_t (1+\delta)+\delta}{\varepsilon 1\, \alpha} \right)^{\sigma 1-1} - \alpha \right]^{\frac{\sigma 1}{1-\sigma 1}} l_{1t}$$

Informal-sector capital demand:

(8) $$k_{2t} = (1-\beta)^{\frac{\sigma 2}{\sigma 2-1}} \left[ \left( \frac{r_t (1+\delta)+\delta}{\varepsilon 2\, \beta} \right)^{\sigma 2-1} - \beta \right]^{\frac{\sigma 2}{1-\sigma 2}} l_{2t}$$

Capital market equilibrium:

(9) $$k_{1t} + k_{2t} = k_t$$

Goods markets or investment-saving equilibrium:

(10) $$(1+n)(1+\gamma)(1+\delta) k_{t+1} = s_t$$

Net wage equalization:

(11) $$wn_t = w_t \left[ 1 - d_t \left( 1 - \frac{v}{1+r_{t+1}} \right) \right]$$

Net non-wage income:

(12) $$m_t = b_t - \left[ \frac{(1+n)(1+\gamma)}{1+r_{t+1}} \right] \left[ b_{t+1} - z_{t+1} \right]$$

Complementary PAYG lump-sum pension:

(13) $$z_{t+1} = d_{t+1}\, w_{t+1}\, l_{1\,t+1} - d_t\, w_t\, l_{1t} \left[ \frac{v}{(1+n)(1+\gamma)} \right]$$

Formal-sector output:

(14) $$y_{1t} = \varepsilon 1 \left[ \alpha \left( k_{1t} \right)^{\frac{\sigma 1-1}{\sigma 1}} + (1-\alpha) \left( l_{1t} \right)^{\frac{\sigma 1-1}{\sigma 1}} \right]^{\frac{-\sigma 1}{1-\sigma 1}}$$

Informal-sector output:

(15) $$y_{2t} = \varepsilon 2 \left[ \beta \left( k_{2t} \right)^{\frac{\sigma 2-1}{\sigma 2}} + (1-\beta) \left( l_{2t} \right)^{\frac{\sigma 2-1}{\sigma 2}} \right]^{\frac{-\sigma 2}{1-\sigma 2}}$$

Aggregate output:

(16) $y_t = y_{1t} + y_{2t}$

Old-age consumption:

(17) $cf_{t+1} = (1+r_{1+1})\left[wn_t\ l_t + m_t - c_t\right]$