Aggregate and Welfare Effects of Redistribution of Wealth Under Inflation and Price-Level Targeting *

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PRELIMINARY

Abstract

Since the work of Doepke and Schneider (2006a) and Meh and Terajima (2007) we know that inflation causes major redistribution of assets –between, households and the government, between nationals and foreigners, between households within the same country. Two types of monetary policy regimes, inflation targeting (IT) and price level targeting (PT), have very different implications on the inflation path subsequent to a shock that results in an unexpected price increase, and consequently, have different redistributional properties which is what we explore in this paper. For Canada, which has a positive net asset position with respect to the rest of the world in Canadian dollars, we show that the magnitude of the effects of an unexpected price level increase of 2% under IT is larger than under PT. Households' wealth loss to foreigners are 0.07% and 0.04% of GDP respectively under IT and PT. The combined effects on GDP (due to the wealth loss, the lower value of the debt and its associated fiscal adjustment (1.10% and 0.34% of GDP respectively) and the non-linear effects on work effort of the redistribution of wealth across households) are 0.44% versus 0.12%. The weighted welfare of households worsens under both IT and PT but, again, the magnitudes are larger under IT. The welfare losses are 0.23% of consumption under IT and 0.11% under PT.

Keywords: Inflation, redistribution of wealth, nominal assets and liabilities.

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1 Introduction

Doepke and Schneider (2006a) and Meh and Terajima (2007) have shown that inflation causes major redistribution of wealth as it erodes the real value of nominal assets and liabilities while leaving real assets unaffected. This is due to differences in portfolio composition between households, as well as the existence of nominally denominated government debt and the fact that the domestic economy's net position with respect to the rest of the world in nominal instruments is non-zero. Some households, mostly young, have real assets and nominal liabilities (mostly mortgages), while others, mostly old and high income, have a large share of their wealth in nominal assets such as long-term bonds and pension benefits. Portfolio composition differs not only as to whether instruments are real or nominal but also with regard to the maturity structure of nominal holdings.

While a sizeable number of central banks have embraced inflation targeting (IT) as their official modus operandi, price-level targeting (PT) is considered as a serious contender. The differences between these regimes are non trivial. The main difference is that under IT past "mistakes" are ignored, while under PT they are corrected. This results in different price level paths; under IT, there is a permanent deviation from the pre-shock path, while under PT the price level eventually returns to its initial path. Short-term nominal assets (e.g., cash), which are depreciated at the instantaneous rate of inflation, and real assets (e.g., houses, business capital), which are not affected by inflation, fare equally under IT and PT. However, long-term nominal assets which are depreciated by the ratio of the current price to the price level at the time of maturity fare differently under these frameworks. More specifically, under PT gains or losses on long-term nominal claims are attenuated with respect to the IT regime since the initial price shock is off-set over time as the monetary authority seeks to return the price level to its pre-shock path. Claims of shorter maturity are impacted more dramatically since they suffer the full effects of the initial shock but fail to enjoy completely the benefits of the policy response.

In this paper, we consider the effects that arise under IT and PT through the redistributional channel as nominal holdings are revalued following an unexpected surge in the price level. More specifically, we address two questions: first, we assess the potential redistributional effects of unexpected inflation under IT and PT regimes; second, we quantify the aggregate and welfare implications of these redistributional effects under both regimes. Essentially, using Canadian data, we model a price level change as an unanticipated shock to the distribution of wealth.

With respect to the first question, we find that the redistributional effects of inflation are important and that they differ significantly between PT and IT. The size of the redistribution is larger under IT than PT; this is because long-term nominal claims are not impacted as dramatically under PT while short-term holdings fare similarly under both regimes. On average, the young poor and the young middle-class are winners, along with foreigners and the government; the old and the rich lose.

Concerning the second question, we show that despite the fact that the redistribution shock is zero sum, the aggregate effects are not zero under either monetary policy regime. Because winners (net borrowers) during a surprise inflation episode are younger and relatively poorer than losers (net lenders), the incentives to work and save are affected in ways that are not offset during aggregation. In particular, we find that the aggregate effects from an unexpected price level surge are greater under IT than PT. For example, a one-time 2% price shock lasting one period leads to an increase in output of up to 0.44% under IT while it increases output by only 0.12% under PT. The increase in output under IT is thus more than three and half times larger than that under PT.

The welfare effects are significant. Welfare of the young (particularly among the middle class) improves by up to 0.186% of consumption under IT while it improves by only 0.025% under PT. The welfare of retirees, on the other hand, suffers substantially. Specifically, the welfare losses of the old range up to 2.94% of consumption under IT and up to 1.46% under PT. Thus, under IT the welfare losses of the old, total twice than under PT.

Using the standard measure of utilitarian aggregate welfare of households alive at the time of the shock, we find that weighted aggregate welfare worsens under both monetary policy regimes but that the welfare loss associated with a price shock is smaller under PT.

Another key result is that the fiscal policy strategy according to which the government dispenses its windfall gains is very important in determining the aggregate and welfare effects of price shocks. To illustrate this point, we consider several fiscal policy strategies such as a reduction in labour taxes over several periods and a lump sum transfer to retirees. A tax cut further enhances gains among the young while a transfer in the form of social security benefits compensates the old for their losses. The transfer to the old is entirely financed by the rich. On average, the aggregate and welfare effects are higher under IT than PT for most fiscal policy strategies; the largest effects coming from the tax cut policy. However, the fiscal policy scenario matters less under PT than IT. For example, when a tax cut policy is adopted so as to balance the government's budget every period, output increases substantially and becomes highly volatile under IT. However, under PT output increases only slightly and is not volatile. The intuition behind this result comes from the fact that under PT, the gains of the government are relatively small and therefore the policy used by the government will not affect as dramatically the incentives facing private agents in labour and capital markets. We interpret our findings as a strong reminder that the effects of monetary policy depend on fiscal policy.

The model that we use for our quantitative analysis is a multiple age overlapping generations model with additional heterogeneity within households in each cohort due to differences in wage profile. The model, though very well suited to the analysis of economies with heterogenous agents, still has an important shortcoming: we take portfolio composition for households of a given age and class as exogenous. Models, even those with a single household type, have difficulty accounting for portfolio composition in terms of long and short nominal holdings and real assets. Therefore, an additional upshot of our work emphasizes the need to understand the portfolio composition of different household types. To isolate the redistribution channel, we abstract from monetary frictions and instead model a price level change as a direct shock to the distribution of wealth that moves the economy from its initial steady state. We calibrate our model to Canadian aggregate statistics as well as to the joint distribution of wealth and earnings.

There exists a literature examining the benefits and costs of IT and PT (see for example, Gaspar, Smets, and Vestin (2007), Vestin (2006), Svensson (1999)). This literature does not, however account for the redistributional effects of price level changes and its macroeconomic consequences under PT and IT. A framework for quantitatively studying the redistributional effects of inflation is developed by Doepke and Schneider (2006b). In this sense, our work is closely related to theirs, but they do not focus on the differential effects under PT and IT. There are other related studies on redistributions. For Canada in the 1970s, Maslove and Rowley (1975) assess the redistributional consequences of inflation but focus on the expenditure effects that arise from the consumption pattern of households while we focus on the wealth effects that come from the valuation of nominal assets. The paper is also related to earlier literature, such as Bach and Stephenson (1974) and Cukierman (1985), who document redistribution of wealth in the 1970s in other countries. However, they do not conduct their analyses within a unified framework where direct and indirect positions are considered together; our focus on both sectoral and household data also distinguishes our approach from theirs. There is also a literature that considers the welfare costs of inflation in monetary models where inflation affects the distribution of wealth (see Albanesi (2007) and Cukierman (1985)). Burnside, Eichembaum, and Rebelo (2006) investigate the fiscal consequences of currency crises in emerging market economies. Their findings suggest that the devaluation of nominal government debt is a more important source of government revenue than seigniorage. Persson, Persson, and Svensson (1998) show that because of incomplete indexation of the tax system and the transfer program, moderate inflation has large effects.

The remainder of the paper is organized as follows. Section 2 elaborates on how IT and PT have different impacts. Section 3 describes the portfolios held by Canadian households and by the foreign and public sectors. Section 4 describes the OLG model and defines equilibrium under both regimes. Section 5 discusses the calibration of the model and describes how agents are impacted when the price level experiences a 2% shock. Section 6 elaborates by describing the effects following the price shock under various fiscal and monetary regimes. Section 7 presents the results of sensitivity analysis with respect to shock magnitude and the PT policy horizon. Section 8 concludes.

2 Long term nominal assets fare differently under IT than PT

This section briefly illustrates the differential effects of a price-level shock on nominal assets under IT and PT.[1]

Under Inflation Targeting Suppose an inflation target of $\overline{\pi}$. Then, an unexpected increase in prices of size $z > \overline{\pi}$ is such that prices will continue growing at rate $\overline{\pi}$ regardless of the initial increase of size z. Hence, **both** the value of the short-term and long-term nominal assets change by $\frac{1}{1+z}$ at the

[1] Appendix C provides a more complete discussion of how nominal assets and liabilities are differently affected by a price-level shock under IT and PT.

time of the price increase. Now, under a $\overline{\pi} = 0$ target, imagine a nominal asset at time 0, which pays \$100 at its maturity of 5 years. The nominal and the real price of this asset are, respectively,

$$q_0 = \frac{100}{P_5}\frac{1}{(1+\bar{r})^5}P_0 \quad \text{and} \quad \frac{q_0}{P_0} = \frac{100}{P_5}\frac{1}{(1+\bar{r})^5}.$$

Suppose $P_0 = P_5$, initially. With $z > 0$, $\tilde{P}_0 = (1+z)P_0$. Under IT,

$$\tilde{P}_5 = \tilde{P}_0 \quad \text{and} \quad \frac{\tilde{q}_0}{\tilde{P}_0} < \frac{q_0}{P_0}.$$

Under Price-Level Targeting Now imagine a price-level path target with the growth rate of the price-level at $\overline{\pi}$. Then, an unexpected increase in prices of size z is such that the central bank lowers the growth rate of prices to be less than $\overline{\pi}$ to get back to the target price-level path in the following period. Consequently, the value of short-term nominal assets changes by $\frac{1}{1+z}$, while the value of long-term nominal assets does not change. Longer adjustment periods for PT is a mix of the previous two. Under PT with the adjustment target horizon of less than 5 years,

$$\tilde{P}_5 = P_0 < \tilde{P}_0 \quad \text{and} \quad \frac{\tilde{q}_0}{\tilde{P}_0} = \frac{q_0}{P_0}.$$

Hence, this simple illustration shows that the real value of the nominal assets are less subject to a price-level shock under PT than under IT, especially when the target horizon is short and the time to maturity of the asset is long.

3 The composition of assets across Economic Agents

Similar to Doepke and Schneider (2006a) which documents the U.S. composition of assets and liabilities, Meh and Terajima (2007) documents its Canadian counterpart. The discussion in this section draws from Meh and Terajima (2007). We focus on three broad category of assets and liabilities, nominal short term, nominal long term and real.[2] We define the nominal short-term instruments to be of 1 year or less to maturity and over 1 year to maturity for the nominal long-term. The real instruments include all assets whose values are not directly affected by a price-level shock in Canada. These include all durable assets and foreign currency denominated assets. In addition, we follow Doepke and Schneider (2006a) in adjusting equity holdings to reflect the business sector's composition of assets. We document the composition for different household types as well as the government and foreign sectors. We pay special attention to the nominal instruments, nominal short and nominal long, as they are the ones affected by a price-level shock.

[2] Meh and Terajima (2007) deals with finer categories of instruments including mortgages and pensions.

3.1 Household Types

The household types we consider are six age groups: $\leq$35, 36-45, 46-55, 56-65, 66-75, and $\geq$76 and three economic classes within each cohort, poor, middle class, and rich. The economic classes are defined as in Doepke and Schneider (2006a) and Meh and Terajima (2007). The top 10% of households in net worth are characterized as rich. The rest of the households (90% of all households) is sorted by income ignoring their net worth. Then among these households, those (70% of the all households) with higher income are characterized as middle class and the remaining households (20% of the all households) as poor.

The data we use are the 2005 Survey of Financial Security (SFS) from Statistics Canada. It is a cross-sectional household survey data set comparable to the Survey of Consumer Finances from the Board of Governors in the U.S. Table 1 documents the households' net positions for each instrument. The numbers are expressed as a percentage of the age and economic class average net worth[3] and hence each set of three numbers adds up to 100%. The numbers are expressed as the net positions, (assets - liabilities). As explained in more detail in Doepke and Schneider (2006a) and Meh and Terajima (2007), the business sector positions are allocated to the three end-user sectors, the household, the government and the foreigners, using their equity holdings against the business sector.

From Table 1, we observe that the nominal positions, nominal short term and nominal long term, in general increase with age and, when young, households tend to have a negative position. As the fraction of nominal instruments becomes larger with age, old households are relatively more susceptible to a price-level shock. Moreover, rich households tend to hold a higher fraction of nominal assets, especially in the nominal long term. The young poor and middle-class households exhibit negative positions in the nominal long-term instrument, a result of the heavy mortgage burden in these groups.

3.2 The Government and Foreign Sector

For the positions of the government and foreign sectors, the Canadian national balance sheet account (NBSA) data from the Statistics Canada are used. All the numbers are for the year 2005. Table 2 shows the results for these two sectors as well as the aggregated household sector positions. As expected, the government sector is a net negative holder in both the nominal short-term and the nominal long-term instruments. In contrast to the U.S. study by Doepke and Schneider (2006a), the foreign sector in Canada has a negative positions in nominal instruments. Hence it is expected that a positive price-level shock will lower their debt burden at the expense of the domestic agents.

[3]The definition of net worth we use here includes the direct holdings of assets and liabilities as well as the indirect ones through the equity holdings.

4 Model

We consider a small open economy populated by overlapping generations with a positive world rate of return $\overline{r}$.

Demography and preferences Agents can live up to I periods and can be one of $j \in \{1, \cdots, J\}$ skill types with endowment of efficient units of labour, e_{ij}. The measure of each type ij is given by $\Omega(i,j)$ where $\sum_{i,j}[\Omega(i,j)] = 1$. Agents retire at the mandatory age i^*. Each agent faces a probability s_i of surviving from age i to age $i+1$. For simplicity, we assume that before retirement age agents do not die (i.e., $s_i = 1$ for $i < i^*$). In period t, each individual of age i and type j maximizes his expected discounted lifetime utility,

$$E\left\{\sum_{i=1}^{I} \beta_j^{i-1}\, u_j(c_{i,j,t}, 1 - n_{i,j,t}) + \; \Psi_j(a_{I,j,t})\right\}, \tag{1}$$

where E is the expectation operator. Expectations are taken over age-specific mortality shocks and stochastic price level shocks z. In equation (1), u_j is the temporal utility function of type j agents, $c_{i,j,t}$ and $n_{i,j,t}$ are respectively consumption and labour supply of age i and type j agents at time t, β_j is the discount factor of type j agents. Agents have a bequest motive and it is modeled as a "warm glow" preference for transfer to the next generation: $\Psi_j(a)$ where only agents of age I give intended bequests to their children.[4] The warm glow preferences imply that that agents derive utility from giving bequest a to their children. The preference for a bequest is type-specific so that we can capture the observed heterogeneity in bequest by type.

We assume that each household chooses savings, labour, and bequest optimally. We assume, however, that the composition of assets is exogenously determined and depends on age and skill. Let us denote α^s_{ij}, α^ℓ_{ij} and α^r_{ij} to be these exogenous shares of assets as follows.

- α^s_{ij} : the share of assets held in short-term nominal form for age i and type j households with a nominal interest rate equal to zero,
- α^ℓ_{ij} : the share held in long-term nominal form for age i and type j households with a nominal rate of return equal to $(1+\overline{\pi})(1+\overline{r})$ where $\overline{\pi}$ is the inflation rate,
- α^r_{ij} : the share held in real assets for age i and type j households with a real rate of return equal to $(1+\overline{r})$.

Production Output in this economy is given by a Cobb-Douglas aggregate production function F

$$F(N_t, K_t) = K_t^{\alpha} N_t^{1-\alpha}, \tag{2}$$

[4]The bequest is modeled to analyze the importance of the intergenerational effects of an inflation shock.

N_t and K_t are respectively aggregate labour and capital inputs at time t. Given prices, firms maximize and as a result we have the following:

$$\bar{r} + \delta = \alpha \left(\frac{K_t}{N_t} \right)^{\alpha - 1} \text{ and } w = (1 - \alpha) \left(\frac{K_t}{N_t} \right)^{\alpha}, \tag{3}$$

where δ is the depreciation rate of capital and w is the wage rate. Given that the world interest rate $\bar{r}$ is constant the capital labour ratio is constant.

Stochastic shock and the central bank The stochastic nature of the model is given by *iid* aggregate proportional shocks z to the price level targeted by the central bank. In this context, under IT, the central bank sets its actions such that

$$\frac{P'}{P} = (1 + \overline{\pi})(1 + z') \qquad \text{or} \quad E\{P'\} = P\ (1 + \overline{\pi}),$$

where z' and P' are respectively the next period shock and price level. Under PT, the central bank sets

$$P' = (1 + \overline{\pi})^t (1 + z') \qquad \text{or} \quad E\{P'\} = (1 + \overline{\pi})^t.$$

Problem of households It is convenient to represent recursively the problem of a household under two different regimes: $\pi = IT$ and $\pi = PT$. Let $v_{i,j,t}(a)$ be the beginning of period value function where a is the current wealth holdings of age i and type j household at time t. The dynamic program of the household can be described as follows.

$$v_{ijt}(a) = \max_{c,n,y} u(c, n) + s_i \beta_j\ E\Big\{v_{i+1,j,t+1}[a'(z')]\Big\} + 1(i = I) \cdot \beta_j E\Big\{\Psi_j(a'(z'))\Big\} \tag{4}$$

$$s.t. \qquad c + y = a + n \cdot w \cdot e_{ij}(1 - \tau_t) + T_{it}, \tag{5}$$

$$a'(z') = y \left(R^{s,\pi}(z')\alpha^s_{i+1,j} + R^{l,\pi}(z')\alpha^l_{i+1,j} + (1 + \bar{r})\alpha^r_{i+1,j} \right), \tag{6}$$

where the respective real returns on short-term and long-term nominal assets under different monetary policy regimes $R^{s,\pi}(z')$ and $R^{l,\pi}(z')$ depend on z' and are given by

$$R^{s,PT}(z') = R^{s,IT}(z') = \tfrac{1}{(1+\overline{\pi})(1+z')},$$

$$R^{\ell,PT}(z') = 1 + \bar{r} \quad \text{and} \qquad R^{\ell,IT}(z') = \tfrac{1+\bar{r}}{1+z'}$$

Equation (5) is the budget constraint of the household. The left hand side of equation (5) is consumption c and savings y for next period. The right hand side of the budget constraint consists of resources at hand a, after-tax labour income with a current labour income tax rate τ_t, and government period t transfer $T_{i,t}$ which is age dependent. The transfer consists of two parts and is given by $T_{it} = T_t^d + T_{it}^r$. The first part T_t^d is the accidental bequest which is distributed equally as a lump sum transfer to all households. The second part $T_{i,t}^r$ is the government retirement income transfer to the retired households in the form of social security or the government's retirement income transfer program. Equation (6) gives the law of motion of next period assets $a'(z')$ where z' is the next period inflation shock. The indicator function $1(i = I)$ is one when the households reach the last age and thus can give bequest $a'(z')$ to their children. It is assumed that the households can not die with negative assets or negative bequests.

Government The government finances government consumption G_t, transfer to retirees, interest payments on government debt B_t by raising revenue from taxing labour income and issuing government debt. The period budget constraint of the government is described as follows.

$$G_t + (1+\overline{r})B_t + \sum_j \sum_{i \geq i^*} \Omega(i,j) T_{i,t}^r \quad = \quad \sum_j \sum_{i=1}^{i^*-1} \Omega(i,j) \tau_t w e_{ij} n_{i,j,t} + B_{t+1}. \tag{7}$$

The transfer to retirees depends on the age of households. The government also collects all accidental bequests and distributes them equally to all households in a lump sum fashion.

$$\sum_{i>1,j} \Omega(i-1,j)(1-s_{i-1}) a_{i,j,t} \quad = \quad T_t^d. \tag{8}$$

The behaviour of the government is taken as exogenous and is calibrated to the steady state of the actual economy. We will consider various fiscal policy reactions after an inflation-induced redistribution shock.

Foreigners The behaviour of the foreign sector is taken as exogenous. The foreign sector period t asset or debt in the domestic asset market is given by a_t^F.

4.1 Equilibrium

Definition 1. *An equilibrium for a given regime $\pi \in \{IT, PT\}$ is a world interest rate $\overline{r}$, a sequence of wage rates $\{w_t\}$, a sequence of individual decisions $\{c_{i,j,t}, n_{i,j,t}, a_{i,j,t}\}$, firm decisions $\{K_t, N_t\}$, government decisions $\{G_t, \tau_t, B_t, T_t\}$, foreigners' debt $\{a_t^F\}$ such that:*

1. *Given $\overline{r}$ and government policies, each household solves the household problem (4)-(6).*
2. *Given prices, firms maximize profits.*

3. *The equal lump sum transfer constraint (8) of accidental bequest holds every period.*
4. *The government budget constraint (7) is satisfied every period.*
5. *The labour market clears in every period:*

$$N_t = \sum_j \sum_{i=1}^{i^*-1} \Omega(i,j) e_{i,j} n_{i,j,t}. \tag{9}$$

6. *The good market clears in every period:*

$$\sum_{i,j} \Omega(i,j) c_{i,j,t} + I_t + G_t + NX_t = Y_t, \tag{10}$$

where $NX_t = (1+\overline{r})a_t^F - a_{t+1}^F$ *is net export,* $I_t = K_{t+1} - (1-\delta)K_t$ *is aggregate investment.*

4.2 Shocks

To have shocks to the environment that directly translate into unexpected price changes, consider a transaction technology such that

$$Y\ v = \frac{M}{P}$$

Where Y is output, v is velocity and M is money, or more precisely, short term nominal assets. A shock to the price level z can be thought of literally as a permanent shock to velocity. Money creation then is in charge of implement both IT and PT. This is not the only possible theory of the shock consistent with this model but it is the simplest.

5 Calibration

5.1 Model Parameters

We calibrate the parameters of the model to the steady state of our model economy by matching the selected moments from the model to the counter parts from the data. We define the six age cohorts, i, and the three economic classes, j, of the model as in the empirical study by Meh and Terajima (2007). Our basic calibration strategy for choosing the household parameters is to jointly match the distributions of wage rates and asset holdings across household groups. For technology and government parameters, we calibrate them to match their relevant targets. Table 3 summarizes the calibrated parameter values for preferences, demography, technology and the government as discussed in this section.

Preferences We assume the following functional form of the utility function.

$$u_j(c_t, n_t) = \frac{c_t^{(1-\eta_j)(1-\sigma)}(1-n_t)^{\eta_j(1-\sigma)}}{1-\sigma} \tag{11}$$

In addition, the preferences for leaving bequests are given by

$$\Psi_j(a_{I,t}) = \xi_j \frac{a_{I,t}^{1-\epsilon_j}}{1-\epsilon_j} \tag{12}$$

The parameters to be determined consist of the intertemporal elasticity of substitution, σ, the economic class specific weight on leisure, η_j, the class specific bequest parameters, ξ_j and ϵ_j, and the class specific time discount factor, β_j. We set σ to 2, a standard value. The value of η_j is set to achieve the average work hour fraction to be 0.4 for each class j. ξ_j is the weight the household puts for leaving bequests to the next generation. The 2005 SFS data set contains the bequest information. According to the data set, the average amounts of bequests received before the age of 35 are \$31,415, \$2,565 and \$1,571 for our classifications of rich, middle class and poor, respectively. Since the values for middle class and poor are relatively small, we set $\xi_j = 0$ for these groups. In determining ξ_3, we target the ratio of the average bequest over the average net worth of rich. This ratio is 0.0886 from the 2005 SFS. The values of ϵ_j are set so that $\epsilon_j = 1-(1-\eta_j)(1-\sigma)$ following Doepke and Schneider (2006a).

The discount factor, β_j, directly influences household asset accumulations. We set the economic class specific value of β_j to match the relative net worth of three classes and the ratio of output to household assets. Specifically, we pin down the three values of β_j to match the following ratios: (1) the average net worth of the rich households to that of the middle class, (2) the average net worth of the middle class to the poor, and (3) the average net worth of the middle-class age-cohort 36-45 to output. The last target is selected to capture an aspect of the asset life-cycle profile. These ratios are 6.33, 4.15 and 0.29, respectively. The annualized values of β_j obtained are 0.99, 1.04 and 1.19 for the poor, middle clan and rich, respectively. In order to match the between-group ratios of the net worth, the β_j for the rich had to be much higher than the other two classes.

Demography The households face the conditional probability of death, s_i. Since the main margin that we like to capture is the relative size of the young and the old. We assume that the households do not die before retirement and start facing a positive probability of death when they retire. In 2005, the ratio of those who were 65 or older to those who were 20 or older was 17% in Canada.[5] We adjust the probability of death of retirees, s_4 and s_5 to achieve this ratio. We assume that a half of the model population of cohort 66-75 survives to the next age category, $\geq$76. The parameter values obtained as a result are $s_4 = 0.547$ and $s_5 = 0.500$. Since the $\geq$76 households will die in the following period, $s_6 = 0$.

[5] The number is from Statistics Canada at "http://www40.statcan.ca/".

Labour Productivity The age-class specific labour endowments, e_{ij}, are directly estimated using the panel data from Statistics Canada. The Survey of Labour and Income Dynamics (SLID) contains information on Canadian households and persons on labour and income over time. We have used the 1999-2004 wave. We estimate the age-class specific endowment by the following fixed-effects regression.

$$\begin{aligned}\ln(\text{wage rate})_{ht} &= \theta_0 + \theta_1(\text{age})_{ht} + \theta_2(\text{age}^2)_{ht} \\ &+ \theta_3(\text{work experience})_{ht} + \theta_4(\text{years of school})_{ht} + \nu_h + \varepsilon_{ht},\end{aligned}$$

where the index h specifies the person and t the time. The wage rate is defined by the total wage and salary income divided by the total hours worked. We use this variable to approximate the labour endowments. The work experience is the number of years worked. The years of school are the number of school years completed. The regression results are presented in Table 4. In order to derive the results for our economic classes, we approximate them using the years of schooling. For each appropriate age group, we sort them into the poor, middle class and rich by the school years so that the size of the sample for each class is as defined previously, 20%, 70% and 10%, respectively for the poor, middle class and rich. With this definition of the groups and the parameters from the regression estimation, we apply the average age, the average school years and the average work experience to derive the average wage rate for each age-class group. Table 5 shows the resulting relative endowment of each household group.

Technology The production technology in our model economy is standard and assumed to be Cobb-Douglas. The capital share parameter α is set to 0.33. The annual depreciation rate is assumed to be 0.07 and appropriately adjusted for the model period of 10 years by setting $\delta = 1.0 - (1.0 - 0.07)^{10}$.

Government Debts and Transfers There are four parameters that concern the government, the labour tax rate (τ), the retirement income transfer, the government spending and the government debts. The tax rate is set to match the ratio of the tax revenue to output of 32% as in the Canadian data in 2005. We obtained $\tau = 0.469$. The average retirement income transfer was 12.51% of the GDP per household in 2006. Hence T_i^r with $i \geq i^*$ is calibrated to achieve this ratio. Government debts, B, were calibrated to match the government nominal debts to the GDP ratio of 59.92% in 2005. Finally, the government spending, G, needs to be pinned down. Since there is no guarantee that the government budget constraint holds under our calibration strategy, we chose to set the value of G to balance the government budget. The resulting government spending to GDP ratio is 26.55%. The number in the data is 35.06% in 2005.

Foreigners The foreigners' asset position, a^f, is set to match its debt to GDP ratio of 3.46% in 2005. Even though the foreign sector in our economy does not interact directly with other sectors due to the assumption of the small open economy, it is important to capture the asset position of this sector to capture all the redistribution entirely. The redistribution through the foreign sector is a leak in and out of the economy. We will conduct a benchmark experiment below where we close down this leak by assuming that the household sector absorbs the foreign sector's positions in order to analyze the difference in the aggregate response to the price-level shock.

5.2 The redistribution impact of an unexpected price increase

Based on net nominal positions of agents in Section 3, we measure the extent of the direct redistribution among these agents from a one-time unexpected price increase of 2% under two monetary policy regimes, Inflation Targeting (IT) and Price-level Targeting (PT) with the 6-year horizon to correct the price level. The mechanism of the differential effects of the two policies were depicted in Section 2. As the discussion in the section shows, under the PT regime, the maturity of an instrument is an important factor in determining the change in the real value of the nominal instrument from a price-level shock while the maturity difference does not affect the real value under IT.

We follow Meh and Terajima (2007) in assuming the maturity structure of these instruments. For the nominal short-term instruments, we set the time to maturity to be 1 year. For the nominal long-term instruments, Meh and Terajima (2007) further disaggregate them into bonds, mortgages and pensions. In determining the maturity structure for each of these sub-categories, we apply the distribution of the time to maturity in 2005. For bonds, the Bank of Canada keeps a record of the outstanding federal government bonds and their maturities in the Communication, Auction and Reporting System. For mortgages, we use the Ipsos Reid Canadian Financial Monitor 2005, a Canadian household survey data set which contains information on the term of the mortgages. For pensions, we derived the expected time to retirement and the expected time to death and assume that the retirees receive a constant stream of pension income during that time. The brief descriptions of these data sets are attached in Appendix A.[6]

Given these maturity structures of the instruments, we calculate the direct impact of a one-time 2% price-level increase on the agents' net worth under the two monetary policy regimes. The very brief summary of the differential effects from the two policies are discussed in the main text. Appendix C provides a detail discussion of the logic and how we calculate the numbers.

Inflation Targeting Under the IT regime, inflation expectations are not affected from a transitory (nominal) shock to the inflation and the central bank will not correct the price-level path (i.e., let bygones be bygones). Hence the price-level increase is a permanent one and all nominal instruments regardless of maturity structures of the portfolio at the time of the shock are subject to change in their real value. We derive the extent of the direct redistributional impact from the price-level shock based on the positions of agents from Section 3.

Price-Level Targeting Under the PT regime, after the initial price-level increase, the central bank is assumed to credibly bring it down to the original price-level path according to the pre-specified time horizon. As a result, while the short-term instruments are still sensitive to the price-level

[6] For more details, see Meh and Terajima (2007).

shock, long-term instruments on the other hand are less subject to it since the price level is closer or back to the originally expected path by its maturity date. Hence we naturally expect the direct redistributional impact from the price-level shock to be smaller under the PT regime. We assume the target horizon to be 6 years for the following analysis.

Table 6 shows the extent of the direct impact from the unexpected 2% price-level increase on different age and class household groups under two monetary policy regimes. It is generally the case that the sign of the direct redistribution is the opposite of that of the net nominal position, which is defined to be the sum of the nominal short-term and the nominal long-term positions as in Table 1. As the exposition in Appendix C shows, the magnitude of the redistribution is smaller under PT than IT. Under IT, the number ranges from the high of 1.71% of net worth for ≤35 and middle class to the low of -0.73% of net worth for ≥76 and rich. Under PT, the numbers for the same groups are 0.36% and -0.29%, respectively. For both regimes, young middle class and young poor households receive the positive redistribution, whereas old or rich households receive the negative redistribution. These are the direct results of young middle class and young poor having a negative nominal position in the nominal instruments.

Table 7 shows the numbers between sectors. Government receives a positive redistribution from the reduction of its nominal debts by 1.10% of the GDP under IT while the foreign sector also receives the positive redistribution by 0.07%. Under PT, the numbers are again smaller with 0.34% and 0.04% for government and foreigners, respectively. All the positive redistributions of these two sectors are off set by the households.

Feeding in the Direct Redistributional Impacts into the Model as Wealth Shocks In order to analyze the aggregate effects from the initial price-level shock, we feed the household direct impact numbers in Table 6 and those of the government and the foreign sectors in Table 7 into the model presented above for both IT and PT. The assets of the households in the steady state equilibrium are redistributed as a shock to the household according to the magnitude presented in Table 6 for each age-class group. Specifically, the positive or the negative redistributions of the age group ≤35 are applied to their beginning-of-period asset position before they make decisions for the period. All other age groups' beginning-of-period assets are shocked similarly. Also, the steady state position of the government and foreign sectors are redistributed according to the numbers in Table 7. Given these one-time shocks, we solve the model for its transition path by assuming that agents' decisions are approximated linearly at the zero price-level shock from the second period on.

6 Findings

The mechanism in which the aggregate effects can result with respect to zero-sum redistributions is the asymmetric responses by different agents. Particularly, since the winners of excessive inflation are younger and poorer than the losers, who are generally older retirees and richer, the incentives to work and save are affected and they are not wiped out by aggregation.

We present the results for the transition dynamics and the welfare from the initial direct impact of the price-level shock described in Section 5.2. We simulate the transition back to the steady state under several different assumptions about the government's fiscal policy regarding the windfall gains it receives and the foreign sector's redistribution. In doing so, we make an assumption about the government's decision on how the government debts change over the transition period. With the positive price-level shock, the real value of the government debts is reduced creating a windfall gain. We assume that the level of debts goes back to the steady state after one period or 10 years.

Also, all the direct redistributional impacts sum up to zero; however, from the stand point of the domestic economy, the redistribution to and from the foreign sector is a leak in and out of the economy. In order for us to analyze the zero-sum redistribution within the economy, we define the baseline simulation to be the one where the household sector "buys out" the foreign sector's nominal position by using its real assets. Hence with this assumption, there will not be any redistribution in the foreign sector from a price-level shock. The additional redistribution in the household sector, as a result of this adjustment, is allocated lump-sum to all households. Section 6.1 presents the baseline simulation results where the government's fiscal policy is the least distortionary one in that it redistributes back its windfall gains to the households in a lump-sum fashion.

Next, we show the results from the simulation where the government's fiscal policy regarding the windfall gains changes. In Section 6.2.1, the government is assumed to lower the tax rate to benefit the workers. With the small open economy assumption where the interest rate is unaffected by the price-level shock and the government fiscal policy, the labour tax change in our economy affects the agent's decisions greatly. To show this, we conduct two simulations regarding the labour tax change government policy, one where the tax rate linearly goes back to the steady state level over the 50-year period while the present value government budget equation is satisfied and the other where the tax rate is adjusted every period to maintain the flow government budget constraint. The results from the first case is shown in Section 6.2.1 and the second in Section 6.2.2. In Section 6.2.3, the results are shown with the assumption that the government gives the lump-sum transfers to only retired households. In Section 6.3, we show the results with the assumption that the redistribution to the foreign sector is lost to the domestic economy by adding back that sector into the simulation. Finally, the welfare analysis on the households who are alive at the time of the shock is conducted in Section 6.4.

6.1 The Response to the Redistributional Effects Across Households

As the baseline simulation to analyze the zero-sum redistribution in the domestic economy, we assume that the foreign sector's nominal positions to be bought out by the household sector in exchange for the real assets. Then, the extra nominal positions from the foreign sector are redistributed lump sum to all households.

We assume in the baseline simulation that the government's fiscal policy is the least distortionary one in that it redistributes back its windfall gains to the households in a lump-sum fashion. During the transition, the government budget equation is held period by period under this baseline case by adjusting the lump-sum transfer.

Households Figures 1 and 2 show the percentage deviations under IT from the steady state in life cycle asset and labour, respectively, for agents who are alive at the time of the shock. In the figures, the age in the title is that of the time of the shock. The values are normalized by the economic class average. The cohort 56-65 has, for example, zero values for the first 3 periods (i.e., $\leq$35, 36-45 and 46-55) as the shock arrives at the forth period of its life.

From the asset figures, all rich cohorts lower their assets over their lives due to the initial shock. Under IT, rich tends to lose the most and especially, the cohort 46-55 and 56-65 decrease their assets by 1.5% of the class average assets. Under PT, all rich cohorts still lose over the life cycle but the magnitudes are much smaller. The rich cohort who loses the most is 66-75 with 0.4%. Middle-class and poor show a similar pattern in that the increases and the decreases are smaller under PT. Under both IT and PT, we also observe that the intended bequest left by rich decreases for all cohorts. This will create a persistent effect through the following generations' initial asset level.

Among rich, we observe one qualitative difference. Under IT, the decrease in assets for the rich 56-65 cohort at the time of the shock is larger than those of the middle class and the poor. However, under PT, it reverses. This is consistent with the numbers in Table 6 and it is a result of the rich 56-65 cohort having a larger position in long-term assets as shown in Table 1. Under PT, the values of long-term instruments are less affected by a price-level shock, while under IT the values of all instruments are equally affected.

From the labour figures, we observe the wealth effects. Whoever gains in assets tend to reduce its labour supply over the life cycle and vice versa. For example, the rich $\leq$35 cohort loses its assets while, to compensate for its loss in assets, the labour supply increases. Figures 3 and 4 show the PT counterparts. Qualitatively similar patterns can be observed in both IT and PT graphs, however, quantitatively they are different. For example, the rich 45-55 cohort increases the labour supply by 0.8% under IT while the number is about 0.25% under PT.

Aggregates Figure 5 shows the aggregate responses over time in output and total household assets under IT and PT. The figures are the percentage deviations from the steady state. At $t = 0$, we observe the magnitude of the contemporaneous responses of output to the direct redistribution. First thing to note is that the initial impact on output is positive at $t = 0$ both under IT and PT. This is not an obvious result. As seen in Figures 2 and 4, some households increase their labour supply while other decrease at the time of the impact. Specifically the decrease in work hours by middle-class $\leq$35 and 36-45 are more than offset by other households. Hence, the net effects on output are positive.

The initial impact in output under IT is 0.145% compared to 0.054% above the steady state under PT and both series almost converge back to the steady state after 40 years. To put things in a perspective, we should consider these numbers with respect to the size of the initial price-level increase of 2%. Hence, the more informative numbers here are such that the initial output responses are 7.2% ($0.072 = \frac{0.145\%}{2\%}$) and 2.7% ($0.027 = \frac{0.054\%}{2\%}$) of the size of the price-level increase under IT and PT, respectively. Comparing the relative initial response of output under IT and PT, the output response under IT is 2.68 times higher than under PT. This is caused by smaller redistributions under PT leading to smaller changes in household behaviors.

In aggregate assets, the initial direct impact out of the household sector results in -0.39% from the steady state value under IT and -0.13% under PT. The increase in the output is caused by the wealth effects among workers. On average, workers receive (even with the lump-sum transfer of the government windfall gains) the negative change in their wealth so that workers supplying more labour on average as a result. Correlating with these initial impacts, the transition back to the steady state seems to take a longer time under IT than under PT, especially observed in the asset figure.

6.2 Redistributional Effects and the Changed Burden of Public Debt

In this section, we discuss the results from three simulations where the government fiscal policy in redistributing the windfall gains differ from the lump-sum transfer to all households. In Section 6.2.1, the government lowers the labour tax rate over a 50-year period to benefit the workers while maintaining the present value government budget constraint. In Section 6.2.3, the government gives the lump-sum transfers to only the retired households. And in Section 6.2.2, the tax rate is adjusted every period to maintain the flow government budget constraint.

6.2.1 Gradual Reduction in Labour Tax

Suppose now that the tax rate is lowered for the first 50-year period where the rate goes back to the steady state level in a linear fashion at the end of the period while maintaining the present value government budget constraint. With this fiscal policy, the aggregate effects displayed in Figure 6 show that the initial reaction of output is much larger than the baseline case in Section 6.1. Output reacts positively to 0.437% above the steady state level under IT and 0.124% under PT. Or in the relative term to the size of the price-level increase, the output responses are 21.9% and 6.2% of the size of the initial price-level shock for IT and PT, respectively. Under both monetary policy regimes, the initial increase in output is caused by the increase in labour supply due to the tax cut. Again comparing the relative initial response of output under IT and PT, the output response under IT is 3.52 times higher than under PT. The relative response under IT is higher with the tax cut policy compared to that, 2.68, with the lump-sum transfer

As time passes, the labour supply keeps decreasing as the tax rate returns to its initial value before the shock. This decrease in the labour supply continues until the tax rate goes back to the steady state level at which point the labour supply is below that of the steady state. This is due to the intertemporal substitution of the labour supply decision. Workers, who are alive before and after the period the tax rate goes back to its steady state level, work longer hours before the period and instead reduce the work hours thereafter.

6.2.2 Labour Tax Changes that Balance the Budget Period by Period

In this section, we show what can happen if the government forces a balanced budget period by period under the tax rate adjustment policy. Figure 8 shows the results. As can be seen, the volatility of output and asset are much higher. The contemporary reactions of output are 1.69% and 0.22% for IT and PT, respectively. Relative to the size of the shock, they are 84.5% and 11% for IT and PT, respectively. The high volatility is due to the fact that, under the small economy assumption with a fixed interest rate, the volatility of output depends solely on the volatility of labour supply. The tax rate has a direct effect on the labour supply. Thus, the government trying to balance the budget by adjusting the tax rate creates this extra volatility we observe in Figure 8 compared to the case in Figure 6. If we compare the relative initial response of output under IT and PT, the output response under IT is 7.68 times higher than under PT. Put differently, under PT this fiscal policy scenario does not generate too much volatility. The results from this section imply that the government fiscal policy of how to redistribute its gain is an important determinant of how the price-level shock affects the aggregate economy, particulary under IT. In addition, the relative responses under IT and PT depends also on the fiscal policy in place.

6.2.3 A Lump Sum Transfer to Retirees

Figure 7 shows the results from the case where the government gives the lump-sum transfers only to retired households in the form of increased retirement transfer income. The reactions of output are positive and 0.207% above the steady state level under IT and 0.075% under PT. Again in relative term to the size of the price-level increase, these output responses are 10.4% and 3.8% of the size of the initial price-level shock for IT and PT, respectively. Since workers do not directly benefit under this fiscal policy, the increase in the labour supply is larger here than under the baseline case where workers, too, receive the lump-sum transfer from the government. The relative output response under IT is 2.76 times that under PT.

6.3 Redistributional Effects, with the Changed Debt, and the Changed Foreign Net Asset Position

So far the analysis has been conducted under the assumption that the domestic households buy out the nominal positions of the foreign sector. However, we put back in the foreign sector such that the redistribution to this sector is lost to the households, and analyze the sensitivity of this assumption. Based on the direct redistribution numbers in Table 6 and 7, Figure 12 shows that the dynamics under the baseline simulation and the one with the foreign sector nominal positions as in the data for the inflation targeting regime with a 2% shock. As can be seen from the figures, there is not much difference between the two lines. In both the output and the asset figures, the initial reaction is larger in absolute value with the foreign sector. This is due to the fact that the household net position is more positive with the foreign sector as in the data. Since the foreign sector has a net negative position, when the household sector buys it out, the households' nominal position goes down on average leading to less direct impact from the positive price-level shock.

6.4 Welfare Analysis

In this section, we look at the welfare of households who are alive at the time of the shock. Even though the direct redistributional impacts in Table 6 gives an idea about the welfare of these households, the ultimate measure of welfare depends also on the government fiscal policy in redistributing its windfall gains as well as the feed back through the amount of assets unintendedly left by early deaths. To observe the ultimate impact of the price-level shock under the two monetary policy regimes, Tables 8 and 9 show for each group of households alive at the time of the shock a welfare measure under IT and PT, respectively. Each table contains the welfare measures with the three fiscal policies. To be more precise, the numbers in the table are the equivalent variations in consumption such that, given a household in the steady state, it is the percentage change in consumption to make the household as well off in the transition dynamics with the respective monetary policy regime and the fiscal policy. For example, in Table 8 under IT with the higher lump-sum transfer government policy, 0.074 for middle-class $\leq$35 households indicates the welfare improvement over the pre-shock steady state by 0.074% of the steady state consumption. The negative numbers indicate the welfare loss. The weighted average of the welfare measure for all household groups is provided in the table. In calculating these numbers, we held constant the other dimensions of the decisions, labour supply and savings at the steady state values. Hence, this welfare measures includes the effects through the labour supply and the savings margins expressed all in the consumption terms.

Under both IT and PT, the tables show that, with the baseline simulation with the government's lump-sum transfer to all households, the group who loses the most is middle-class $\geq$76. The loss is higher under IT at -2.35% than under PT at -1.275%. On the other hand, two youngest groups in middle class show welfare gains both under IT and PT. The three youngest poor cohorts show a welfare loss both under IT and PT even though they receive positive redistributions from a price-level increase. This is due to a change in the amount of the accidental bequest. Retired households who die leave their assets as accidental bequests which are transferred lump-sum to all households. Since all retired households lose initially from the price-level increase, the accidental bequests from the following period will be reduced. Especially for poor households, this change in the amount of accidental bequests affects their wealth greatly and thus it is reflected in the welfare measure. Comparing the two tables, the welfare losses and gains are much smaller under PT than under IT. There is an average welfare losses from all households of -0.227% and -0.096% under IT and PT, respectively. Hence the loss is more than twice bigger under IT then under PT.

With the gradual tax change fiscal policy, as expected, more working households gain than the baseline case. For example, poor 36-45 and 45-55, and rich 36-45 now gain under IT relative to the baseline case. The welfare loss of older households increased as the tax cut dis-proportionally benefits the young relative to the lump-sum transfer. Especially the loss of middle-class ≥76 increased from -2.35% to -2.941%. The average welfare loss under IT is -0.226%. Under PT, relative to IT, we observe a sign change from positive to negative for the three youngest poor cohorts and the ≤35 rich cohort. For the ≤35 rich cohort, it is simply that the tax rate reduction under PT is not enough to compensate for the initial loss of assets. For the three youngest poor cohorts, even though the tax cut helps them, it is not enough to overcome the lower accidental bequests resulting from the asset losses of retirees. The average welfare loss is -0.109% under PT.

With the increase in the retirement income transfer, more retired household groups gain compared to all retirees having a negative sign under the baseline case under both IT and PT. However, this increase in retirement income is not enough to compensate the loss of rich retirees as they are still in loss with the increased retirement transfer. Under PT, middle-class ≥76 households still lose by 0.264%. This is simply due to the smaller government windfall gains to be transferred back under PT. The two youngest middle-class cohorts also show a welfare loss under PT in contrast to under IT due to the change in accidental bequests. The average welfare measures under this fiscal policy are more positive than under the other two fiscal policies with -0.002% and -0.025% for IT and PT, a greater loss under PT. Since the major losers from a positive inflationary shock and the direct redistributional impact thereof are the retired households, who have less means to adjust their behavior (i.e., labour supply), this welfare result suggests that compensating those can minimize the average welfare gains and losses from price-level shocks.

The interaction of the monetary policy and the fiscal policy can have important welfare effects. Under IT, different fiscal policies can lead to a wide range of welfare gains and losses. For example, the middle-class ≥76 cohort displays a welfare loss of -2.35% and -2.941% of consumption under the lump-sum transfer policy and the tax cut policy, and a gain of 0.9% under the higher retirement transfer policy. In comparison, under PT, these respective numbers are -1.275%, -1.459% and -0.264%. Thus, under IT, different fiscal policies lead to a wider variation of the welfare losses and gains than under PT. Or in other words, households are more shielded from the actions taken by the government. This is because, under IT, the government's gain from a price-level shock is larger than under PT. Hence there is less room for the different fiscal policies to distort the economy. The smaller gains by the government under PT are due to the fact that the government long-term debts are less affected by the price-level increase.

7 Sensitivity Analysis

Several sensitivity analysis are conducted in this section to the main analysis in Section 6. Specifically, we look at the three margins of the analysis. In Section 7.1, we study the results from a wider range of the price-level shocks. In Section 7.2, we observe the effects of changing the horizon of the price-level targeting policy.

7.1 Different Shocks

Figures 10 and 11 show transitions of output and asset for the different size and sign of shocks under IT and PT, respectively. Under IT, for the shocks of 5%, 2%, 1%, -1%, -2% and -5%, the initial reactions in output are 0.334%, 0.148%, 0.078%, -0.062%, -0.131% and -0.347%, respectively. The respective numbers under PT are 0.122%, 0.054%, 0.031%, -0.018%, -0.042% and -0.116%. Under both IT and PT, initial output reactions monotonically change with shocks. Also, the sign of the output responses coincides with that of the shock. The transitions seem close to being symmetric between the same size shock of the different sign both for IT and PT. Table 10 presents the aggregated welfare measures for the IT and PT with different fiscal policies. The welfare numbers are in general monotonic with respect to the size of the shock and smaller in the absolute value under PT than under IT.

7.2 Different Price-Level Target Horizons

Figure 9 shows the output and asset responses in the transition for IT, PT with the 15-year horizon and PT with the 6-year horizon. It is expected that, as the horizon under PT prolongs, the magnitude of the redistribution converges to that under IT. As a result, we would expect the reactions in output and asset under PT also to converge to those under IT as the PT horizon increases. This is what the figures show. The line for PT with the 15-year horizon stays in between IT and PT with the 6-year horizon. The initial responses in output are 0.147%, 0.059% and 0.054% for IT, PT with the 15-year horizon and PT with the 6-year horizon, respectively. Table 11 summarizes the welfare effects to each household group under IT, PT with the 15-year horizon and PT with the 6-year horizon. As was the case for the transition dynamics, the welfare numbers are in general monotonically decreasing in the absolute value from IT to PT with the 15-year horizon, and to PT with the 6-year horizon.

8 Conclusion

We have documented that there are substantial differences in the real effects of inflation targeting monetary policies and price level targeting monetary policies. These differences arise from the redistributive effect of inflation and the fact that the different policies imply different levels of correction from surprise inflation. The channels through which this happens are the changes in net asset position relative to foreigners arising from the fact that part of that position is denominated in local currency, the changes in the real value of the public debt and consequently in the burden of taxation needed and changes in the wealth distribution due to the different portfolios of various households groups. Overall, we find that inflation targeting tends to have much larger economic effects than price-level targeting.

Appendix

A Data Sets

Survey of Financial Security The Survey of Financial Security (SFS) provides a comprehensive picture of the balance sheet of Canadian households. Information was collected on the value of all major financial and non-financial assets and on the money owing on mortgages, vehicles, credit cards, student loans and other debts. We have used the 2005 wave of the SFS and the sample consists of about 5,300 households.

National Balance Sheet Account The National Balance Sheet Accounts (NBSA) in Canada are statements of the non-financial assets owned/used in the sectors of the economy and of the financial claims outstanding among the economic units in the sectors in the economy. They consist of the National Balance Sheet for the nation as a whole, as well as the underlying sector balance sheets. The four broad sectors in NBSA consist of "Persons and Unincorporated business", "Corporations and Government Business Enterprises", "Government", and "Non-residents." The data set reports the market values of the assets and liabilities for 1990 and onwards.

Survey of Labour and Income Dynamics The Survey of Labour and Income Dynamics (SLID) are panel data based on a household survey from Statistics Canada, on Canadian persons and households with information on employment, hours of work, education, family and personal income and work transitions over life stages. There are several waves of the data set. The latest one covers the period of 1999-2004. The sample for this wave consists of roughly 15,000 households.

Canadian Financial Monitor The Canadian Financial Monitor is a private database provided by Ipsos Reid. It is based on a household survey in Canada. The sample consists of about 12,000 households every year starting in 1999. It provides detailed information across a wide range of issues related to Canadian household finances. The scope of information includes chequing & saving account detail, investment values and asset allocation, debt obligations, financial service delivery channels utilized and insurance coverage.

Communication, Auction and Reporting System The Communication, Auction and Reporting System (CARS) is a system maintained by Bank of Canada on behalf of the Government of Canada, which conducts auction operations, allows communication between Bank of Canada and external parties, and provides reports for operations and analysis. The Statistical data captured in CARS datasets are a by-product of auction operation which contains the Government of Canada loan details, issue and repurchase information, and loan outstanding information. This system contains the history for all issues after 1998 and outstanding in 1998.

B Estimation of Labour Productivity

Table 4 shows the regression results from Section 5 using the SLID data set from Statistics Canada. All the parameter estimates are significant at the 1% level. The numbers in Table 5 were calculated by applying the average school years and the average work experience for each group to obtain the average wage rate for the group. The numbers are normalized by the wage rate of the poor and ≤35 household group.

C Redistribution and Monetary policy regime

We study the redistribution of wealth from a one-time unanticipated inflation or equivalently a price-level shock. An unanticipated rise in the price level redistributes wealth from lenders to borrowers, and this is because such an increase in the price level lowers the real value of nominal assets and liabilities. We assess the magnitude of the redistribution wealth by computing the present value gain or loss of such a price level shock for each sector and different groups of households that we presented in the previous sections. This assessment of the redistribution of wealth is done for two different monetary policy regimes: an inflation targeting regime and a price-level targeting regime. Under inflation targeting, let bygones be bygones, the price level remains at its new path after a price level shock. Under price-level targeting, on the other hand, a credible central bank brings the price level back to its original path. Given that the unanticipated price level shock will be brought back to the initial path under price-level targeting, the redistribution of wealth would be on average smaller under PT than IT.

C.1 Inflation targeting

Suppose there is a one-time transitory unanticipated inflation increase of Δ that leads to a surprise jump in the price level. Under inflation targeting, the central bank does not bring the price level back and thereby the price level will remain at its new path after the shock. This surprise jump in the price level leaves nominal interest rates unchanged. Redistribution of wealth emerges since a jump in the price level reduces proportionally the real value of nominal claims.

Let us now discuss formally the present value gain or loss of a one-time transitory surprise inflation. Define i_t^{t+n} to be the nominal return on an $n-$year nominal zero-coupon bond at date t. Let $V_t(n) = \exp(-i_{t+n}^n)$ be the present value of one dollar at date $t+n$ before the price level shock of Δ. Because the nominal term structure does not change under inflation targeting after the surprise price-level shock at time t, the new time t present value of one dollar due at time $t+n$ is given by $V_t^{IT}(n)$ defined as follows

$$\begin{aligned} V_t^{IT}(n) &= \exp(-i_t^{t+n})\exp(-\Delta) \\ &= V_t(n)\exp(-\Delta). \end{aligned} \tag{13}$$

Equation (13) shows that the present value of a one dollar claim at time t is lowered by $\exp(-\Delta)$ and that such a present value is independent of the maturity of that claim. Therefore, the present value gain or loss G^{IT} is given by the following expression

$$G_t^{IT} = V_t(n) - V_t^{IT}(n) \quad = \quad V_t(n) \left[\exp(-\Delta) - 1 \right]. \tag{14}$$

As equation (14) shows, the net present value gain or loss is independent of of the maturity of a position and depends only on the size of the shock and the size of the overall position. The gain is, indeed, proportional to the net position with a coefficient of $\exp(-\Delta) - 1$. If $G^{IT} > 0$ then there is a gain from the price level shock and otherwise there is a loss. In the next section, equation (14) will be used to compute the size of the redistribution under inflation targeting. More specifically, the gain/loss of a sector or an individual household at a given point in time, will be computed by multiplying the overall net nominal position documented in the previous section by the factor of $\exp(-\Delta) - 1$.

C.2 Price level targeting

An important difference between inflation targeting and price level targeting is that the central bank commits to bring the price level back to its initial path after the shock. Under a price level targeting regime, assuming that the central bank is credible, agents in the economy expect that the central bank will bring the price level back to its targeted path after H periods, where the target horizon is given by H. Assume for simplicity that the central bank follows a linear rule (which is publicly known) with a constant slope Δ' to bring the price level back to its targeted path

$$\Delta' = -\frac{\Delta}{H}. \tag{15}$$

To bring the price level back after an unanticipated rise in inflation, the central central must generate inflation that is lower than the slope of the targeted price level. For example, if central bank targets full price stability (that is, a flat targeted price level), the central bank must create deflation in order to bring the price level back.

Since price level targeting does not exist currently in Canada, we can think of our experiment of redistribution of wealth under price level targeting as follows. In period t, there is a surprise one-time credible announcement of a price level targeting regime starting from t and at the same time there is a surprise one-time transitory increase in the price level. After the surprise price level shock and the surprise announcement of the new regime, bond prices will instantly change to account for the new inflation path or price level path. Assume that the Fisher equation holds ex ante: $i_t^{t+n} = r_t^{t+n} + \pi_t^n$, where r_t^{t+n} is the real interest rate and π_t^n is the cumulative expected inflation. Supposing that the real return does not change after the shock, the nominal $n-$year return is $\widehat{i}_t^{t+n} = i_t^{t+n} + \Delta' \min\{n, H\}$.

In this case, the time t present value of a dollar at $t+n$ becomes

$$\begin{aligned} V^{PT}(n,H) &= \exp(-\Delta)\exp(-\widehat{i}_t^{t+n}) \\ &= \exp(-\Delta)\exp(-i_t^{t+n} - \Delta' \min(n,H)) \\ &= \exp(-\Delta)\exp(-i_t^{t+n})\exp(-\Delta' \min(n,H)) \\ &= V_t(n)\exp(-\Delta)\exp\left(\frac{\Delta}{H}\min(n,H)\right). \end{aligned} \tag{16}$$

Using equation (16), we derive the present value gain or loss $G^{PT}(n,H)$ of a given position of maturity n under price level targeting with a target horizon H:

$$G^{PT}(n,H) = V^{PT}(n,H) - V_t(n) \quad = \quad V_t(n)\left[\exp(-\Delta)\exp\left(\frac{\Delta}{H}\min(n,H)\right) - 1\right]. \tag{17}$$

The total present value gain or loss $G^{PT}(H)$ under a price level targeting regime with a target horizon equal to H periods is given by the summation of $G^{PT}(n,H)$ over the maturity n:

$$G^{PT}(H) = \sum_n G^{PT}(n,H) = \sum_n \left\{ V_t(n)\left[\exp(-\Delta)\exp\left(\frac{\Delta}{H}\min(n,H)\right) - 1\right]\right\}. \tag{18}$$

Equations (16)-(18) show that the size of the present value gain or loss from a price level shock depends not only on the size of the position but also on the interaction between the target horizon H and the maturity structure n of assets and liabilities. More specifically, equation (18) illustrates that the contribution of a particular instrument to the total gain or loss from a price level shock depends on three elements in addition to the size of the shock: (i) the size of the position, (ii) the maturity of that position, and (iii) the target horizon used by the central bank. Note that, the dependence of the present value gain under price level targeting on the maturity structure is in contrast to inflation targeting.

Following Doepke and Schneider (2006a), we assume that once a position comes to maturity at time $t+n$, the funds are reinvested at the real interest rate.[7] For example, if the target horizon is high ($n < H$) then

$$V^{PT}(n,H) = V_t(n)\exp(-\Delta)\exp\left(\frac{\Delta}{H}n\right) \tag{19}$$

$$G^{PT}(n,H) = V_t(n)\left[\exp(-\Delta)\exp\left(\frac{\Delta}{H}n\right) - 1\right]. \tag{20}$$

In this case, only nominal assets and liabilities with maturity $n = 1, ..., H-1$ will be affected by the shock. For a given target horizon H, gains or losses will be higher for shorter maturity positions.

[7] Actually, for the wealth effects we are investigating, the precise manner in which short-term instruments are protected from inflation after coming to maturity is irrelevant. In the real world, it is possible to see funds generated by the short instrument be consumed, or be reinvested at a higher nominal interest rate or at the real interest rate. Moreover, because the central bank is credible and agents in the economy have perfect foresight, the wealth effects are exactly the same whether long-term bonds are held to maturity or sold early at loss.

This comes from the fact that $G^{PT}(n,H)$ is increasing in n. Moreover, $\lim_{H\to+\infty} G^{PT}(n,H) = G^{IT}$. This means as the target horizon under price level targeting goes to infinity, one converges towards an inflation targeting regime. Put it differently, for a given maturity n, gains or losses are larger for longer target horizons (G^{PT} is an increasing function of H).

Let's now discuss the case where the target horizon is small ($n \geq H$). The time t present values of a dollar at time $t+n$ and gain or loss are now given by

$$V^{PT}(n,H) = V_t(n)\exp(-\Delta)\exp\left(\frac{\Delta}{H}H\right) = V_t(n) \tag{21}$$

$$G^{PT}(n,H) = 0. \tag{22}$$

The present value of nominal assets and liabilities of maturity $n \geq H$ remains unchanged. This is because the price level will be brought back by the central bank by the time the instruments come to maturity. Therefore, if the target horizon is short, longer duration assets and liabilities are more likely to be unaffected by the price level shock.[8]

It is convenient to represent also graphically the relationship between the maturity structure, the monetary policy regime and the redistribution of wealth induced by a one-time transitory price level shock. Figure 13 illustrates such relationship.

We consider two nominal positions that differ only in their maturity: one with shorter maturity ($n = 2$) and another with longer maturity ($n = 5$). They are represented by the two vertical black solid lines. We also consider an inflation targeting regime (purple dotted horizontal line) and two different price level targeting regimes: one with a shorter target horizon ($H = 3$)—blue line—, and another with a longer target horizon ($H = 6$)— red line. Suppose that at time 0, there is a price-level shock that moves the initial price level (P_0) to a new level P_{IT}. Comparing the intersections A and B, the figure shows that given a maturity of assets and liabilities, gains and losses under price level targeting are larger for longer target horizons. Comparing also intersections B and C, one can see that for a given price level targeting horizon, gains and losses are larger (smaller) for shorter (longer) maturity positions. The gains or losses are smaller for long-term positions because the central bank has almost brought the price level back before the asset or liability comes to maturity. In fact, in the figure when the target horizon $H = 3$, the gain or loss of the position of a longer maturity $n = 5$ is zero and this is because the price level was brought back before this positions matures. As the target horizon gets larger and larger, one converges to inflation targeting (dotted purple line).[9] Under inflation targeting, gains and losses are independent of the maturity and they depend instead proportionally on the size of the shock and the size of the positions. This is because under inflation, the central bank does not take any action to return the price level to its initial targeted path. Overall the figure shows that gains and losses (or the redistribution of wealth) are larger under inflation targeting than under price level targeting.

[8] This section suggests that the target horizon under price level has important implications for the choice of maturity structure of assets and liabilities.

[9] Inflation targeting could be seen as a price level targeting with a target horizon equal to infinity.

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Table 1: Household Positions as % of Net Worth, 2005

Age cohort	≤ 35	36-45	46-55	56-65	66-75	≥ 76
	All households					
Short-term	3.91	-1.76	0.43	1.34	8.11	11.44
Long-term	-33.99	-2.31	16.22	24.98	23.97	25.37
Real	130.08	104.08	83.35	73.68	67.91	63.18
	Rich households					
Short-term	2.90	-4.30	-2.96	-3.26	7.45	7.22
Long-term	1.64	17.99	30.19	32.96	27.61	30.19
Real	95.46	86.31	72.77	70.29	64.94	62.59
	Middle-class households					
Short-term	5.05	1.39	3.32	4.52	8.27	14.40
Long-term	-92.05	-26.84	4.47	19.03	22.62	22.59
Real	187.00	125.45	92.21	76.45	69.11	63.01
	Poor households					
Short-term	16.88	-1.50	6.18	13.57	13.13	11.10
Long-term	-58.74	-19.07	-9.08	10.29	5.28	16.09
Real	141.86	120.57	102.90	76.14	81.59	72.81

Table 2: Sectoral Positions as % of GDP, 2005

Sectors	Households	Government	Foreigners
Short-term	8.96	-6.68	-2.27
Long-term	50.96	-49.77	-1.19
Real	320.89	32.06	14.35

Table 3: Calibrated Parameters

Parameter	Value	Target
Preferences		
σ	2	RBC literature
η_3	0.95	40% of time at work
η_2	0.51	40% of time at work
η_1	0.52	40% of time at work
β_3	1.19^{10}	$\frac{\text{Wealth of rich}}{\text{Wealth of middle class}} = 6.33$
β_2	1.04^{10}	$\frac{\text{Wealth of 36-45 middle class}}{\text{GDP per HH}} = 0.29$
β_1	0.99^{10}	$\frac{\text{Wealth of middle class}}{\text{Wealth of poor}} = 4.15$
ξ_3	0.0008	$\frac{\text{Bequest}}{\text{Average wealth}} = 0.088$
Demography		
s_4	0.547	Fraction of Retirees = 0.17
s_5	0.500	$\frac{\text{Size of} \geq 76}{\text{Size of 66-75}} = 0.5$
Technology		
α	0.33	RBC literature
δ	0.516	7% annual depreciation
Government		
τ	0.469	$\frac{\text{Tax revenue}}{\text{GDP}} = 0.3247$
$T_{retired}$	0.037	$\frac{\text{Retirement Income Transfer}}{\text{GDP per HH}} = 0.1251$

Table 4: Fixed Effects Estimates of the Average Wage Rate of Workers

	Model Result
Age	0.076012*
	(0.002876)
Age Squared	-0.000847*
	(0.000029)
School Years	0.029377*
	(0.002994)
Work Experience[1]	0.016393*
	(0.001752)
Constant	0.536536*
	(0.053876)
R^2	0.2695
Number of observations	57360

Note: (∗) indicates significance at the 1% level. (1) Number of years working as full-time.

Table 5: Relative Labour Productivity

	≤35	36-45	46-55	56-65
Poor	1.00	1.52	1.67	1.49
Middle Class	1.12	1.70	1.87	1.67
Rich	1.30	2.03	2.25	2.11

Table 6: Gains and Losses as % of Net Worth with 2% Shock

Age cohort	≤ 35	36-45	46-55	56-65	66-75	≥ 76
	Inflation targeting					
All	0.59	0.08	-0.33	-0.52	-0.63	-0.72
Rich	-0.09	-0.27	-0.53	-0.58	-0.69	-0.73
Middle	1.71	0.50	-0.15	-0.46	-0.61	-0.73
Poor	0.82	0.40	0.06	-0.47	-0.36	-0.53
	Price level targeting (six-year horizon)					
All	0.10	0.04	-0.07	-0.13	-0.25	-0.34
Rich	-0.06	-0.02	-0.10	-0.11	-0.26	-0.29
Middle	0.36	0.12	-0.05	-0.14	-0.24	-0.37
Poor	0.01	0.11	-0.06	-0.27	-0.24	-0.27

Table 7: Redistribution of Wealth across Sectors as % of GDP with 2% Shock

Sectors	Government	Household	Foreign
Inflation targeting	1.10	-1.17	0.07
Price level targeting (six-year horizon)	0.34	-0.38	0.04

Table 8: Welfare Effects Based on Redistribution in 2005 for Different Fiscal Policies under IT with 2% Shock, Foreign Sector Bought Out

	Higher Lump-sum Transfer			Tax Cuts			Higher Retirement Income Transfer		
Age	Poor	Middle	Rich	Poor	Middle	Rich	Poor	Middle	Rich
≤35	-0.040	0.074	-0.077	0.043	0.186	0.052	-0.149	0.008	-0.151
36-45	-0.019	0.085	-0.399	0.091	0.174	-0.344	-0.110	0.053	-0.443
46-55	-0.045	-0.112	-0.712	0.019	-0.082	-0.739	-0.122	-0.106	-0.738
56-65	-0.195	-0.314	-0.665	-0.229	-0.343	-0.688	-0.211	-0.258	-0.671
66-75	-0.186	-0.369	-0.388	-0.387	-0.441	-0.405	1.064	0.247	-0.284
≥76	-0.375	-2.350	-0.296	-0.965	-2.941	-0.312	2.876	0.900	-0.209
Total		-0.227			-0.226			-0.002	

Table 9: Welfare Effects Based on Redistribution in 2005 for Different Fiscal Policies under PT with 2% Shock and six-year Horizon, Without Foreign Sector

	Higher Lump-sum Transfer			Tax Cuts			Higher Retirement Income Transfer		
Age	Poor	Middle	Rich	Poor	Middle	Rich	Poor	Middle	Rich
≤35	-0.020	0.009	-0.039	-0.019	0.022	-0.022	-0.060	-0.023	-0.063
36-45	-0.012	0.016	-0.032	-0.004	0.025	-0.029	-0.044	-0.004	-0.046
46-55	-0.032	-0.031	-0.126	-0.034	-0.032	-0.136	-0.055	-0.030	-0.134
56-65	-0.099	-0.087	-0.126	-0.123	-0.102	-0.134	-0.094	-0.055	-0.127
66-75	-0.110	-0.132	-0.149	-0.176	-0.158	-0.155	0.290	0.077	-0.116
≥76	-0.253	-1.275	-0.116	-0.438	-1.459	-0.121	0.757	-0.264	-0.089
Total		-0.096			-0.109			-0.025	

Table 10: Welfare Effects Based on Redistribution in 2005 for Different Fiscal Policies under IT and PT with a Range of Shocks, Without Foreign Sector

Shocks	Higher Lump-sum Transfer	Tax Cuts	Higher Retirement Income Transfer
	Inflation targeting		
-5%	0.610	0.555	-0.025
-2%	0.237	0.231	-0.014
-1%	0.117	0.126	-0.011
1%	-0.114	-0.127	-0.003
2%	-0.227	-0.226	-0.002
5%	-0.551	-0.517	0.008
	Price level targeting (six-year horizon)		
-5%	0.257	0.257	0.049
-2%	0.100	0.114	0.014
-1%	0.050	0.066	0.005
1%	-0.048	-0.065	-0.002
2%	-0.096	-0.109	-0.025
5%	-0.235	-0.243	-0.058

Table 11: Welfare Effects Based on Redistribution in 2005 for Lump-Sum Transfer Policy under Different Monetary Policies with 2% Shock, Without Foreign Sector

	IT			PT15			PT06		
Age	Poor	Middle	Rich	Poor	Middle	Rich	Poor	Middle	Rich
≤35	-0.040	0.074	-0.077	-0.043	0.035	-0.039	-0.020	0.009	-0.039
36-45	-0.019	0.085	-0.399	-0.027	0.059	-0.180	-0.012	0.016	-0.032
46-55	-0.045	-0.112	-0.712	-0.048	-0.045	-0.368	-0.032	-0.031	-0.126
56-65	-0.195	-0.314	-0.665	-0.160	-0.174	-0.367	-0.099	-0.087	-0.126
66-75	-0.186	-0.369	-0.388	-0.168	-0.242	-0.254	-0.110	-0.132	-0.149
≥76	-0.375	-2.350	-0.296	-0.394	-1.892	-0.198	-0.253	-1.275	-0.116
Total		-0.227			-0.156			-0.096	

Figure 1: Lifecycle Asset, 2% shock, Lump-sum Transfer Policy under IT, Without Foreign Sector

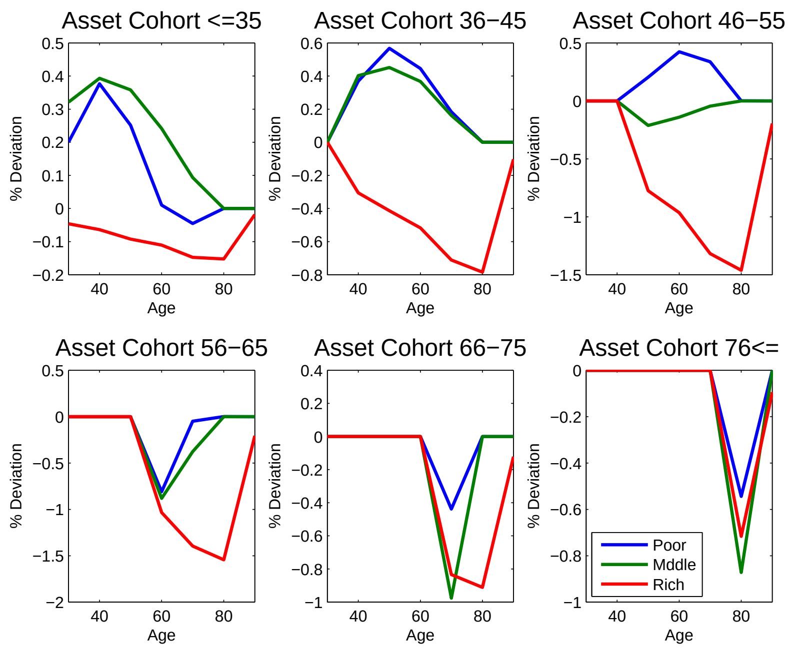

Figure 2: Lifecycle Labour, 2% shock, Lump-sum Transfer Policy under IT, Without Foreign Sector

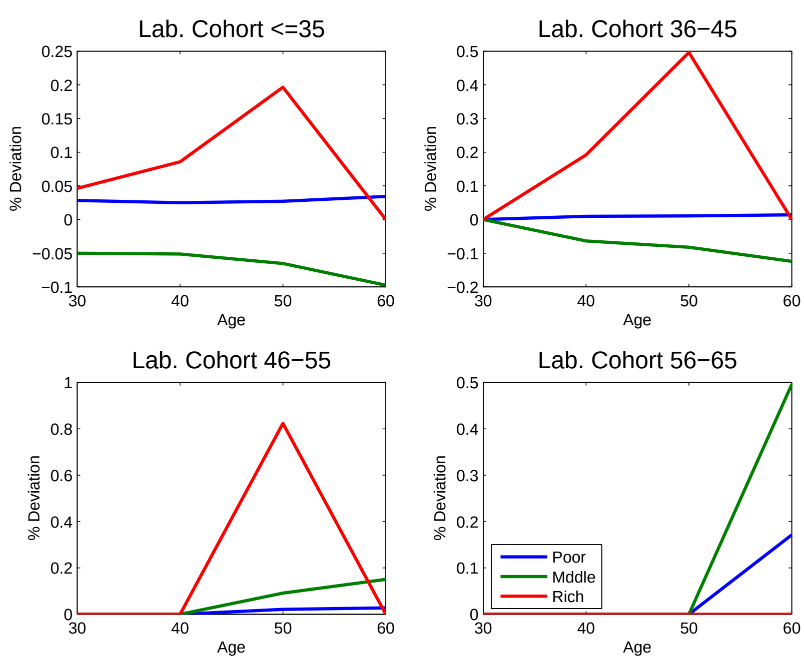

Figure 3: Lifecycle Asset, 2% shock, Lump-sum Transfer Policy under PT, Without Foreign Sector

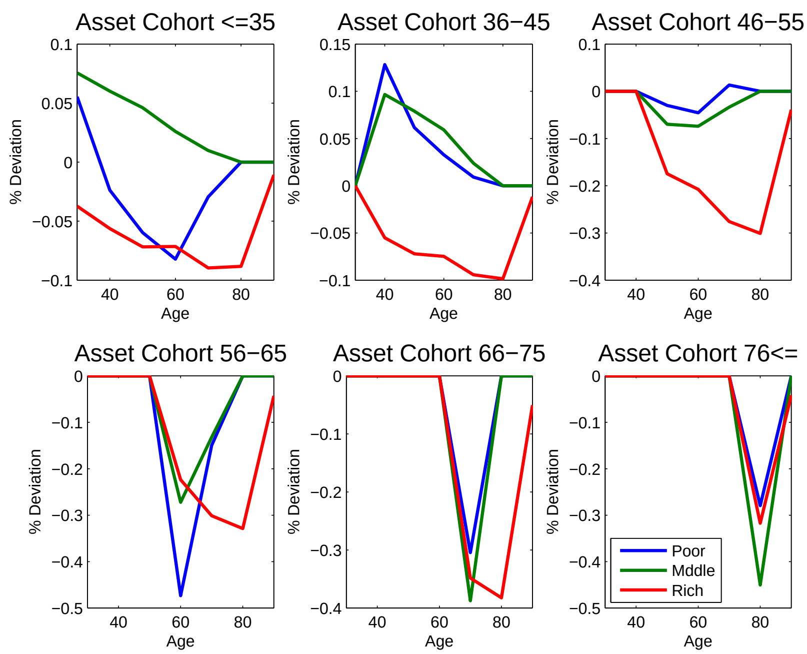

Figure 4: Lifecycle Labour, 2% shock, Lump-sum Transfer Policy under PT, Without Foreign Sector

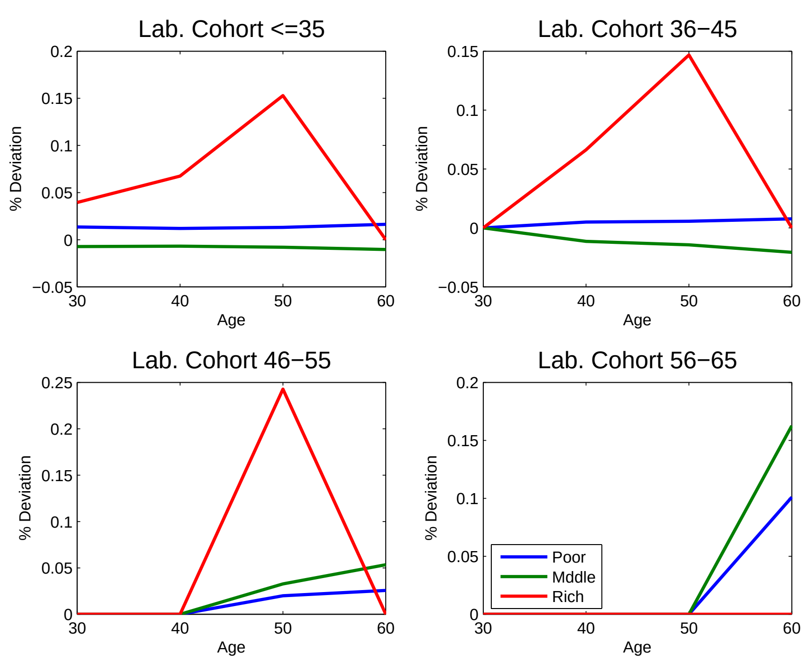

Figure 5: Output and Asset, 2% shock, Lump-sum Transfer Policy under IT and PT, Without Foreign Sector

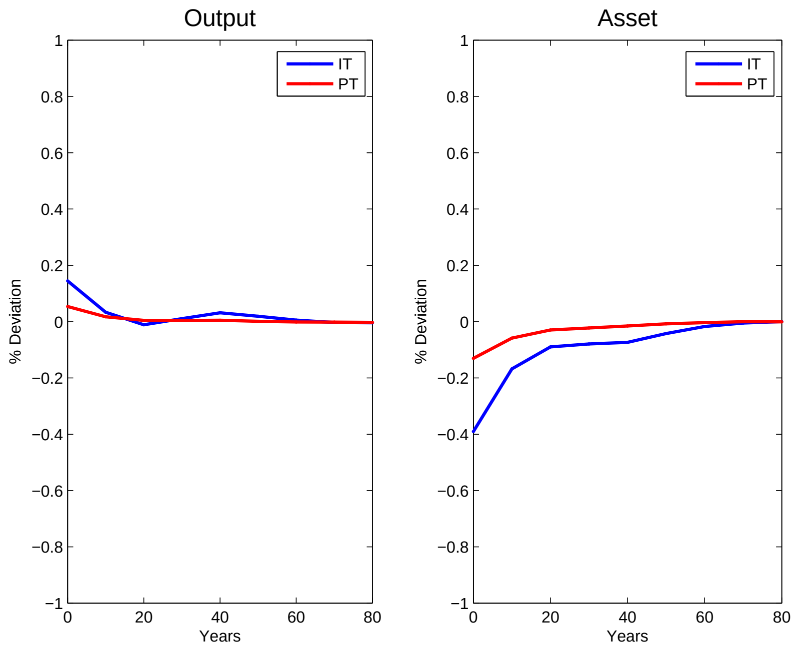

Figure 6: Output and Asset, 2% shock, Labour Tax Reduction Policy under IT and PT, Without Foreign Sector

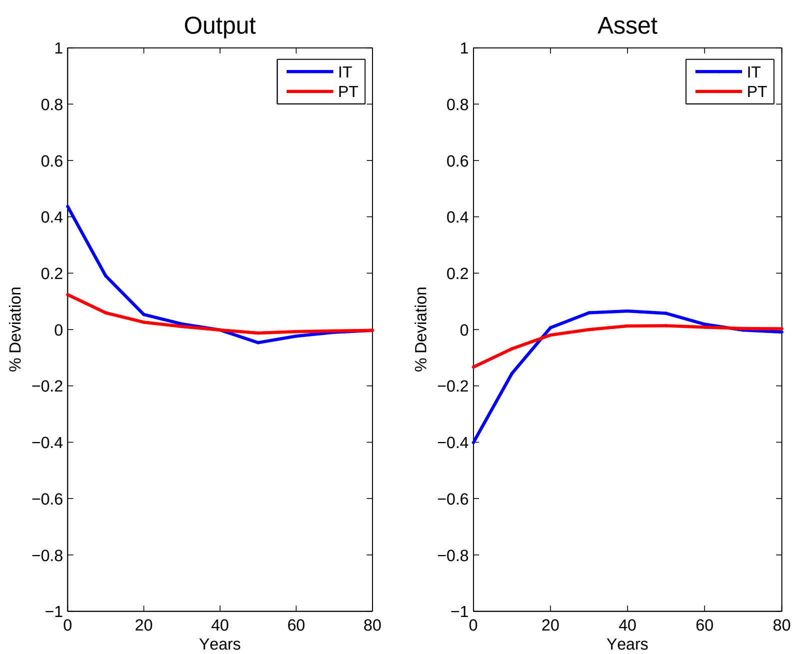

Figure 7: Output and Asset, 2% shock, Transfer to Retirees Policy under IT and PT, Without Foreign Sector

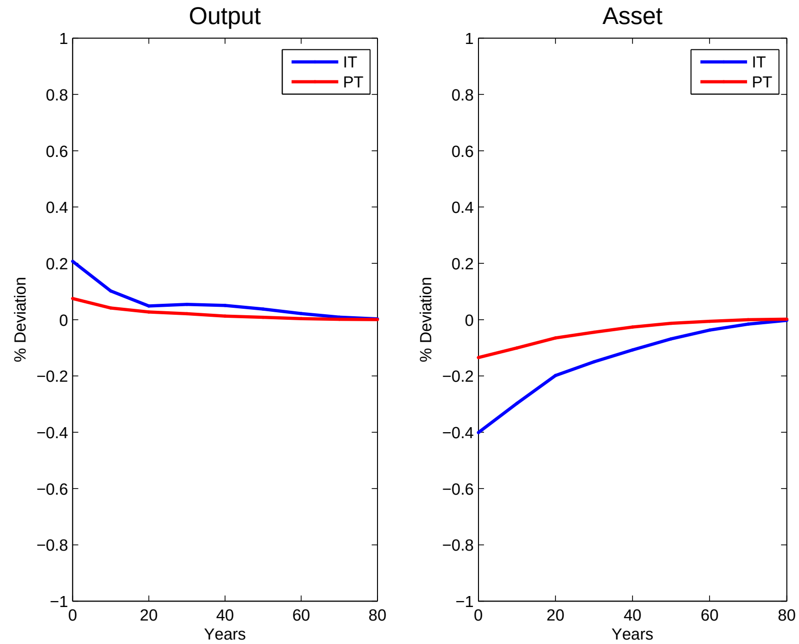

Figure 8: Output and Asset, 2% shock, Labour Tax Rate Adjustment Period by Period under IT and PT, Without Foreign Sector

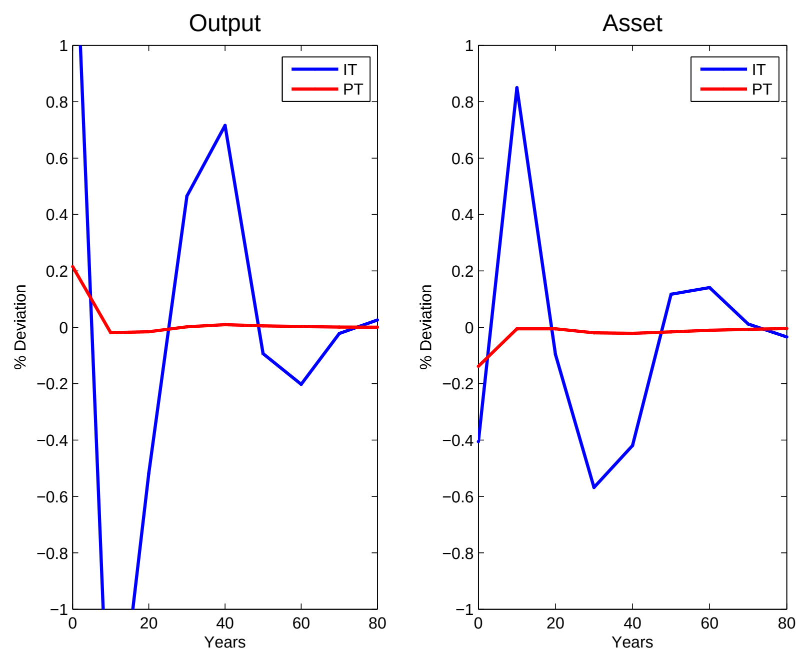

Figure 9: Output and Asset, 2% shock, Lump-sum Transfer Policy under IT, PT6 and PT15 , Without Foreign Sector

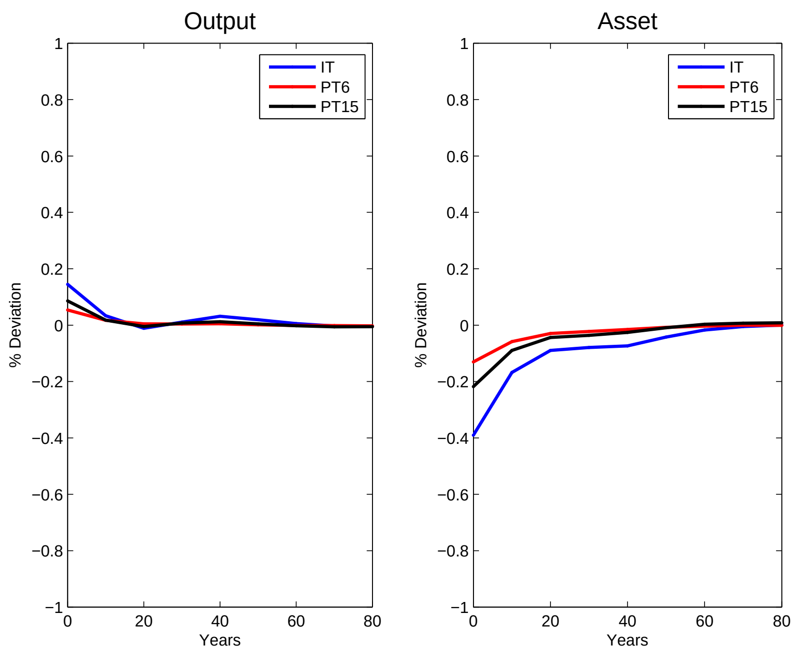

Figure 10: Output and Asset, -5 to 5% Shocks, Lump-Sum Transfer Policy under IT, Without Foreign Sector

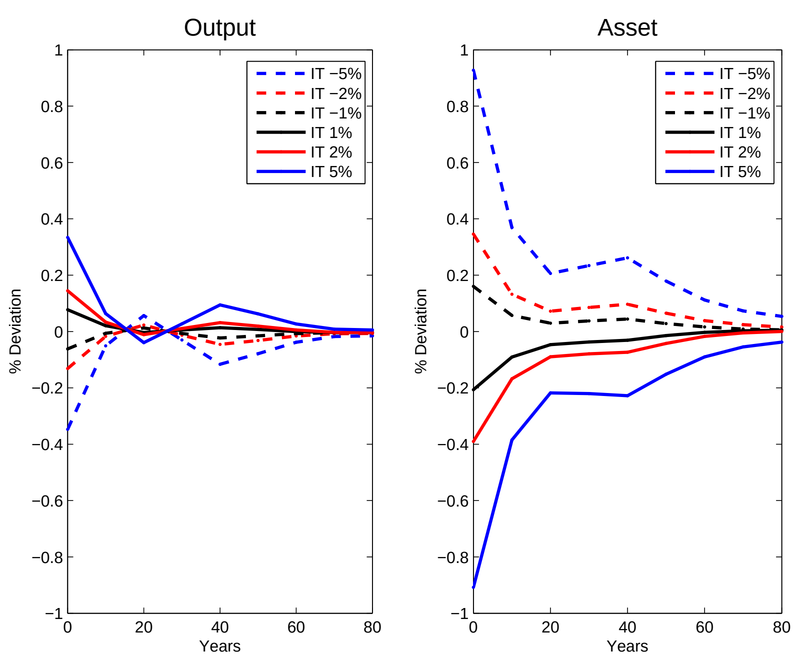

Figure 11: Output and Asset, -5 to 5% Shocks, Lump-Sum Transfer Policy under PT, Without Foreign Sector

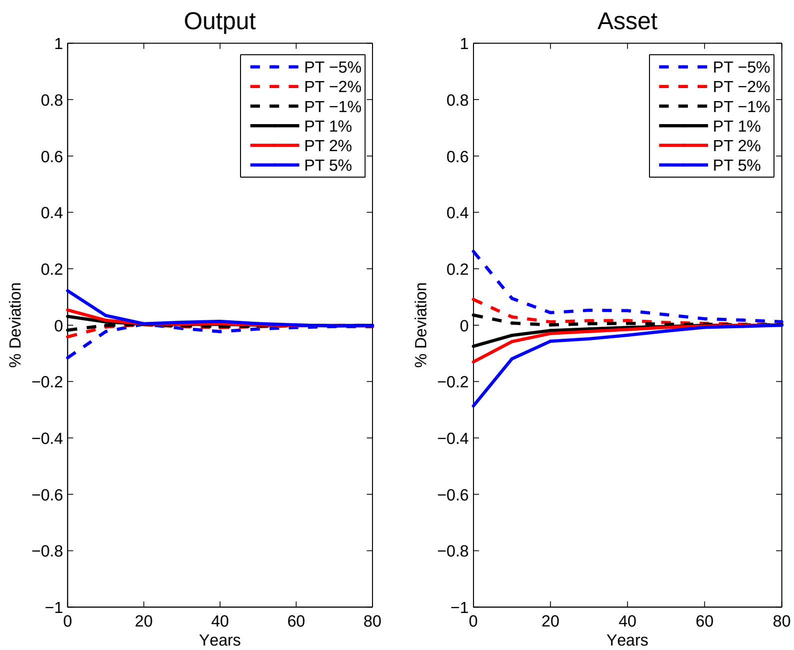

Figure 12: Output and Asset, 2% Shock, Lump-sum Transfer Policy under IT, with and without Foreign Sector

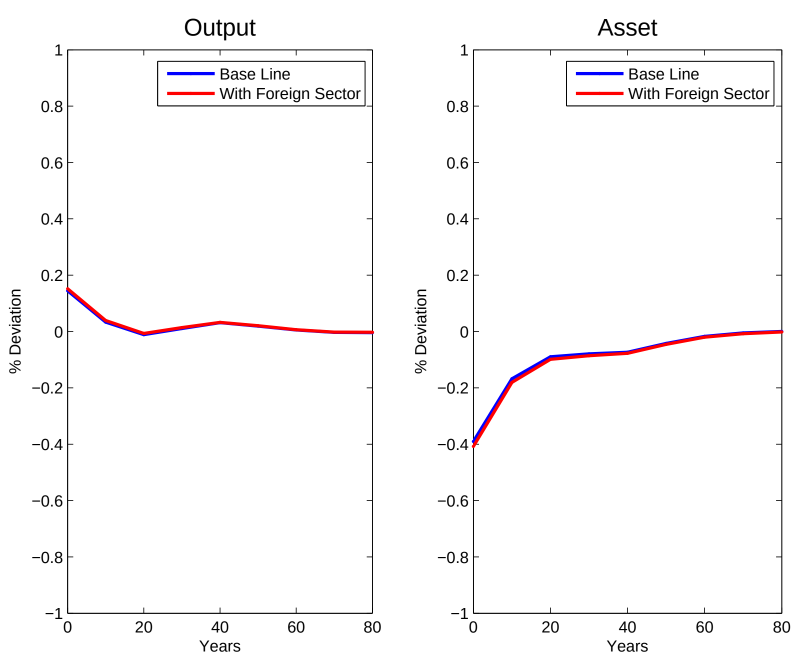

Figure 13: Gains or Losses as a Function of the Maturity Structure and the Monetary Policy Regime