Journal of Monetary Economics 57 (2010) 637–652

Contents lists available at ScienceDirect

Journal of Monetary Economics

journal homepage: www.elsevier.com/locate/jme

Aggregate and welfare effects of redistribution of wealth under inflation and price-level targeting ☆

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ARTICLE INFO

Article history:
Received 9 September 2008
Received in revised form
5 May 2010
Accepted 6 May 2010
Available online 2 June 2010

ABSTRACT

An unanticipated rise in the price level redistributes wealth from lenders to borrowers. Its size depends on the monetary policy regime, as inflation targeting (IT) and price-level targeting (PT) have different implications for the price-level path following price-level movements. The effects of an unexpected 1% price-level increase are measured and assessed under both regimes. Overall, the redistribution of wealth and the implied aggregate and welfare effects are larger under IT than they are under PT. The youngest, the poorest, and the government gain at the expense of the rest of the population and, when the government gain is given to households as lump-sum transfers, the effects on GDP are negative and long-lasting.

1. Introduction

Because many assets and liabilities are fixed in nominal terms, a positive shock to inflation redistributes wealth from lenders to borrowers. These redistributional effects of inflation are analyzed under two monetary policy regimes: inflation targeting (IT) and price-level targeting (PT).[1] The main nontrivial difference is that under IT, unexpected disturbances to the price level are ignored, while under PT, they are reversed. 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 returns to its initial path. Short-term nominal assets (e.g., cash), whose real values are depreciated at the instantaneous rate of inflation, fare equally well under IT and PT. However, long-term nominal assets, which depreciate by the ratio of the current price to the price level at the time of maturity, are subject to higher depreciation under IT than under PT. Consequently, considering the redistributional effects of inflation is important when comparing these two regimes. We analyze, using Canadian data, the effects that arise under IT and PT through the redistributional channel, as nominal holdings are revalued following an unexpected surge in the

☆ We are grateful to the editor and anonymous referees for their feedback. We also thank participants in the Workshop on Demographic Changes and Policy Implications at the Bank of Canada, the Bank of Canada-European Central Bank Conference on Defining Price Stability, 2008 Midwest Macro Meetings, 2008 Canadian Economic Association Meetings, 2008 North American Econometric Society Summer Meetings, 2008 Far Eastern and South Asian Econometric Society Summer Meetings, 2008 Computing in Economics and Finance Conference, 2008 Society of Economic Dynamics, and the Bank of Japan. We also thank Ian Christensen, Allan Crawford, Matthieu Darracq-Paries, Marty Eichenbaum, Walter Engert, Martin Schneider, Nancy Stokey, and Michele Tertilt for comments. We thank David Xiao Chen and Thomas Carter for excellent research assistance. Ríos-Rull thanks the National Science Foundation (Grant SES-0079504). The views expressed herein are those of the authors and not necessarily those of the Bank of Canada, the Federal Reserve Bank of Minneapolis, or the Federal Reserve System.

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[1] While many central banks have embraced IT as their official modus operandi, PT is considered a serious contender.

0304-3932/$ - see front matter
doi:10.1016/j.jmoneco.2010.05.001

price level.[2] The paper addresses two issues: (i) The redistribution of unexpected inflation under IT and PT and (ii) the output and welfare implications of unexpected inflation under IT and PT.

The direct redistribution induced by unexpected inflation, as indicated by the nominal portfolios of the different households and sectors in the economy is large: a one-time positive 1% price-level shock lasting one period under IT leads to a household sector wealth loss of 0.40% of GDP or $5.5 billion. Under PT, the redistribution is still sizeable but much smaller, about 0.15% of GDP. Redistributions occur because the portfolios of households are different. Moreover, the difference between the two monetary policy regimes arises because the use of long-term assets and liabilities is prevalent in the economy, as long-term claims are less affected under PT. The government has sizeable long term net liabilities that are held by households (and to a much lesser extent by foreigners). In addition, there is a large redistribution of wealth within the household sector: the young middle class and the poor are net nominal borrowers mostly due to mortgage liability holdings, a long-term liability, while the rich and the old are net savers due to long-term assets such as pensions and long-term bond holdings. The middle aged are also savers due to pensions. These features speak to the potential importance with respect to monetary policy analysis of taking into account the portfolio of assets and liabilities with different terms to maturity.

Furthermore, even though the redistributive effects of unexpected price shocks are zero sum across sectors in the economy, there are aggregate effects on output under both monetary policy regimes. The redistribution of assets across households (including the necessary fiscal adjustment of the windfall gains for the government, which is lower lump-sum taxation in our baseline scenario) induces wealth effects across households that do not wash out. An overlapping generations model, where households are heterogeneous in preferences and productivity to match the observed patterns of consumption, hours worked, and wealth holdings across age and income groups, provides the framework for analysis. A positive price-level shock generates direct redistributions of wealth mostly from high-income, old, and middle-aged savers to young and low-income households. The induced wealth effects are that young households reduce their work effort, and middle-aged households increase their work effort. The retirees also face a wealth loss, but they cannot increase their work effort. Differences of productivity among households also affect the extent of their responses. Because the beneficiaries of price-level increases are mostly the young and the poor that have a higher response per dollar, the total reduction in labor effort is larger than the increase in work effort carried out by richer and older households (a good part of whom, because of retirement, do not increase their work effort). The calculation of the output path requires a careful equilibrium analysis, the reason being that changes in work effort of households translate into changes in government revenues, and a proper assessment of the effects of the price changes requires that the government fiscal position remains neutral. Consequently, there is a need to find the exact transfers to households that leave the government finances balanced, a fixed point problem.

Under IT, the effects on output, when the windfall gains for the government are rebated in a lump-sum fashion, last for a long period of time. They imply a cumulative reduction of output over 40 years equivalent to 0.54% of one-year GDP or $600 per household. Because the initial redistribution is much larger under IT, its effects on work effort and output are also larger than under PT, for which the 40-year cumulative output loss is 0.13% or about $145 per household.

Finally, the model economy can be used to assess the welfare of both monetary policy regimes. However, the aggregation of the welfare effects is a tricky proposition given that households differ in their preferences. This difference in preferences makes it very hard to do inter-household welfare comparisons that summarize the findings into one single aggregate number. Consequently, the welfare numbers are reported in terms of the added value for each household type of the change triggered by the price increase. These changes are clearly different from the initial changes in the value of nominal assets and liabilities and incorporate the changes arising from the government asset position. Such asset position is affected not only by the price hike but also by the subsequent tax revenues that depend on households' work effort. The particular details of the redistribution of the government gains from the price-level increases matter a lot for the specific details of the welfare gains or losses from the price increase. In general, as with the initial redistribution, the young and the poor gain from the increase and the old and the rich lose.

The use in the model of the portfolios held in the United States becomes a form of sensitivity analysis regarding the importance of portfolios. There are some differences in the effects of price-level shocks relative to the model with Canadian portfolios. Under IT and with lump-sum transfers of the government windfall, output over 40 years decreases by 0.39% of one-year GDP (instead of 0.54%), whereas under PT it decreases by 0.11% (instead of 0.13%). The output effects are slightly smaller with the US portfolio than with the Canadian counterpart because less nominal lending and borrowing took place in the United States than in Canada.[3] Still these numbers are not sufficiently different to change the main findings of our paper.

There are several strands of existing literatures that are relevant to this paper. The documentation of nominal portfolios of households is done by Doepke and Schneider (2006a) in their seminal paper for the United States and by Meh and Terajima (2008) for Canada. Both of these papers have shown that inflation causes a major redistribution of wealth as it

[2] The Canadian data are particularly relevant for at least two reasons. First, Canada presently implements inflation targeting. Second, a review of the monetary policy framework is currently under way and a price-level targeting policy is considered as a serious option. However, the insights of the paper are applicable to other countries. US data are also used for a sensitivity analysis.

[3] Unlike the numbers for Canada, which are based on portfolio holdings of 2005, those of the United States are from Doepke and Schneider (2006a), who use 1989 data. Another difference is that the American data do not include defined benefit pensions.

erodes the real value of nominal assets and liabilities. 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, yet they do not consider monetary policy regimes and the differential effects under IT and PT as possible sources of government-created redistribution. Their focus is on the effects of inflation in general. There is literature studying the benefits and costs of IT and PT[4]; however, this literature does not consider the redistributional effects of price-level changes and their macroeconomic consequences under IT and PT. There is also literature that considers the welfare costs of inflation in monetary models where inflation affects the distribution of wealth.[5]

The remainder of the paper is organized as follows. Section 2 describes in detail how IT and PT have different redistributional impacts. Section 3 documents the nominal and real portfolios held by Canadian households and by the government and the foreign sectors. Section 4 describes the overlapping generations model and defines equilibrium under both regimes. Section 5 discusses the calibration of the model and describes how households are affected when the price level experiences a 1% shock. Section 6 calculates the extent of direct redistribution from the price-level shock and discusses the aggregate and welfare results under various fiscal and monetary regimes. Section 7 applies the United States portfolio of nominal claims to the Canadian economy as a sensitivity analysis. Section 8 concludes.

2. Calculating the redistribution of wealth under IT and PT

The method used to compute the extent of redistribution of wealth from a price-level shock is described in this section. Its effects depend crucially on the monetary policy regime in place, as the size of the redistribution of wealth depends on the subsequent price-level path which is determined by policy. Hence, either *inflation targeting* (IT) or *price-level targeting* (PT) is explicitly incorporated in our framework to capture the difference in the post-shock price-level path.

An unanticipated rise in the price level redistributes wealth from lenders to borrowers as it lowers the real value of nominal assets and liabilities. Using the framework in this section and the nominal portfolio documentation in Section 3, the magnitude of the redistribution of wealth is assessed by computing the present value gain or loss of such a price-level shock for each sector as well as different groups of households under IT and PT. Under IT, bygones are bygones, and the price level remains at its new path after a price-level shock. On the other hand, under PT, 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 PT, nominal claims with long-term maturities are less affected by these price changes. Hence, the redistribution of wealth with respect to these claims is expected to be smaller under PT than under IT.

2.1. Inflation targeting

Suppose there is a onetime transitory unanticipated inflation increase of size Δ that leads to a surprise jump in the price level. Under IT, the central bank does not bring the price level back, and therefore 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.

To see the present value gain or loss of a onetime transitory surprise inflation, let $i_{t,n}$ be the nominal return on an n-year nominal zero-coupon bond at date t and $V_t(n)=\exp(-i_{t,n})$ 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 IT 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 $V_t^{IT}(n)=\exp(-i_{t,n})\exp(-\Delta)=V_t(n)\exp(-\Delta)$, which 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

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

The net present value gain or loss is independent of the maturity of a position and is proportional to the net position with a coefficient of $\exp(-\Delta)-1$. Eq. (1) will be used to compute the size of the redistribution under IT.

2.2. Price-level targeting

When a shock hits, the central bank that follows PT brings the price level back to its initial path after H periods. Assume that the central bank follows a linear rule with slope $\Delta'=-(\Delta/H)$ to bring the price level back to its targeted path. Such policy generates inflation that is lower than the slope of the targeted price-level path. For example, if the central bank targets full price stability, i.e., a constant targeted price level, it must create deflation in order to bring the price level back.

Since PT does not currently exist in Canada, the experiments under PT can be considered as having in period t a surprise onetime credible announcement of a PT regime starting from t, followed immediately by a surprise onetime increase in the price level. Also, an assumption is made that the real interest rate is unaffected by the whole process and that bond prices

[4] See, for example, Gaspar et al. (2007), Ambler (2007), Cote (2007), Vestin (2006), Svensson (1999), and Duguay (1994).

[5] See Albanesi (2007), Erosa and Ventura (2002), and Cukierman et al. (1985).

adjust instantaneously to account for the new price-level path so that the Fisher equation continues to hold. So relative to the before-shock nominal n-year return $i_{t,n}$, the after-shock n-year return is $i^{PT}_{t,n} = i_{t,n} - (\Delta/H)\min\{n,H\}$.

In this case, the time t present value of a dollar at $t+n$, $V^{PT}(n,H) = \exp(-\Delta)\exp(-i^{PT}_{t,n})$, becomes $V^{PT}(n,H) = V_t(n)\exp(-\Delta)\exp((\Delta/H)\min(n,H))$. Defining the present value gain or loss $G_{PT}(n,H)$ of a given position of maturity n under PT with a target horizon H to be as $G^{PT}(n,H) = V^{PT}(n,H) - V_t(n)$ and aggregating it over the future to obtain the total present value gain or loss $G^{PT}(H)$ yields

$$G^{PT}(H) = \sum_n G^{PT}(n,H) = \sum_n \left\{ V_t(n) \left[\exp(-\Delta)\exp\left(\frac{\Delta}{H}\min(n,H)\right) - 1 \right] \right\}. \tag{2}$$

The net gain 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. In contrast with IT, Eq. (2) illustrates that the contribution of a particular instrument to the total gain or loss from a price-level shock under PT depends on two elements in addition to the sizes of the shock and the nominal position: (i) the maturity of that position and (ii) the target horizon used by the central bank.

For a given target horizon, H, gains or losses will be smaller for longer maturity positions; moreover, $\lim_{H \to +\infty} G^{PT}(n,H) = G^{IT}$, as the target horizon under PT goes to infinity, the resulting price-level path converges toward that under IT. Alternatively, if the target horizon is small ($n \geq H$), the time t present value of a dollar at time $t+n$ is $V^{PT}(n,H) = V_t(n)\exp(-\Delta)\exp((\Delta/H)H) = V_t(n)$ and consequently, the net gain $G^{PT}(n,H)$ is zero.

3. Nominal assets and liabilities

Given the methodology to calculate the size of redistributions for a given nominal instrument, the documentation of portfolios of households in the economy in Canada is now discussed. The methods and specific variables used for constructing net nominal positions as well as the resulting positions are detailed in Meh and Terajima (2008). Hence, they are briefly discussed in this section. Nominal assets and liabilities are defined to be all nominal securities denominated in Canadian dollars. Four sectors of the economy are observed: household, government, foreign, and business. Positions of the business sector are allocated to the other three sectors as indirect positions, leaving us with the first three sectors.[6] The net nominal position (NNP) of a sector or a household group is the difference between the market value of its nominal assets and liabilities, both direct and indirect.

For the sectoral positions, our main data source is the National Balance Sheet Accounts (NBSA) in 2005, as provided by Statistics Canada.[7] For detailed household nominal positions, the 2005 Survey of Financial Security (SFS), which provides microdata on income and wealth collected by Statistics Canada, is used. For our purposes, any financial instruments denominated in Canadian dollars are considered nominal unless their returns are fully indexed to inflation. Nonfinancial instruments and those denominated in foreign currencies are real. Four broad categories of nominal financial instruments are defined: short-term instruments, bonds, mortgages, and employer pension plans.[8] All nominal assets and liabilities of sectors and household types are assigned to one of these categories.

For household types, six age groups are considered: up to 35 years, 36–45, 46–55, 56–65, 66–75, and over 75. Within each age group, households are divided into three economic classes: *rich*, *middle class* and *poor*. The top 10% of households in net worth are defined as rich. The rest of the households (90% of all households) are sorted by income ignoring their net worth. Then among these households, those (70% of all households) with higher income are characterized as middle class and the remaining households (20% of all households) as poor.

Table 1 describes the net nominal positions and nominal portfolios for different classes and age groups from the 2005 SFS.[9] Overall, young households are net nominal borrowers (i.e., negative NNPs) and old households are net nominal lenders (i.e., positive NNPs). Poor households borrow mainly through mortgages and bonds when young. The youngest poor cohort holds debts in mortgages (37.77% of net worth) and in bonds (37.66%). Poor households save mainly through short-term nominal instruments. Middle-class households borrow mostly through mortgages. In fact, the youngest middle-class households are the most indebted, with an NNP of 89.44% of net worth. The majority of this debt is in the form of mortgages, which account for 81.62% of net worth. For the middle-aged and old middle class, pensions are the largest savings category. Rich households of all age groups except for the youngest are net nominal savers. Rich households save mostly through mortgages and bonds.[10]

For the sectoral positions, Table 2 shows the NNPs as a percentage of GDP. The household sector is the main net nominal lender who has a positive NNP of 40.14% of GDP. The government sector is the net nominal borrower whose debts amount

[6] Since the business sector is entirely owned by other sectors through the equity claim they hold against businesses, the redistribution effects on the business sector are indirectly carried over to these sectors.

[7] Brief descriptions of the data sets used in the paper are found in Appendix, available as *Supplementary Material* to this paper.

[8] The short-term instrument category includes nominal assets and liabilities with a term to maturity of one year or less (e.g., deposits and short-term paper), while bonds are nonmortgage and nonpension nominal financial instruments with a term to maturity greater than one year (e.g., corporate and government bonds).

[9] Real asset positions are also shown in the table. Note that the NNP and the real position add up to 100%.

[10] Mortgage positions can be positive because of the indirect positions that reflect the financial business sector's mortgage assets.

Table 1
Nominal and real positions as percentage of net worth by age and income class.

Type of instrument	Age cohort					
	≤ 35	36–45	46–55	56–65	66–75	> 75
All households						
Short	4.83	−1.01	1.48	2.40	9.00	12.27
Mortgage	−37.95	−13.57	0.07	4.48	3.55	3.29
Bond	−2.63	4.70	6.50	7.90	6.70	7.68
Pension	−0.05	−1.31	5.01	7.36	8.68	8.65
Total NNP	−35.80	−11.19	13.06	22.14	27.93	31.89
Real	135.80	111.19	86.94	77.86	72.07	68.11
Poor households						
Short	18.90	−0.06	5.04	13.84	12.58	10.95
Mortgage	−37.77	−19.44	−9.39	2.35	−2.56	2.10
Bond	−37.66	−3.53	0.17	2.59	1.40	6.06
Pension	4.42	−4.09	0.92	1.95	2.73	4.63
Total NNP	−52.11	−27.13	−3.26	20.73	14.15	23.75
Real	152.11	127.13	103.26	79.27	85.85	76.25
Middle-class households						
Short	5.83	2.24	4.40	5.49	9.06	14.91
Mortgage	−81.62	−35.43	−11.11	−2.91	1.62	1.70
Bond	−18.11	−0.90	2.16	4.10	4.56	4.56
Pension	4.46	7.63	15.96	19.36	14.11	12.71
Total NNP	−89.44	−26.47	11.40	26.04	29.36	33.88
Real	189.44	126.47	88.60	73.96	70.64	66.12
Rich households						
Short	3.86	−3.73	−1.97	−2.36	8.48	8.57
Mortgage	−11.31	4.71	12.92	13.66	7.15	5.71
Bond	7.71	9.72	11.73	13.00	10.50	12.37
Pension	−2.92	−8.53	−6.25	−6.77	1.38	3.18
Total NNP	−2.66	2.16	16.43	17.53	27.51	29.82
Real	102.66	97.84	83.57	82.47	72.49	70.18

Notes: Numbers represent the percentages of household group net worth for each category. Total NNP is the total net nominal position (i.e., nominal assets minus nominal liabilities) which is the sum of the four nominal sub-categories. Real is the total real asset position. Numbers are expresses as a fraction of age-income group net worth. The sum of total NNP and real is 100.

Table 2
Nominal positions as percentage of GDP by sector.

	Households	Government	Foreigners
Short	12.25	−7.60	−4.65
Mortgage	−11.94	3.19	8.75
Bond	22.14	−29.67	7.53
Pension	17.69	−8.91	−8.79
Total NNP	40.14	−42.99	2.85
Real	327.42	31.92	12.72

Notes: Numbers represent the percentages of annual GDP. Total NNP is the total net nominal position which is the sum of the four nominal sub-categories. Real is the total real asset position.

to 42.99% of GDP. The NNP of the foreign sector is positive and small. The household sector mainly borrows through mortgages and saves through bonds and pensions. The government is the issuer of those bonds. Both the government and the foreign sectors hold pension debts to households. More detailed discussions of nominal positions can be found in Meh and Terajima (2008).

When the portfolios of households in Canada (Table 1) and the United States (Table 1 in Doepke and Schneider, 2006a) are compared, the main difference is that the middle-aged middle-class households, specifically those in the 46–55 age bracket, are net nominal lenders in Canada, whereas they are net nominal borrowers in the United States. Also, in Canada the 56–65 group, the other middle-aged group, has 26% of its assets in nominal terms whereas their US counterparts have only 14%. Another major difference between Canada and the United States lies in the composition of short-term and long-term claims. US households tend to hold more long-term debt, e.g., mortgages. For example, the US middle-class households in the 46–55 age group hold mortgage debts of about 21% of net worth relative to 11% for their Canadian counterparts. As discussed in Section 7, these differences are important factors that contribute to the aggregate and welfare consequences of inflation.

4. Model

Given the redistributions, calculated in the previous sections, the analysis of the aggregate and welfare effects of those redistributions requires a structural model. The model consists of a small open economy populated by overlapping generations with a positive world rate of return, $\bar{r}$.

4.1. Model environment

The description of the model requires the description of its demographics and preferences, production capabilities, the details of the price shock and the central bank as well as the induced problem of the households, the budget constraint of the government and the role played by foreigners.

4.1.1. Demography and preferences

Households can live up to I periods, with s_i being the probability of surviving from age i to age $i+1$, and they can be one of $j \in \{1, \ldots, J\}$ skill types with an endowment of efficient units of labor, e_{ij}. The measure of each type ij is given by $\Omega(i,j)$ where $\sum_{i,j}[\Omega(i,j)] = 1$. Households retire at the mandatory age i^*. In period t, each individual of age i and type j maximizes his expected discounted lifetime utility,

$$E\left\{\sum_{i=1}^{I} \beta_j^{i-1} u_j(c_{i,j,t}, 1-n_{i,j,t}) + \beta_j^I \Psi_j(a_{I,j,t})\right\}, \tag{3}$$

where E is the expectations operator. Expectations are taken over age-specific mortality shocks and stochastic price-level shocks z. In Eq. (3), u_j and β_j denote the temporal utility function and the discount factor that may vary by type, and $c_{i,j,t}$ and $n_{i,j,t}$ are, respectively, consumption and labor of age i, type j households at time t. Households have a bequest motive, and it is modeled as a "warm glow" preference for transfer to the next generation: $\Psi_j(a)$, where only age I households give intended bequests to their children. The bequest is modeled to analyze the importance of the intergenerational effects of an inflation shock. The warm glow preference implies that households derive utility from giving bequests to their children. Bequests left by age I households of type j at time t are equally allocated to all age 1 of the same type j at time $t+1$. The preference for a bequest is also type-specific in order to capture the observed heterogeneity in bequests by type.

Each household chooses savings, labor, and bequests optimally. However, the composition of assets is assumed to be exogenously determined and depends on age and skill. Let us denote α_{ij}^s, α_{ij}^ℓ, and α_{ij}^r to be these exogenous shares of assets. Specifically, α_{ij}^s is 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_{ij}^ℓ is the share held in long-term nominal form for age i and type j households with a nominal rate of return equal to $(1+\bar{\pi})(1+\bar{r})$, where $\bar{\pi}$ is the targeted inflation rate; and α_{ij}^r is the share held in real assets for age i and type j households with a real rate of return equal to $(1+\bar{r})$.

4.1.2. Production

Output in this economy is given by a Cobb–Douglas aggregate production function $F(N_t,K_t) = K_t^\alpha N_t^{1-\alpha}$, where N_t and K_t are, respectively, aggregate labor and capital inputs at time t. Given prices, firms maximize profits and as a result following equations hold in the equilibrium: $\bar{r}+\delta = \alpha(K_t/N_t)^{\alpha-1}$ and $w = (1-\alpha)(K_t/N_t)^\alpha$, 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 labor ratio is constant.

4.1.3. 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

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

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

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

4.1.4. Problem of households

It is convenient to recursively represent the problem of a household under two different regimes indexed by $\rho \in \{IT, PT\}$. 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:

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

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

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

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

$$R^{s,PT}(z') = R^{s,IT}(z') = \frac{1}{(1+\bar{\rho})(1+z')},$$

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

Eq. (5) is the budget constraint of the household. The left-hand side of Eq. (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 labor income with a current labor income tax rate τ_t, and government period t transfer T_{it}, which is age dependent. The transfer consists of two parts and is given by $T_{it} = T^d_t + T^r_{it}$. The first part, T^d_t, is the accidental bequest which is distributed equally as a lump-sum transfer to all households.[11] The second part, T^r_{it}, is the government retirement income transfer to the retired households in the form of social security or the government's retirement income transfer program. Eq. (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 households reach the last age and thus can give bequest $a'(z')$ to their children. It is assumed that households cannot die with negative assets or negative bequests.

4.1.5. Government

The government finances government consumption (G_t), transfer to retirees, and interest payments on government debt B_t by raising revenue from taxing labor income and issuing government debt. There are two types of government budget constraints: the period-by-period budget constraint and the present value budget constraint. The period-by-period budget constraint of the government is described as follows:

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

Similarly, the present value budget constraint is given by

$$\sum_{t=0}^{\infty}\left(\frac{1}{1+\bar{r}}\right)^t G_t + \bar{r}\sum_{t=0}^{\infty}\left(\frac{1}{1+\bar{r}}\right)^t B_t + B_0 + \sum_{t=0}^{\infty}\left(\frac{1}{1+\bar{r}}\right)^t \sum_j \sum_{i \geq i^*} \Omega(i,j) T^r_{i,t} = \sum_{t=0}^{\infty}\left(\frac{1}{1+\bar{r}}\right)^t \sum_{i=1,j}^{i^*-1} \Omega(i,j)\tau_t w e_{ij} n_{i,j,t}, \quad (8)$$

where the left-hand side shows the present value of all current and future expenditures and the right-hand side of the tax revenues. Both types of the budget equation are used in the simulations.

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:

$$\sum_{i>1,j} \Omega(i-1,j)(1-s_{i-1})a_{i,j,t} = T^d_t. \quad (9)$$

The behavior of the government is taken as exogenous and is calibrated to the steady state of the actual economy. Different types of fiscal policy reactions after an inflation-induced redistribution shock are considered.

4.1.6. Foreigners

The behavior 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^F_t.

4.2. Equilibrium

An equilibrium for a given regime $\rho \in \{IT,PT\}$ is a world interest rate $\bar{r}$, 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 $\{G_t, \tau_t, B_t, T_t\}$, and foreigners' debt $\{a^F_t\}$ such that: (i) given $\bar{r}$ and government policies, each household solves the household problem (4)–(6); (ii) given prices, firms maximize profits; (iii) the equal lump-sum transfer constraint (9) of accidental bequest holds every period; (iv) the

[11] The accidental bequest is the reallocation of those assets left behind by households who died before reaching age I.

government budget constraint (7) or (8) is satisfied; (v) the labor market clears in every period:

$$N_t = \sum_j \sum_{i=1}^{i^*-1} \Omega(i,j) e_{i,j} n_{i,j,t} \quad \text{and} \tag{10}$$

(vi) the good market clears in every period:

$$\sum_{i,j} \Omega(i,j) c_{i,j,t} + I_t + G_t + NX_t = Y_t, \tag{11}$$

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

4.3. Shocks

To have shocks to the environment that directly translate into unexpected price changes, consider a transaction technology such that $Y\nu = M/P$, where Y is the output, ν is the velocity, and M is the 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 implements either IT or PT. This is the simplest, but not the only, possible theory of the shock consistent with this model.

5. Calibration

Recall that the population is partitioned into three income and wealth classes and six age groups. The main nonstandard part of the calibration has to do with the cross-sectional distribution of earnings and wealth. Class-dependent preferences and endowments are matched with the joint distribution of earnings and wealth in the data. In addition, demographics, taxes, and technology are specified to match population structure, macroeconomic aggregates, and government policy. In Table 3, a summary of those targets and parameter values, that are not sufficiently described in the text and that are necessary to solve the model, is given. All numbers are reported in yearly terms and have to be adjusted to get to the 10-year model periods.

5.1. Preferences

Instantaneous utility and the rewards from bequests are, respectively,

$$u_j(c_t, n_t) = \frac{c_t^{(1-\eta_j)(1-\sigma)}(1-n_t)^{\eta_j(1-\sigma)}}{1-\sigma}, \tag{12}$$

$$\Psi_j(a_{I,t}) = \xi_j \frac{a_{I,t}^{1-\varepsilon_j}}{1-\varepsilon_j}. \tag{13}$$

Table 3
Calibrated parameters.

Parameter	Value	Target
Preferences		
η_1	0.61	33.1% of time at work
η_2	0.55	40.9% of time at work
η_3	0.64	42.7% of time at work
β_1	0.99	$\frac{\text{Wealth of middle class}}{\text{Wealth of poor}} = 3.8$
β_2	1.01	$\frac{\text{Wealth of middle class}}{\text{Annual GDP per household}} = 2.4$
β_3	1.10	$\frac{\text{Wealth of rich}}{\text{Wealth of middle class}} = 6.5$
ξ_3	0.012	$\frac{\text{Bequest}}{\text{Average wealth}} = 0.088$
Government		
τ	0.484	$\frac{\text{Tax revenue}}{\text{GDP}} = 0.32$
$T_{retired}$	0.039	$\frac{\text{Retirement income transfer}}{\text{GDP per household}} = 0.13$

Notes: The table contains the list of nine calibrated parameters, the parameter values obtained and the targeted moments. All targeted moments are from Canadian data.

The intertemporal elasticity of substitution, σ, is set to a standard yet arbitrary value of 2. Remaining preference parameters to specify are economic class-specific weights on leisure, η_j, bequest parameters, ξ_j and ε_j, and time discount factors, β_j. The elasticity of substitutions for bequests is set equal to that of consumption for the retirees. With the other nine parameters the following three sets of moments are targeted. First, the fractions of time worked by the poor, the middle class, and the rich are set to 33.1%, 40.9% and 42.7% of their time at work, respectively. The numbers are obtained from Dorolet and Morissette (1997), who use the 1995 Survey of Work Arrangements from Statistics Canada. Second, the private wealth to annual GDP ratio, captured by the ratio of average net worth of the middle class to annual GDP per household, 2.4. The distribution of wealth: the ratios of net worth of the poor and the rich to the middle class: 0.26 and 6.5, respectively, as reported by the 2005 SFS. Third, in the 2005 SFS data, the lifetime bequests received by the rich, the middle class, and the poor are \$146,103, \$26,766, and \$11,584. Given this large size differences, a per-period bequest to wealth ratio of 0.088 for the rich and zero for the middle class and the poor are obtained as targets.

5.2. Portfolios

The information in Table 1 is used. Long-term nominal assets are defined as the sum of Mortage, Bond, and Pension. Then, the model shares of assets, the implied α_{ij}'s, are directly obtained from the table.

5.3. Demographics

Only the precise definition of the age group matters. Households are assumed not to die before retirement. The survival probabilities of the last two ages are targeted to obtain a ratio of over 65 to over 20 of 17%[12] and a survival rate between 66 and 76 years of 0.5.

5.4. Labor productivity

The age-class specific labor endowments, e_{ij}, are estimated using panel data (the 1999–2004 wage of the Survey of Labor and Income Dynamics, SLID). The economic classes are approximated by years of education with shares of 0.2, 0.,7 and 0.1 of the population. A fixed-effects regression is used to estimate specific hourly wage rates:

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

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. Work experience is the number of years worked. The results are in Table 4. With this definition of the groups and the parameters from the regression estimation, the average age, the average school years, and the average work experience are used to derive the average wage rate for each age-class group. The table also shows the resulting relative endowments for each group.

5.5. Technology

For the implied path of GDP after the price-level shock, the labor input chosen by households is the driving factor. Then, when posing a Cobb–Douglas production function with a capital share of 0.33 and an annual depreciation rate of 0.07, the capital stock can be inferred from the constant capital labor ratio implied by the small open economy assumption. Output follows from these elements.

5.6. Government debts, transfers and foreigners

Four parameters define fiscal policy: labor tax rate, retirement income transfer, government spending, and government debts. Tax revenue in Canada in 2005 was 32% of GDP, which requires the labor tax rate to be $\tau = 0.484$. The average retirement income transfer was 13% of GDP per household in 2005. Government debt was 43% of GDP in 2005. Government spending that balances the period-by-period budget is 16% of GDP. Foreigners' asset position, a^F, is set to 2.85% of GDP, as it was in 2005.

6. Findings

The effects of a 1% price-level shock under IT and PT are studied by discussing the direct redistribution of wealth (Section 6.1), the impact on aggregate output (Section 6.2), and, finally, the welfare implications (Section 6.3).[13]

[12] Source: Statistics Canada at http://www40.statcan.ca/.

[13] We also explored the effects of larger shocks. Because this is not a linear model, the effects of large shocks need not be just proportional to those of smaller shocks. Our results with larger shocks, however, do not alter the gist of our findings, and they are available on request.

Table 4
Labor productivity.

Age	Age squared	School years	Work experience[a]	Constant
Fixed effects estimates of the average wage of workers (R^2= 0.2695; 57 360 *observations*)				
0.076012*	−0.000847*	0.029377*	0.016393*	0.536536*
(0.002876)	(0.000029)	(0.002994)	(0.001752)	(0.053876)
	≤ 35	36–45	46–55	56–65
Implied relative labor productivity				
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

Notes: Standard deviations are shown in parentheses. * Indicates significance at the 1% level. The upper panel shows the regression results from Section 5.4 using the SLID data set from Statistics Canada. The numbers in the lower panel of the table 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 the age cohort of the household group 35 years old or younger.

[a] Number of full-time years worked.

6.1. Direct redistribution of wealth from an unexpected price-level increase

Based on the net nominal positions (NNPs) of the household groups and the sectors documented in Section 3, the extent of the direct redistribution of wealth among these households is measured, which are triggered by an unexpected price-level increase of 1% under IT and PT. As discussed in Section 2, under the PT regime the term to maturity of a nominal instrument, together with the PT policy horizon, is an important factor in determining the change in its real value following a price-level shock, while the maturity difference does not affect the real value under IT. Under PT, if a household holds a large fraction of its NNP in long-term claims, it faces a smaller redistribution than another household whose portfolio consists mostly of short-term claims. The term to maturity is set to be one year for the nominal short-term instruments. For bonds, mortgages, and pensions, their distributions of the terms to maturity in 2005 are directly applied.[14] As for the PT policy horizon, it is set to six years.

Table 5 shows the direct redistribution of household group wealth from a 1% price-level increase, under both IT and PT. Typically, the sign of the direct redistribution is the opposite of that of the NNP in Table 1.[15] The data for households both as a proportion of their own total nonhuman wealth and as a percentage of GDP per household are reported.

Two main messages arise from this table. The first message is that the young and the poor gain, and that the rich and the old lose from unexpected inflation. In particular, loss for older rich households amounts to almost 5% of yearly GDP per household. The other main message is that the magnitude of the redistribution is smaller under PT than under IT. This is because longer-term positions are less sensitive to price-level shocks under PT. A change in the real value of the nominal claim, and hence the redistribution, occurs only if the price level at the maturity date is different from what was expected. If the central bank brings the price level back to the original path before the maturity date, the price level would be exactly as expected originally. Under IT, the redistribution ranges from a gain of 0.89% of net worth for the youngest middle class to a loss of 0.34% of net worth for the eldest middle class. Under PT, the gain or the loss for the same groups is 0.19% and −0.19%, respectively. Under both regimes, young middle class and young poor households gain, whereas old or rich households lose. This results from the fact that the young middle class and young poor households both have negative NNPs.

The last row of Table 5 displays the size of the redistribution aggregating the household sector and including the government sector. A large gain for the government and a small loss for foreigners, who hold a bit of Canadian nominal assets, are observed. Again, the sizes are much larger under IT than under PT, almost three times larger.

6.2. Impact of wealth redistribution on aggregate output

The redistributional impacts of the price-level shock from the previous section are fed into the model by posing shocks to the wealth of households of the size implied by the numbers in Table 5. The model is then solved for its transition path back to steady state. However, feeding the numbers into the households requires two important adjustments. One is the allocation of the government's gain of 0.40% of yearly GDP. The other is a general equilibrium effect. The redistribution of wealth generates changes in the hours worked by households, and hence of economic activity and government finances. Consequently, the calculation of the transfers back to the household of the changes in the government asset position

[14] See Meh and Terajima (2008) for these distributions.

[15] Exceptions occur under PT due to the maturity mismatch between assets and liabilities.

Table 5
Direct redistribution of wealth with 1% shock.

	Inflation targeting			Price-level targeting		
	Poor	Middle	Rich	Poor	Middle	Rich
Across households as percentage of own net worth						
≤ 35	0.52	0.89	0.03	0.03	0.19	−0.02
36–45	0.27	0.26	−0.02	0.06	0.07	0.01
46–55	0.03	−0.11	−0.16	−0.01	−0.01	−0.03
56–65	−0.21	−0.26	−0.17	−0.13	−0.07	−0.04
66–75	−0.14	−0.29	−0.27	−0.11	−0.12	−0.12
> 75	−0.24	−0.34	−0.30	−0.13	−0.19	−0.14
Across households as percentage of yearly GDP per household						
≤ 35	0.03	0.38	0.13	0.00	0.08	−0.08
36–45	0.11	0.49	−0.35	0.02	0.13	0.15
46–55	0.03	−0.37	−3.49	−0.01	−0.05	−0.60
56–65	−0.23	−1.17	−4.56	−0.15	−0.34	−1.02
66–75	−0.15	−1.12	−4.99	−0.12	−0.48	−2.27
> 75	−0.17	−1.01	−4.31	−0.10	−0.57	−2.04
	Inflation targeting			Price-level targeting		
	Households	Government	Foreigners	Households	Government	Foreigners
Aggregate groups as percentage of yearly GDP						
	−0.40	0.43	−0.03	−0.15	0.14	0.01

Notes: The upper panel shows the direct redistribution of wealth for each household group as percentage of group net worth under IT and PT. The middle panel shows the direct redistribution of wealth for each household group as percentage of GDP per household under IT and PT. The lower panel shows the sectoral direct redistribution of wealth as percentage of GDP under IT and PT.

(regardless of the method by which it is redistributed) requires us to solve a fixed point problem: given an amount of transfers to households, their labor choices induce a chain in government finances that when added to the 0.4% reduction in government liabilities generates a change in the government assets position equal to the transfers.

Moreover, this occurs over various periods, and what we do is to assume that the government does not change the path of its debt, that is, that every period it redistributes (or taxes) the changes in its finances, which results in a multidimensional fixed point problem. For instance, in the baseline case, with lump-sum redistribution of the government windfall, in addition to the 0.40% reduction of the debt there is a reduction in the present value of future tax revenues of −0.05% but an increase in tax revenues in the first period of 0.01% of GDP.

The main channel through which the redistribution of wealth affects aggregate output is the wealth effect on work effort, which occurs under both monetary policy regimes, albeit with different magnitudes. Households that are not retired and experience a wealth loss from a price-level shock work more, while those that face a wealth gain enjoy more leisure. Specifically, the three youngest cohorts (≤ 35, 36–45, 46–55) of poor households and the two youngest cohorts of middle-class households reduce their work effort, since they experience a positive wealth effect from the price-level shock. The other nonretired cohorts of the different economic class increase their work effort, with the largest increase coming from the middle-aged middle-class and rich households. The retirees, however, despite having wealth loss, cannot change their labor supply. These asymmetric responses from heterogeneous households play an important role in obtaining nonzero aggregate effects from a zero-sum redistribution of wealth.

The dynamics of output (i.e., percentage deviations from the steady-state level) over time in the baseline scenario (the windfall is rebated as a lump-sum transfer) are shown in Panel A of Fig. 1 under IT (solid line) and PT (dashed line) and in Table 6. The initial impact of the shock on output is positive but almost zero (0.0055% under IT and 0.0026% under PT). The rich, particularly the rich of ages 46–55, and the older middle-class cohorts increase their work effort, while the younger cohorts of the poor and middle classes, who profit from a positive wealth effect, choose to enjoy more leisure. Both effects almost cancel out each other. In the following period, however, some of the cohorts that suffered the negative wealth effect are now retired and, hence, the shock no longer has effects on output via those people. Consequently, the effects of the shocks are concentrated on younger cohorts on which the overall wealth effect was positive. There is now a sizeable effect on output. In the second period, under IT, there is a negative effect on output of 0.023%, which is much larger than that under PT, a loss of 0.007%. In the third period, the reduction in output is even larger under IT, 0.027%. Under PT, the decline is about the same in the third period as in the second. After that the reduction in output fades out.

We want to emphasize that even though one might conclude that the size of the effects is small, we do not agree with that conclusion. A 1% price shock is small, and under IT its accumulated effect of reducing output after 40 years is about 0.54% of one-year GDP or \$600 per household. The reduction of output is smaller under PT, 0.13% of one-year GDP or \$145 per household.

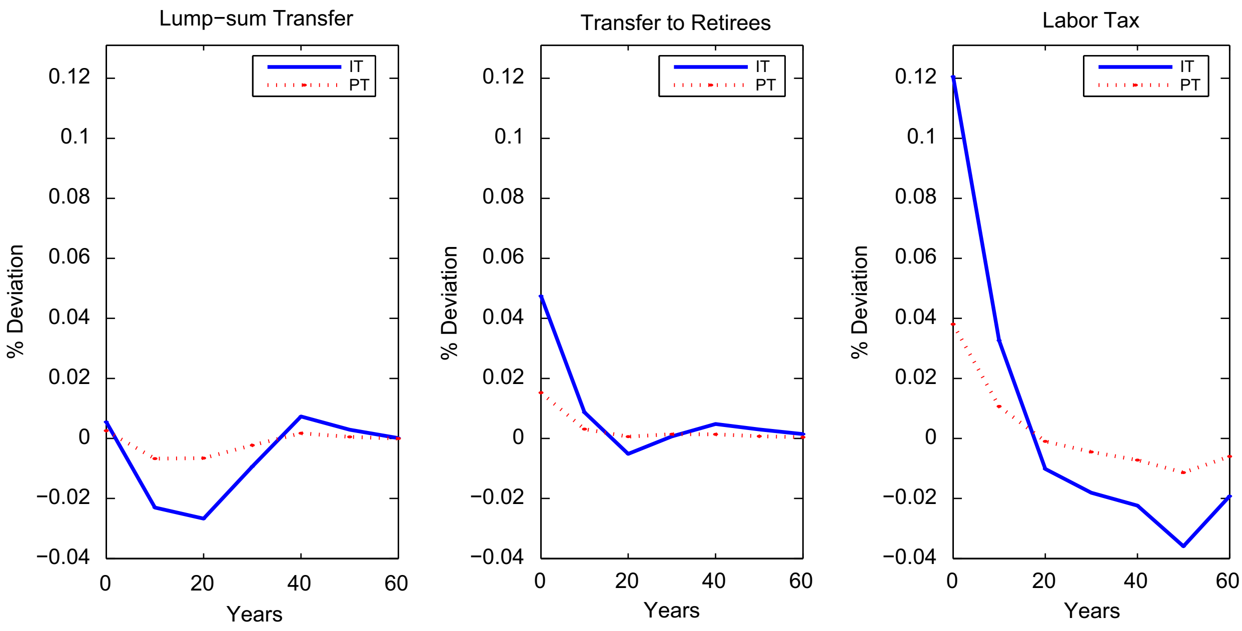

Fig. 1. Dynamics of output under IT and PT (1% shock), various fiscal scenarios. *Note*: The figure shows output dynamics in percentage deviations from the steady state level of output under IT and PT.

Table 6
Output effects in percentage changes from the steady state during different periods, 1% price shock.

	1st decade	2nd decade	3rd decade	4th decade	40-Year cumulative value
Inflation targeting					
Lump-sum transfers	0.0055	−0.0230	−0.0267	−0.0093	−0.54
Transfers to retirees	0.0475	0.0087	−0.0051	0.0007	0.52
Labor tax cut	0.1206	0.0327	−0.0102	−0.0181	1.25
Price-level targeting					
Lump-sum transfers	0.0026	−0.0067	−0.0065	−0.0023	−0.13
Transfers to retirees	0.0152	0.0031	0.0006	0.0014	0.20
Labor tax cut	0.0381	0.0107	−0.0010	−0.0045	0.43
Lump-sum transfer with US portfolio					
IT	−0.0021	−0.0135	−0.0166	−0.0071	−0.39
PT	0.0029	−0.0037	−0.0066	−0.0036	−0.11

Notes: First four columns show the yearly percentage deviation from annualized steady state output. The last column shows the cumulative value with respect to annualized steady state output. Two upper panels are the output effects using Canadian data. The bottom panel shows the output effects based on the US portfolio.

6.2.1. Transfer to retirees

If the fiscal adjustment of the windfall to the government is given as increased transfers to retirees, the redistribution of wealth has different effects. Workers do not receive the lump-sum transfers. For the young and the old, the positive wealth effect that reduced their work effort is mitigated, whereas for the high-income middle aged, the negative wealth effect is even larger. All this contributes to an increase, not a reduction, of output. The results are detailed in Panel B of Fig. 1 and in Table 6. Overall, there is an accumulated increase, not decrease, in output over 40 years of about 0.52% of one-year GDP under IT and 0.20% under PT, or $580 and $228 per household, respectively.

6.2.2. Labor income tax reduction

A third fiscal policy scenario which compensates only workers through a labor income tax cut is considered (see Panel C of Fig. 1 and Table 6).[16] Under this policy, there is a reduction in the distortion against market-produced goods, that is, an incentive to work harder. This substitution effect strongly overturns the wealth effect that would induce a reduction in

[16] The labor tax rate is reduced in the first period, returning linearly to the steady-state rate over the first five periods, which implies that for this scenario the fiscal adjustment involved only one variable.

work effort: it generates a large accumulated output increase over 40 years of 1.25% of one-year GDP under IT and of 0.43% under PT, or $1402 and $485 per household, respectively. Also note that this is the case even if the negative wealth effects are concentrated among the retirees who do not get any of the government gains.

6.3. Welfare analysis

This section analyzes the welfare changes due to the price-level shock taking into account not only the wealth redistribution but also the induced changes in the welfare of households. Again, like the effects on output, the welfare effects depend on the monetary policy regime and on the fiscal scenario that redistributes the government's windfall from the shock. The calculation of welfare requires some discussion. In the model economy, households differ in age and class, "class" meaning different preferences, endowments of efficiency units of labor, and wealth holdings at the time of the price surprise. Consequently, it is difficult to compare the implications of the changes for different groups. Perhaps the best way of reporting the welfare benefits is by reporting the total value of the transfer to each household group, including the direct government windfall from the price change and the indirect government windfall coming from the differences in its budget from changing revenues, which is shown in Table 7.[17] The rows indicated as "Induced Changes in Government Position" show the changes in the tax revenues in the present value and for the period of the price change.

The left three columns of Table 7 display the welfare effects for the 1% shock in the baseline case (i.e., the lump-sum transfer) under IT and PT. These numbers show the total value of the changes that the household receives. Relative to the direct redistribution described at the bottom of Table 5, there are some changes: the gains are larger, since the government windfall is now included. For some groups, this effect overturns the original impact: the middle income 46–55 years and the rich 36–45 years groups now gain. Future changes in government revenues are incorporated in this welfare measure. However, these further changes are small, amounting to no more than 20% for the youngest and even less for older generations. Note that future generations, however, are worse off. This is the outcome of the lower government budget revenues induced by the lower work effort of the young cohorts at the time of the initial price increase. Again, the effects are larger for IT than for PT, with the same groups of winners and losers.

6.3.1. Transfer to retirees

The three columns in the center of Table 7 show the results of redistributing the government windfall gain as transfers to retirees. The first thing to notice is that for the youngest there are essentially no changes relative to the direct redistribution, shown in Table 5. This is clearly because they are not affected by the government windfall that goes directly to the current retirees. It is only the current retirees that gain. In fact, they gain more than just the lower value of the debt for the government. This is because there is an overall negative wealth effect over the working population that makes them work harder, thereby increasing the government coffers that go straight to the current retirees. This effect is short-lived and after the initial period there are essentially no more changes in government finances. Once again, the effects are much larger for IT relative to PT. There is a small change in the lists of winners and losers. Note that among the rich, the youngest gain under IT and the second youngest experience the opposite effect. This is due to the particular composition of the portfolios, specifically the respective maturities of their nominal assets.

6.3.2. Labor income tax reduction

The last three columns of Table 7 present the welfare effects when the government windfall gain is rebated to the working-age population through a labor income tax cut. In this case households face a change in relative prices so the present value of all transfers is not sufficient to assess the welfare changes. Consequently, a different welfare measure is needed to address this problem. Such measure, which is the one reported in Table 7, displays the change of assets needed so that in the economy without relative price changes households are as well off as they are after the price-level shock. In this context a positive number indicates that households gain with a price-level shock. The price-level shock under both IT and PT now improve the fate of the young, especially the young rich. The reason is twofold: the transfer is larger for those with larger labor income, and the lower tax induces a substitution effect that increases work effort a lot during the first period (the effect goes the other way in subsequent periods).

To summarize the welfare analysis, positive price-level shocks change the wealth distribution of the population. The exact form in which this happens depends on how the windfall of the government is redistributed. In the baseline, there is a loss for the old and the rich, whereas when the windfalls are transferred to the retirees, the old clearly fare better. The opposite happens with an adjustment of the labor income tax; that tends to benefit the young and the rich.

7. A comparison with the US portfolios

The use of the nominal asset and liability portfolio of the United States in 1989, displayed in Table 1 of Doepke and Schneider (2006a), permits a sensitivity analysis of the robustness of the findings to the details of the portfolio holdings.

[17] In the data the age structure of the population is not stable. To compute a stationary equilibrium, though, the age distribution has to be stable. This is reconciled with adjustments to the government asset position that amount in the largest case (IT with a labor tax cut) to about 0.05% of Annual GDP.

Table 7
Welfare effects in percentages of yearly GDP per household of a 1% price shock.

Age	Rebates as lump-sum transfers			Rebates as income transfers to retirees			Rebates as labor income tax cuts		
	Poor	Middle	Rich	Poor	Middle	Rich	Poor	Middle	Rich
Inflation targeting									
≤ 35	0.50	0.84	0.59	0.05	0.40	0.15	0.71	1.36	1.55
36–45	0.57	0.96	0.12	0.12	0.51	−0.33	0.91	1.57	0.95
46–55	0.49	0.09	−3.03	0.01	−0.39	−3.52	0.62	0.38	−2.91
56–65	0.23	−0.71	−4.09	−0.19	−1.13	−4.51	−0.01	−0.92	−4.56
66–75	0.34	−0.63	−4.50	3.56	2.59	−1.28	−0.15	−1.12	−4.99
≥ 76	0.35	−0.48	−3.79	3.46	2.63	−0.68	−0.17	−1.01	−4.31
Induced changes in government position									
Present value		−0.05			0.12			−0.51	
1st period		0.01			0.10			−0.13	
Price level targeting (six year horizon)									
≤ 35	0.15	0.23	0.06	0.01	0.09	−0.08	0.22	0.39	0.36
36–45	0.12	0.23	0.25	0.03	0.14	0.16	0.28	0.47	0.55
46–55	0.08	0.05	−0.50	0.00	−0.04	−0.59	0.17	0.19	−0.41
56–65	−0.05	−0.24	−0.92	−0.12	−0.31	−0.99	−0.08	−0.26	−1.02
66–75	−0.02	−0.38	−2.17	1.02	0.66	−1.13	−0.12	−0.48	−2.27
≥ 76	0.00	−0.47	−1.94	1.01	0.54	−0.93	−0.10	−0.57	−2.04
Induced changes in government position									
Present value		−0.01			0.04			−0.15	
1st period		0.01			0.03			−0.04	

Notes: The table shows the total value of the transfer to each household group, including the direct government windfall from the price change and the indirect government windfall coming from the differences in its budget from changing revenues. The rows indicated as "Induced Changes in Government Position" show the changes in the tax revenues in the present value and for the period of the price change.

The analysis in this section focuses on the effects of a 1% unexpected price-level shock using the baseline case with lump-sum rebates of the government windfalls.

As discussed in Section 3, the main difference is that middle-class middle-aged households were nominal lenders in Canada in 2005 and borrowers in the United States in 1989. In addition, at the sectoral level, the household sector in the United States has a smaller positive NNP than its Canadian counterpart. In a similar fashion, the government sector also has a smaller negative NNP in the United States than in Canada. The foreign sector NNPs in both countries are positive and small relative to other sectors.

Fig. 2 and Table 6 show the output dynamics under IT and PT. The general pattern of the response of output over time with the United States portfolio is similar to that in Canada: There is a reduction in output over a long period of time and it is larger under IT than under PT. The response is larger in Canada (0.54% of one-year GDP or $600 per household) than in the United States (0.39%, and $440, respectively). In fact, under IT the initial response, while smaller in absolute value to that of subsequent periods, is negative in the United States and positive in Canada. Recall that what drives output in the model are changes in work effort due to wealth effects. Relative to Canada, the United States has more household groups of working age who are net nominal borrowers and hence benefit from the price-level shock. Together with a positive lump-sum transfer from the government, the positive wealth shock for these households leads to a reduction in their work effort and hence the reduction in output. Specifically, this result highlights the importance of the difference in the net nominal position of the middle-aged middle-class households between the two sets of portfolios. These households are net nominal lenders in Canada and borrowers in the United States and this is what accounts for the higher reduction in output in Canada relative to the United States.

Figs. 1 and 2 show that under PT, the initial output effects are similar between the two countries. This is in contrast to the IT case where the initial output effects were quite different between the two countries. The reason why the initial output effect was not pushed down to be negative, as it is under IT, is that US workers tend to have more long-term debts than their Canadian counterparts. For example, age 46–55 middle-class households in the United States have 21% of their assets as mortgage debts, whereas their Canadian counterparts have only 11%. Since long-term claims are less affected under PT, the positive wealth effect from the reduction in the real value of debt is smaller with the United States portfolio. Hence, these workers face smaller wealth increases under PT such that their reduction in work effort is also smaller, leading to a positive output effect. This positive output effect occurs only under PT and offsets the negative effect from the higher indebtedness of US workers, as observed under IT. After 40 years, the accumulated effect is a reduction of output by 0.11% of one-year GDP or $122 per household with the United States portfolio, compared to 0.13% of one-year GDP or $145 with the Canadian one.

The sensitivity analysis based on the United States portfolio shows that portfolio differences are quantitatively as well as qualitatively important when IT and PT are compared for their aggregate and welfare implications. These differences

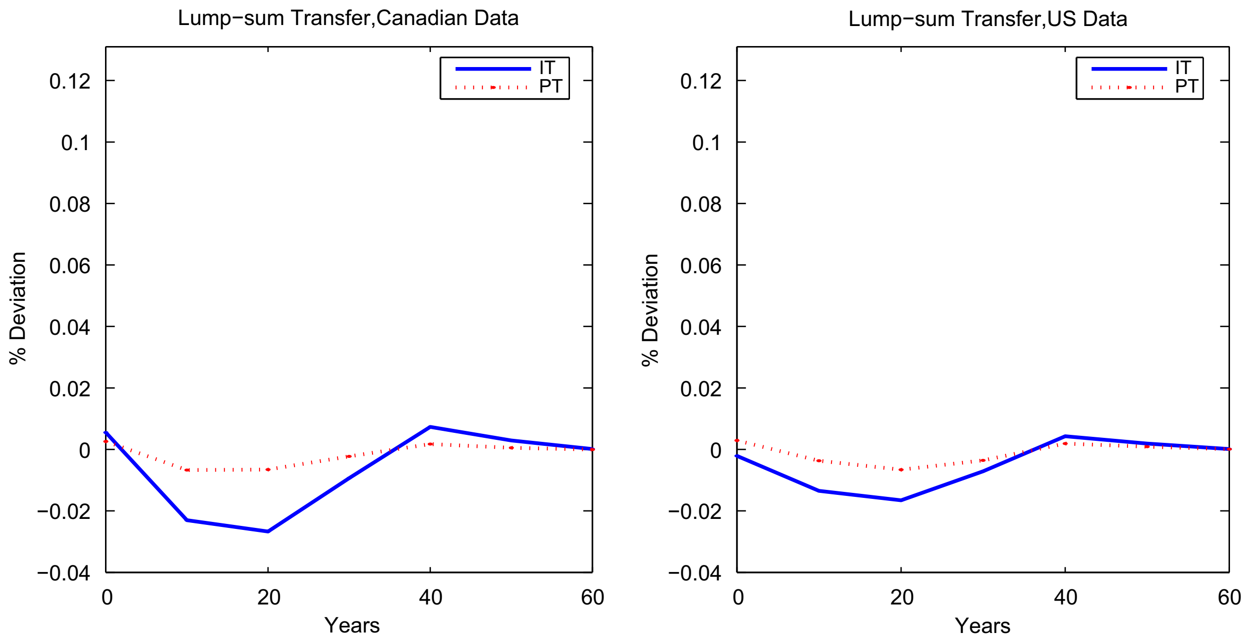

Fig. 2. Dynamics of output under IT and PT (1% shock), lump-sum transfers, the US data. *Note*: The figure shows output dynamics in percentage deviations from the steady state level of output under IT and PT, based on US portfolios.

arise because the differences in portfolios interact with monetary policies and generate different degrees of wealth redistribution that are specific to the particular portfolio and the monetary policy combination.

8. Conclusions

The goal of this paper is to assess the different aggregate and welfare consequences of a price-level shock under inflation targeting and price-level targeting monetary policy regimes. To this end, nominal asset and liability portfolios over different terms to maturity. Substantial differences in portfolios exist across household groups as well as between different sectors of the economy. As a result, unexpected changes in the price level redistribute resources across households and sectors. The extent of the redistribution depends on the monetary policy regime in place. As long-term claims are less affected by a price-level shock under price-level targeting, the size of the redistributions is much larger under inflation targeting than under price-level targeting.

The differences in the extent of the redistribution translate into substantial differences in the aggregate and welfare effects of price-level changes under inflation targeting and price-level targeting monetary policy regimes. The differences arise because redistributions of household assets and liabilities generate wealth effects on household work effort decisions. When a household receives a negative (positive) redistribution, the household increases (decreases) its work effort to make up for the wealth loss (gain). Since households are heterogeneous in age, productivity, and preferences, their work effort responses are also heterogeneous. In addition, changes in work effort due to the wealth effects induce further changes in government finances that need another round of redistributions back to the households, which is the main reason why there is a need to compute equilibrium changes to assess welfare.

The main finding of the paper is that given the nature of the portfolios of Canadian households and how they are partitioned into short-term nominal, long-term nominal, and real assets, the effect of a 1% price surprise under inflation targeting is a reduction of output over 40 years that accumulates to about 0.54% of yearly output or about $600 when the government gives back its reduced liabilities in the form of a lump-sum transfer. This is because the young and the poor accumulate relatively few nominal assets that are concentrated on the rich and the old. Because the old are no longer capable of working much, the lower wealth induces just a reduction in consumption, while the young accommodate their better position by increasing both consumption and leisure.

When the government follows price-level targeting instead of inflation targeting the effects have similar qualitative properties, but the quantitative impact is about a third. The reason is that price-level targeting produces a much lower redistribution of wealth, as price increases do not reduce the value of long-term nominal assets.

Our findings show that the specific details followed by the government to adjust the windfall originated by the price-level increase matter a lot. In this context, if the government, instead of using lump-sum transfers, concentrates its transfers on the referees, the effects are exactly the opposite in sign with similar magnitudes. The reason is that the lack of redistribution of the government windfall to the young generates on the most productive of them a sizeable negative wealth effect that induces them to work harder. This effect is concentrated in the early years and accumulates to 0.52% of one year's output. Again, under price level targeting the effects are about a third (or in this case close to 40%) of those of inflation targeting.

Moreover, if instead of giving the windfall as lump-sum taxes or higher transfers to the referees, the government were to reduce labor income taxation, the effects would now include a substitution effect that increases consumption at the expense of leisure. In this case, despite the young having a positive wealth effect, the substitution effect is very strong and there is a large increase in work effort that amounts to 1.25% of one year's output.

A sensitivity analysis looks at the differences in the effects of price-level shocks with respect to the underlying portfolio using the 1989 United States portfolio of nominal assets and liabilities of households and sectors. There are two main differences between the 2005 Canada portfolio and the 1989 United States portfolio: More United States workers are net nominal borrowers, and they borrow in long-term debts. These differences in portfolios led to some differences in the aggregate and welfare results. The redistributive effect of the 1% price-level shock on aggregate output (an increase) is a bit smaller under the US portfolio; in fact, the initial effect is a slight reduction. In terms of the cumulative value of the output reduction, the effect is about 70% of that of Canada under IT, and 85% of that of Canada when the monetary policy regime is PT.

Two important questions remain. One is the need to address a shortcoming in our analysis: The assumption of fixed portfolios of households. Analyzing how household portfolios change following the implementation of a PT regime is important in deriving more precise measures of redistributions, aggregate effects, and welfare effects. Still, we know little about the real versus monetary nature of households' portfolios. Furthermore, considering the process of price-level shocks, rather than just a one-time shock, is also important. Although the welfare analysis with one-time shocks in this paper gives us insight into how bad these shocks are under different monetary policies, it does not directly imply, before the implementation of the policy, that one policy is preferred over the other. This is because the relevant measure of welfare over different monetary policies should be with respect to all possible realizations of shocks (i.e., the distribution of shocks) in order to take into account how higher-ordered moments affect household welfare.

Appendix A. Supplementary data

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jmoneco.2010.05.001.

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