Downward Nominal Wage Rigidity In Canada: Evidence Against a 'Greasing Effect'

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Abstract

The existence of downward nominal wage rigidity has been used to justify positive inflation targets. It has been traditionally assumed that properly calibrated inflation targets can reduce both the severity as well as improve the speed at which both unemployment and inflation return back to pre-crisis levels. To assess this claim, this paper adapts an otherwise standard dynamic stochastic general equilibrium where forward looking agents take into account the possibility of being bound by downward nominal wage rigidity now and into the future. The model used is based on that proposed by Daly and Hobijn (2014), adapted to replicate the transition path of unemployment and inflation during the periods following the Great Recession in Canada. This research finds the cyclical response of DNWR increases in response to a negative demand shock when inflation targets increases. This effectively, eliminates the hypothesized 'greasing' effect across reasonable inflation targets. Thus, due to risk compensation, this paper finds that the speed at which unemployment returns back to pre-crisis levels during recessions is relatively unaffected by variation in inflation targets.

Keywords: Canadian Phillips Curve; Downward Nominal Wage Rigidity; Monetary Policy

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1 Introduction

The theorized trade-off between inflation and unemployment as well as its policy implications have been the subject of intense debate. Phillips (1958) hypothesized that the non-linear relationship observed between unemployment and wage inflation was due to workers who are reluctant "... to offer their services at less than the prevailing rates when demand for labour is low and unemployment is high so that wage rates only fall very slowly." There are a variety of reasons why firms as well as workers would be reluctant to reduce wages in response to poor labour market conditions. Whether due to concepts of fairness, nominal illusion or historical conventions, this phenomenon is commonly referred to as downward nominal wage rigidity (DNWR). During recessions, DNWRs imply that labour market corrections occur disproportionately through the employment margin rather than through reduced wages. At first glance, policymakers would be tempted to increase inflation targets in order to effectively 'grease the wheels' of the labour market by promote downward pressure on real wages. This would allow labour markets to adjust (if only partially) through wages, thereby shortening the overall time required for unemployment to return back to pre-crisis levels.

The conventional view, made popular by Friedman's (1967) speech to the American Economic Association is that the output-inflation trade-off mentioned above is only temporary with the costly increases in long-run inflation outweighing the benefits accrued in the short run. These costly distortions resulting from the misallocation of goods as prices adjust is commonly referred to as the 'sand' effect due to its drag on the economy. This is the current opinion held by majority of macro economists, that the long-run Phillips curve (LRPC) is perfectly vertical, with no long-run trade-off between output and inflation. Any change in inflation rates are fully compensated by higher prices and wages in the long run. In the short run however, the conventional view is that increasing inflation targets 'grease the wheels' of the labour market, allowing unemployment to return back to pre-crisis levels at a faster rate. While economists such as Akerlof, Dickens and Perry (2000), Benigno and Ricci (2011) and Daly and Hobijn (2014) have produced arguments favoring the bending of the LRPC, very few have questioned that later claim-that increasing inflation targets 'grease the wheels' of labour market adjustments in the presence of DNWR.

Building on the work done by Daly and Hobijn (2014), this paper introduces DNWR into a standard new Keynesian model where forward-looking agents make optimal wage

setting decisions in response to both aggregate and idiosyncratic shocks. Goods production is perfectly competitive. Households provide a variety of labour types, where each type of labour is subject to a time-dependent shock. These idiosyncratic shocks vary the household's preference for providing that type of labour. Each period, a fraction of workers are unable to adjust wages downward with the remainder free to choose any non-negative wage rate. To replicate the impact the Great Recession had on inflation and employment, a negative demand shock is used to shift household's preferences from present to future consumption. We then evaluate the transition path of unemployment and wages as they return to pre-crisis levels over various degrees of DNWR and inflation targets.

The novel contribution of this research is the reversal of the arguments listed above. With DNWR, this paper finds that there exists a long-run trade-off between employment and inflation. In the short run, however, the speed at which unemployment returns back to pre-crisis levels is unaffected by changes in inflation targets. With DNWR, agents choose wage rates based on the perceived risk of being bound by DNWR at some point in the future. Inflation provide an alternative mechanism whereby workers bound by DNWR can reduce real wages downward while leaving nominal rates unchanged. When inflation rates are low, they offer little relief to workers bound by DNWR. In response, households reduce their nominal wage rates now in order to avoid the potential cost of being bound by DNWR at some point in the future. Lower wage rates cause households to reduce their overall supply of labour, causing output to decrease and unemployment to rise. Higher inflation targets therefore reduce the overall costs of DNWR to the economy, as they provide an alternative mechanism for agents to lower real wages. Potential output increases as workers choose on average a higher wage rate as the perceived risk of doing so declines. As a result, when a recession hits, a greater number of workers now migrate to the zero-lower bound, and the percentage increase in the number of workers bound by DNWR increases with progressively higher inflation targets.

The bending of the long-run Phillips curve discussed here differs from near-rational explanation proposed by Akerlof, Dickens and Perry (2000). They hypothesize that there exists a trade-off between unemployment and inflation when workers fail to take all information into account when forming expectations of future inflation. When workers fail to fully appreciate the impact inflation has on the nominal demand for their services, real wages decline with inflation. This leads to a rise in output and a drop in unemployment at low inflation rates. Their work suggests, contrary to Phillips, that output increases rather than declines with progressively lower inflation targets.

In the short run the opposite is true. Economists such as Tobin (1972), Akerlof et al (1996), Hyslop (1997), Brouillette et at. (2015a and 2015b) argue that high inflation rates 'grease the wheels' of the labour market. However, when the wage distribution is determined endogenously, this is no longer the case. While progressively higher inflation targets imply that agents can rely on inflation to reduce real wages when bound by DNWR, it also alters the pre-crisis distribution of wage-growth rates. Agents, with perfect foresight, choose a wage rate based on both current and future inflation rates. Higher inflation targets cause workers to choose more aggressive wage rate now knowing that they can rely on future inflation to reduce wages if necessary. Thus while higher inflation targets provide relief to those bound by DNWR, real wages now need to drop by more then prior to the inflation target increase. Furthermore, the percentage increase in the number of workers bound by DNWR increases with higher inflation targets during recessions. As a consequence, the speed at which unemployment returns back to pre-crisis levels remains roughly unchanged. Inflation rates however, become more volatile in response to higher inflation targets as more workers bound by DNWR move to and from the zero-lower bound on wage growth. This builds on the work done by Card and Hyslop (1996) and Daly and Hobijn (2014) who show empirically that higher inflation rates provide only a modest 'greasing' effect on labour market corrections.

A further insight this paper produces is the relevance of both labour market rigidity along with DNWR in replicating the sudden deceleration in wage growth experienced in Canada following the Great Recession. With the high degree of labour market inelasticity in the Canadian labour market, we conclude that approximately 11-12% of the population is bound by DNWR annually. While conservative compared to estimates by Brouillette et al (2015a) of 25%, this value is capable of replicating the observed dynamics of unemployment and wage inflation during the periods following the Great Recession. The lower estimate could also reflect the inclusion self-employed workers in our aggregate data. While there may be DNWR in a traditional employer employee environment, the same is likely not true for self-employed workers who are more likely to reduce wages when profits decline. Thus when this group is selectively removed from the group, the estimate of DNWR will likely be higher. This paper finds that properly identifying the proportion of the population facing DNWR has significant policy implications. Understanding the amount of DNWR and thus correctly gauging the degree of slack in the Canadian labour market is critical in forming policy and avoiding unnecessary inflationary or deflationary pressures. For this reason, this research investigates the impact DNWR has on inflation, unemployment and the policy rate. We then compare these values to those which would exist if policymakers miscalculate the degree of DNWR. When underestimating the degree of DNWR, policymakers overestimate the decline in future wage inflation as well as underestimate the degree of slack in the Canadian economy in the following periods. In response to an economic downturn, policymakers then take a hawkish stance and aggressively reduce interest rates. In contrast, overestimating the degree of DNWR causes policymakers to choose to drop policy rates by less as they anticipate an attenuated response in inflation. Thus understating the degree of DNWR, as is currently the case, leads to an unnecessary upward pressure on inflation as well as increase the volatility of policy rates. Given that upward pressure on inflation rates are desired during periods of economic decline, this experiment leans in favor of underestimating the degree of DNWR.

The remainder of the paper will proceed as follows: Section two explores the non-linear dynamics of unemployment and wages following the Great Recession. Section three then outlines the model used to replicate the sudden deceleration in wage growth experienced in Canada from 2008Q1 to 2012Q4. Section four discusses the calibration required to match what we observe in the Canadian data. Section five sketches and defends the conclusions listed above; that higher inflation targets lead to similar transition paths of unemployment back to steady state, despite the 'greasing effect' proposed in the literature. This section also emphasizes the necessity for policy makers to properly identify the rate of DNWR when forming economic policy. Section six concludes.

2 Bending of the Short Run Phillips Curve in Canada

Motivated by the record number of workers experiencing zero wage growth in the United States following the Great Recession, Daly and Hobjin (2014) investigated whether this phenomenon is due to the impact DNWR has on wage growth. At the onset of the Great Recession, US wage growth remained relatively constant, leading a majority of the labour market corrections to occur disproportionately through the employment margin rather than through reduced wages. Only when unemployment peaked in 2009 did wages start to decline and workers experience what Daly and Hobijn's (2014) referred to as 'pent up wage deflation.' As demonstrated in Figure 1, the relationship observed between unemployment and wage inflation by Daly and Hobijn (2014) for the United States varied dramatically from the Canadian experience.

Figure 1 plots the transition path of wage growth and the unemployment gap observed in Canada and the United States post 2008.¹ Starting in 2008 the Canadian labour market was characterized by a tempered increase in unemployment which reached its peak in 2009 followed by a sharp deceleration in wage growth. Similar to Canada, the United States experienced a rise in unemployment, along with a deceleration in real wage growth. The experience in Canada differed significantly from that observed in the United States in three ways. First as can be observed in Figure 1, the severity of the shock was greater in the United States with unemployment rising approximately 4.5 percent above the natural rate of unemployment in the United States compared to the approximately 1.2 percent observed in Canada. Second, while the short-run Phillips curve sloped downward for the United States, the Canadian equivalent remained flat. Last of all, wages in Canada fell sharply with very little change in unemployment. During the same period the US labour market was characterized by a decline in unemployment while the growth rate of wages decelerated.

The starkest of these three differences is that the shock which led to the Great Recession did not lead to a dramatic drop in wages in Canada. Rather, from the initiation of the Great Recession up until unemployment reached its peak, there appears to be little downward pressure on wages. Only when unemployment peaked in 2009 did wages begin to decline. As proposed by Daly and Hobijn (2014), the flat trajectory is the result of workers inability to adjust wages downward. This causes unemployment to increase until a sufficient number of workers accept a wage freeze and aggregate wages start to decline. This flat trajectory is also in line with the results found by Beaudry and Doyle (2000) who argue that the flattening of the Phillips curve is the result of Bank of Canada's neutral stance on monetary policy. To fully appreciate the rationality behind the joint behavior between unemployment and

¹Wage growth is calculated using principal component analysis (outlined in the appendix), adjusted by the 10 year ahead inflation forecast. This is done to isolate the impact of cyclical nominal wage growth from the impact anticipated inflation has on wage decisions. The unemployment gap is measured as the unemployment rate less the natural rate of unemployment.

wage inflation observed in Canada, we first need to understand how the distribution of wage growth varied over the Great Recession.

With DNWR, the proportion of workers experiencing negative wage growth declines, with all these workers forced to accept a wage freeze instead of a wage cut. In addition, with perfect foresight, workers and firms are aware of the potential risk of being bound by DNWR, and consequentially choose a lower wage rate now to mitigate this risk, causing the distribution to also be squeezed from the right. Therefore, the distribution of wage growth data should be asymmetric with a majority of wage changes being non-negative and a pronounced spike at the zero-lower bound. Brouillette et al. (2015a) assess the importance of DNWR in Canada by evaluating the distribution of wage growth data collected from the Survey of Labour and Income Dynamics from 1993 to 2011. This self-reporting survey follows individuals for 6 years, and collects information amongst other things, on income and job status. Brouillette et al. (2015a) focus on the portion of the labour-force between 16 and 69 years old, who were neither self-employed, unemployed nor an unpaid worker. Looking at those surveyed who remained in their current job for 24 months, they calculate wage growth by calculating the hourly wage change from January to December. Figure 2 plots the distribution of average yearly wage growth observed from 2001 to 2008 and from 2009 to 2011. As can be observed, the proportion of the population bound by DNWR increased from 25% to 40% with very little evidence of workers experiencing wage cuts. Thus Brouillette et al. (2015a) conclude that there exists DNWR in Canada and that the number of people bound by DNWR increased during the Great Recession. Furthermore, their estimates for the number of workers experiencing wage freezes both before and during the Great Recession are substantially higher than Daly and Hobijn's (2014) estimates of 12% and 16% respectively for the United States.

Loboguerrero and Panizza (2006) speculate that the macroeconomic consequences of DNWR are more severe for countries with heightened labour market regulations. They argue that the degree to which inflation is capable of 'greasing the wheels' depends on the degree of labour market regulation, with countries characterized by higher levels of regulation also observing a higher degree of DNWR. These labour market distortions could result from; unionization, from the proportion of the labour-force which are publicly employed or the degree of labour regulations to name a few. Union participation rates, identified by Holden (2004) and Dickens et al., (2007) as a measure of labour market elasticity, is one feature that distinguishes the Canadian labour market from its American counterpart. Higher unionization rates limit the ability for both firms and workers to adjust wages in response to changing labour market conditions. Karabegovic, Grabler and Veldhuis (2012) calculate the average the total union participation rate across Canada is approximately 31.4 percent, as compared to an average total unionization rate of 13.3 percent across the United States. With the exception of Alaska and New York, Canadian unionization rates across all provinces and territories are higher than their American counterparts.

Brouillette et al. (2015b), building on the work done by Crawford and Wright (2001), examine the importance of DNWR amongst unionized workers using Major Wage Settlement data. These data on wage growth is calculated from administrated data from large (>500 employees) unionized firms in Canada. Performing the same exercise as above Brouillette et al. (2015a), they find that the percentage of unionized workers experiencing zero wage growth increased from 10% to 20% then to 40% between 2001-2008, 2009-2011 and 2012-2015 respectively. As can be seen in Figure 3, regardless of the time period considered, fewer unionized workers experienced wage cuts compared to the aggregate measure (including both unionized and non-unionized workers), suggesting that the effect of DNWR is higher for unionized workers. Second, from 2009-2011, while both pools of workers experienced an increase in DNWR, the effect was less pronounced for unionized workers than it was with non-unionized workers.

Figure 4 demonstrates the differing experience of unionized and non-unionized workers following the Great Recession in Canada from 2008Q1 to 2012Q4 at the aggregate level. From 2008Q1 to 2009Q1 each group of workers experienced an increase in unemployment, following a relatively flat trajectory towards the new intermediate state. During this time, changes in the labour market occurred disproportionately through unemployment margin rather than through wages. Starting in 2009, both types of workers experienced a sudden deceleration in wage growth, with non-unionized workers experiencing the most pronounced decline in wage growth amongst the two types. Unionization as a measure of labour market flexibility highlights the linkage between DNWR and employment elasticity, with unionized workers mostly avoiding the negative wage growth experienced by non-unionized workers. As for the flat trajectory, it appears that unionization does not play a significant factor in recreating this phenomenon as both unionized and non-unionized workers experienced very little volatility in wage growth at the onset of the Great Recession, with non-unionized workers even experiencing a wage increase. Rather, as shown in the following sections, the flat trajectory comes as a result of the size of the shock, with larger disruptions to employment generating a larger response in wages.

3 Model

The observed bending of the short-run Phillips curve has been attributed to the limitations in a worker's ability to adjust wages. Taylor (1979) linked the bending of the *short-run* Phillips curve to the length of the wage contract. Calvo (1983) suggested that it was the result of workers/firms inability to adjust wages each year given a predetermined probability. Daly and Hobjin (2014), who build upon the work of Benigno and Ricci (2011), propose that the number of people constrained by DNWR varies according to the agents outlook for future growth and inflation. In all three scenarios, agents choose wage rates based on the probability that they will be unable to do adjust wages downward at some point in the future. However, unlike the two predecessors, Daly and Hobijn (2014) theorize that the number of people who want to lower their current wage but are unable to do so due to DNWR varies with the business cycle, with a greater number of people bound by DNWR following a recession. This leads to a curvature in the *short-run* Phillips curve as workers are only comfortable increasing their wage rate when economy fully recovers. This paper examines the degree to which DNWR impacts dynamics of unemployment and inflation in the Canadian following the Great Recession.

The closed economy model used to replicate the non-linear transition dynamics of unemployment and inflation experienced in Canada after the Great Recession is based on the discrete time model proposed by Daly and Hobijn (2014). Their work builds on the dynamic stochastic general equilibrium models of Benigno and Ricci (2011) and Fagan and Messina (2009), who were in turn inspired by the wage setting model of Erceg, Henderson, and Levin (2000). The novel contribution of Daly and Hobijn's (2014) research is their focus on the non-linear transitional dynamics of unemployment and inflation following a negative demand shock. Their model is particularly adept at taking into account the evolution of the wage distributions following a negative demand shock. While the fraction of the workers who are unable to adjust wages downward is fixed, the fraction of workers where the restriction is binding varies over time. Thus the number of workers bound by DNWR can rise and fall over the business cycle. To begin our discussion, let's first look at the aggregate goods producer.

3.1 The firm

A firm, operating within a perfectly competitive goods market produces the aggregate good Y_t according to the following linear production function:

$$Y_t = A_t L_t. \tag{1}$$

Given technology A_t , production of the consumption good only requires a labour input L_t . The labour input is an aggregate labour bundle consisting of a continuum of various labour types L_{it} provided by households. It's assumed that there exists a perfectly competitive firm that aggregates across labour types in order to produce the final aggregate labour bundle ready for goods production according to the following aggregator:

$$L_{t} = \left[\int_{0}^{1} L_{it}^{\frac{\eta-1}{\eta}} di \right]^{\frac{\eta}{\eta-1}}.$$
 (2)

Differing labour types L_{it} are imperfect substitutes, earning varying wage rates, denoted by W_{it} . The labour demand elasticity, denoted by η , determines the degree to which one type of labour can be substituted for another.² Lastly, L_{it} is the quantity of labour type *i* provided by the representative household. The conditional input demand is given by

$$L_{it} = \left(\frac{W_t}{W_{it}}\right)^{\eta} L_t,\tag{3}$$

where W_t denotes the nominal aggregate wage rate, which is calculated as follows:

$$W_t = \left[\int_0^1 \left(\frac{1}{W_{it}} \right)^{\eta - 1} di \right]^{-\frac{1}{\eta - 1}}.$$
 (4)

Since firms are perfectly competitive, the only source inflation is wage inflation and technological growth. The aggregate price level is determined by the ratio of wages to technology

 $^{^{2}}$ We assume that each labour type can differentiate themselves costlessly.

 $P_t = \frac{W_t}{A_t}$, which due to perfect competition, is the per unit cost of production. The growth rate of technology is given by

$$a_t = \frac{A_t}{A_{t-1}} - 1. (5)$$

Given a detrended real wage rate for labour type *i* of $w_{it} = \frac{W_{it}}{A_t P_t}$, the aggregate real wage rate can be calculated as

$$w_t = \left[\int_0^1 \left(\frac{1}{w_{it}} \right)^{\eta - 1} di \right]^{-\frac{1}{\eta - 1}}.$$
 (6)

3.2 Households

The focal point of this paper is the concept that downward nominal wage rigidities alter the behavior of the households in their joint labour and wage setting decision. The model consists of a continuum of identical and infinitely lived households. The representative household chooses a path for consumption, wages and labour supply $\{C_t, w_{it}, L_{it}\}_{i=0,t=0}^{1,\infty}$ so as to maximize the present discounted value of lifetime utility

$$\sum_{t=0}^{\infty} \beta^t e^{-\sum_{t=0}^{t-1} D_S} \left[\ln C_t - \frac{\gamma}{\gamma+1} \int_0^1 Z_{it} L_{it}^{\frac{\gamma+1}{\gamma}} di \right],\tag{7}$$

where $\gamma > 0$ denotes the Frisch labour supply elasticity, β is the discount factor, D_s is a preference shock, and Z_{it} denotes the time dependent idiosyncratic disutility experienced by households when providing labour type L_{it} . This idiosyncratic disutility is not constant, but rather varies over time. The disutility shock Z_{it} is drawn from normal distribution where ln(Z) is $N\left(-\frac{\sigma^2}{2},\sigma\right)$ with E(Z) = 1. Increases in Z_{it} , increase the disutility caused by households in providing labour type L_{it} , causing households to demand higher wages. It is assumed that households are to small to alter aggregate wage rate, labour input, the price level or the interest rate. Thus the household takes all four as given. Lastly, households, combine their wage rate and labour supply decisions into one decision regarding wages by taking the firms labour demand as given.

Households who value both consumption and leisure, maximize their lifetime utility sub-

ject to the budget constraint

$$B_t + P_t C_t = (1 + i_t) B_{t-1} + \int_0^1 W_{it} L_{it} di.$$
(8)

Households provide $\int_0^1 L_{it} di$ units of labour to the firm, earning a total income of $\int_0^1 W_{it} L_{it} di$. They possess B_{t-1} assets from the previous period, earning a nominal interest rate i_t . These two components make up the household's total income. Household's then choose either to consume this income P_tC_t or to postpone purchases and increase their bond holdings B_t .

Downward nominal wage rigidities will be the final constraint binding the household's optimization problem. Each period, the representative household makes a decisions to either increase, decrease or keep the current wage rate W_{it} constant over time. With probability $\lambda = [0, 1)$, a worker is unable to adjust wages downward. If labour type L_{it} finds themselves counted within the fraction λ of workers unable to adjust wages downward, their wage setting decision is limited to $W_{it} \geq W_{it-1}$. Agents optimize their lifetime utility taking into account the present and future values for aggregate labour L_t their idiosyncratic shock Z_{it} as well as the future path for inflation π_t , technology growth a_t and the preference shock D_t .

With DNWR, the distortionary effect it has on the household's optimal wage decision allows for monetary policy to affect the aggregate outcome of the economy. The central bank, charged with the task of mitigating both output and inflation volatility, base their policy rate decision using a simple Taylor rule.

$$i_t = \frac{(1+\bar{\pi})(1+\bar{a})}{\beta} \left(\frac{y_t}{\bar{y}}\right)^{\phi^Y} \left(\frac{1+\pi_t}{1+\bar{\pi}}\right)^{1+\phi^{\pi}} - 1$$
(9)

Where π_t is the inflation rate and $\bar{\pi}$ the central banks inflation target, \bar{a} is the steady state growth rate of technology, (y_t/\bar{y}) and $(1 + \pi_t)/(1 + \bar{\pi})$ denotes the output and inflation gap respectively. $\phi^Y \ge 0$ and $\phi^{\pi} \ge 0$ denote the weight assigned by the central bank to the output and inflation gaps respectively.

3.3 Model Solution

The solution to the model listed above will involve finding the equilibrium time path of aggregate output Y_t and labour L_t , as well as the real and nominal interest rates i_t and r_t and inflation rate π_t . Given the household's utility function (7) and budget constraint (8) the optimal solution will satisfy the Euler equation for the household

$$\frac{1}{Y_t} = \beta e^{-D_t} (1+r_t) \frac{1}{Y_{t+1}}.$$
(10)

The optimal time path for $\{Y_t, L_t, i_t, \pi_t, r_t\}$ for both models will satisfy the Euler equation listed above along with the production function (1), the monetary policy rule (9) as well as the fisher equation $r_t = (1+i_t)/(1+\pi_{t+1})-1$. Last of all, the detrended aggregate real wage rate w_t equals one in equilibrium.

The remaining elements yet to be resolved include the household's wage and labour supply decision and the implied rate of inflation. For instructive purposes, we'll begin with the model without DNWR, as this model will be use to understand movements in output, inflation, and interest rates when DNWR restrict the household's wage decision.

3.4 Flexible Wages

This section considers the case where wages are fully flexible (I.E. $\lambda = 0$). Note that absent DNWR, monetary policy is inconsequential. There is still monopolistic competition in the supply of labour, which will have a role in determining both the optimal wage as well as the steady-state labour supply. In this environment, households choose a wage rate that maximizes their lifetime utility (7), given the input demand function (3) along with the aggregate real wage rate. The optimization problem faced by i^{th} member of the household can be written as follows.

$$\mathcal{L}_{i}{}^{f} = E_{t} \sum_{t=0}^{\infty} \beta^{t} e^{-\sum_{t=0}^{t-1} D_{S}} \Omega(Z_{it}, w_{it}, L_{t}),$$
(11)

where

$$\Omega(Z_{it}, w_{it}, L_t) = w_{it}^{1-\eta} - \frac{\gamma}{\gamma+1} Z_{it} w_{it}^{-\eta \frac{\gamma+1}{\gamma}} L_t^{\frac{\gamma+1}{\gamma}}$$
(12)

Deriving an optimal wage rate using equation (12) gives

$$w_{it}^{f} = \left(\frac{\eta}{\eta - 1}\right)^{\frac{\gamma}{\gamma + \eta}} Z_{it}^{\frac{\gamma}{\gamma + \eta}} L_{it}^{f\frac{1 + \gamma}{\gamma + \eta}}.$$
(13)

With wage flexibility this implies an equilibrium labour supply of

$$L_t^f = \left(\frac{\eta}{\eta - 1}\right)^{\frac{\gamma}{\gamma + \eta}} Z_t^{\frac{\gamma}{\gamma + \eta}},\tag{14}$$

where

$$Z_t = \left[\int_0^1 \left(\frac{1}{Z_{it}}\right)^{\frac{\gamma(\eta-1)}{\eta+\gamma}} di\right]^{-\frac{\eta+\gamma}{\gamma(\eta-1)}} = e^{-\frac{\eta(1+\gamma)}{\gamma+\eta}\sigma^2}.$$
(15)

The detrended steady-state level of output/employment under flexible wages L_t^f will serve as a measure of potential employment in our calculation of the unemployment rate in the model *with* DNWR discussed next.

3.5 Downward Nominal Wage Rigidities

When wages are fully flexible, agents choose an optimal wage based on the current state of the economy. With $\lambda > 0$, this is no longer the case. Even with no aggregate uncertainty, each individual of the household still faces uncertainty regarding the future value of the idiosyncratic shock Z_{it} . When $\lambda > 0$, the i^{th} member of the household takes into account the current value of Z_{it} and L_t , as well as the entire time-path for $\{\pi_t, a_t, D_t\}_{t=0}^{\infty}$ when determining the optimal wage decision for period t. The resulting optimization equation can be expressed through the following Bellman equation:

$$V_{t}(w) = (1 - \lambda) \int_{0}^{\infty} \max_{w_{it} \ge 0} \left(\Omega(Z_{it}, w_{it}, L_{t}) + \beta e^{-D_{t}} V_{t+1}(w') \right) dF(Z_{it})$$
$$+ \lambda \int_{0}^{\infty} \max_{w_{it} \ge w} \left(\Omega(Z_{it}, w_{it}, L_{t}) + \beta e^{-D_{t}} V_{t+1}(w') \right) dF(Z_{it}).$$
(16)

Where $F(Z_{it})$ denotes the distribution of the idiosyncratic disutility shock Z_{it} and $w' = w_{it}/((1 + \pi_{t+1})(1 + a_{t+1}))$. The optimal solution to the household's maximization problem will be a real wage rate w_{it} that takes into account the probability that they will be bound by DNWR. As a result, workers choosing real wage that is a fraction of those observed under flexible wages. The solution to equation (16) implies a steady state value of employment L_t of

$$L_t = \left(\frac{\eta - 1}{\eta}\right)^{\frac{\gamma}{1 + \gamma}} \left(\frac{1}{Z_t^*}\right)^{\frac{\gamma}{1 + \gamma}},\tag{17}$$

where the first component represents the distortionary effect of monopolistic competition in labour supply. The second component is the distortion to labour supply arising from DNWR. The aggregate disutility term Z_t^* given by

$$Z_{t}^{*} = \left((1+\lambda) \int_{0}^{\infty} \left(\frac{1}{Z_{it}} \right)^{\frac{\gamma(\eta-1)}{\eta+\gamma}} \left(\frac{w_{t}^{f}(Z_{it})}{w_{t}^{*}(Z_{it})} \right)^{\eta-1} dF(Z_{it}) + \lambda \int_{0}^{\infty} \left(\frac{1}{Z_{it}} \right)^{\frac{\gamma(\eta-1)}{\eta+\gamma}} G_{t-1} \left(w_{t}^{*}(Z_{it})(1+\pi_{t})(1+a_{t}) \right) \left(\frac{w_{t}^{f}(Z_{it})}{w_{t}^{*}(Z_{it})} \right)^{\eta-1} dF(Z_{it}) + \lambda \int_{0}^{\infty} \left(\frac{1}{Z_{it}} \right)^{\frac{\gamma(\eta-1)}{\eta+\gamma}} \left(\int_{w_{t}^{*}(Z_{it})}^{\infty} (1+\pi_{t})g_{t-1}(w(1+\pi_{t})(1+a_{t})) \left(\frac{w_{t}^{f}(Z_{it})}{w_{t}^{*}(Z_{it})} \right)^{\eta-1} dw \right) dF(Z_{it}) \right)^{-\frac{\eta+\gamma}{\gamma(\eta-1)}},$$
(18)

where the optimal wage rate is $w_t^*(Z_{it})$. $G_t(\cdot)$ and $g_t(\cdot)$ denote the distribution and density of the wage rates respectively.

4 Calibration

The model listed above replicates the work done by Daly and Hobijn (2014) who investigate the impact DNWR has on the transitional path both wages and unemployment take back to pre-crisis levels. What separates our work from theirs comes through the parameter choices used to match Canadian data. Table 1 outlines the parameter choices used to match Canadian data alongside the parameters chosen by Daly and Hobijn (2014).

Many of the parameters used here are from the Bank of Canada's quarterly projection model ToTEM (Terms-of-Trade Economic Model), with some exceptions. Amongst the parameter choices listed in Table 1, the most notable is our choices for η . Labour demand elasticity η is set equal to 1.333, which is lower than that used by Daly and Hobijn of 2.5 for the United States. As Benigno and Ricci (2011) illustrate, the rate at which workers lower their current wage (compared to optimal wage rate under flexible wages) increases as the substitutability of various labour types declines. The elasticity of labour demand will play an important role in matching the distinct transition path both wages and unemployment takes back to steady state. One should note that a majority of the parameter calibrations listed above impact the value the natural rate of unemployment. As a consequence, the size of the idiosyncratic shocks will need to be calibrated to hold the steady-state level of unemployment constant at 7%. As for the remaining parameters, we will first focus on the parameters governing the household preference followed by those parameters governing technological growth and the monetary policy decisions.

The subjective discount factor β is set equal to 0.9921. The difference between the value chosen here compared to that chosen by Daly and Hobijn (2014) is negligible. Both are within the acceptable range found in the literature. The parameter governing the elasticity of labour supply γ is left unchanged from the value used by Daly and Hobijn (2014). The steady state quarterly growth rate of labour augmenting technology a is set equal to 0.005, generating an annual growth rate of 2 percent. This is set to a value lower to reflect the decreased speed at which the Canadian economy is growing compared to the United States.

Parameters	Function	DH Value	Canadian Value
η	Labour demand elasticity	2.5	1.33
γ	Frisch elasticity of labour supply	0.5	0.5
eta	Discount factor	0.995	0.9921
$\bar{\pi}$	Target inflation	0.005	0.005
ϕ^Y	Taylor rule parameter for the output gap	1	1 (ToTEM closer to 0)
ϕ^{π}	Taylor rule parameter for the inflation gap	0.3	0.3 (ToTEM has 1.14)
\bar{a}	Output growth	0.0066	0.005
σ	Standard deviation of the idiosyncratic disutility shock to labour	0.25	0.294

Table 1Parameter Values

The remaining parameters yet to be calibrated are those which govern the policy decision of the monetary authority. The target inflation is set to 0.005 per quarter (as done by DH) which works out to 2% annualized inflation target. Taylor parameter ϕ^Y measures the sensitivity of the nominal interest rate to changes in the output gap, measured by the ratio of current output to the steady-state value. This parameter is set equal to 1 as done by DH (2014). Taylor parameter ϕ^{π} measures the sensitivity of the nominal interest rate to changes in inflation from the steady-state value. This parameter is set equal to 0.3, which is the same value used by Daly and Hobijn (2014). While this value is lower than the value chosen in ToTem II of 1.14, the only source of inflation in this model comes through wage growth. Thus it is likely that a lower value is necessary to replicate the policy-rate decision of the Bank of Canada.

5 Results

We are now in a position to understand the impact DNWR has on the joint dynamics of unemployment and inflation following an economic downturn in Canada. The focus of this section will be threefold. First, to what extent does DNWR impact the wage setting decisions of both workers and firms in Canada? Second, is there a 'greasing' effect when inflation targets are increased? To this end, we'll be looking at the transition paths of unemployment, inflation, interest rates, and the percentage of the workforce bound by DNWR following a negative demand shock. This will be done across a range of inflation targets. Third, what are the policy implications in Canada? How do policy rates change with variation in the degree of DNWR and what happens if policymakers miscalculate the severity of DNWR in the Canadian economy? We begin by assessing the degree of DNWR in the Canadian labour market.

5.1 Transition Path Back to Pre-Crisis Levels

In this section we examine whether the same mechanism that explains the curvature in the SRPC in the United States can also explain the non-linear transition path of unemployment and inflation observed in Canada following the Great Recession. Since calculations for output and inflation are dependent on the distribution of wage growth in the previous period, the model outlined in Section 3 cannot be solved analytically and must be solved numerically. To plot the transition path of unemployment and wage inflation implied by our model, we'll be looking at the intersection of aggregate demand (AD) and the short run aggregate supply (SRAS) as they response to a negative demand shock given by the following law of motion:

$$D_t = \rho_D D_{t-1} + \epsilon_t \tag{19}$$

Where ρ_D determines the persistence of the preference shock and ϵ_t is an innovation shock to preferences. As done by Daly and Hobijn (2014) the persistence of the preference shock is set equal to 0.95. The variance of the preference innovation σ^D is set to match the initial drop in unemployment observed in Canada during the Great Recession. Figure 5 demonstrates how the transition path for unemployment and inflation are calculated through the evolving interaction of AD and the SRAS curves following a negative demand shock. The AD curve is calculated by a combination of both the Taylor rule (9) and the Euler equation (10) for the consumption savings decision of the household. High inflation rates lead to a lower level of output (higher unemployment) as they trigger an increase in the policy rate. Low inflation rates lead to reduction in the policy rate and an increase in output (drop in unemployment). The AD curve also shifts in response to changes in the policy rates outside of the Taylor rule (9), variations in preferences as well as shifts in technology.

The SRAS curve calculates the relationship between unemployment and inflation resulting from workers optimizing over their lifetime utility subject to the possibility of being bound by DNWR, as outlined in equation (16). Higher inflation rates imply that agents can choose the optimal wage rate now knowing that future inflation rates will be adequate enough to reduce real wages if the need arises. In contrast, low inflation rates lead workers to choose lower wage rates now as to avoid being bound by DNWR at some point in the future. In this scenario, agents would want to reduce their wage and increase their employment but are unable to do so. This relationship implies that the SRAS curve is downward sloping when inflation is plotted against the unemployment rate. Thus SRAS curve plots the positive relationship between output and inflation rates, and consequentially the negative relationship between inflation and unemployment.

The intersection of the AD and SRAS curves is calculated by either iterating up or down the inflation rate until the implied output given by both the AD and SRAS curve are equal. As can be seen in Figure 5a, a negative demand shock leads to a rightward shift in both AD and SRAS curves. The transition path back to pre-crisis levels displays a noticeable curve as the SRAS curve moves back to steady state at a faster speed then the AD curve. Figure 5b reproduces the initial flat trajectory observed in Canada that results when we take into account the higher degree of labour demand inelasticity in Canada when compared to the United States. As labour demand becomes increasingly inelastic, the slope of SRAS curve increases. As we will show, this is required to recreate the initial flat trajectory of the transition path along with the periods of pent up wage deflation observed in Canada.

Figure 6 plots the joint dynamics of unemployment and inflation in response to a negative demand shock across various degrees of DNWR. For each value of λ , the variance of idiosyncratic shock is adjusted in order to keep the natural rate of unemployment constant across simulations. For comparison, Figure 6 also plots the transition path of unemployment and wage inflation observed in Canada following the Great Recession. Both a high degree of DNWR (higher value of λ) along with a high degree of labour demand inelasticity (lower value of η) are required to replicate the initial flat trajectory as well as the pent-up wage deflation observed in Canada during the Great Recession. Decreasing the elasticity of labour demand decreases the responsiveness of wage inflation in response to the negative demand shock. With high inelasticity, labour-types are less substitutable, hence firms are less responsive to changes in wage rates. When labour demand is low, workers have to be willing to offer deep discounts on their hourly wage rate to encourage firms to hire. As demonstrated in Figure 7, this results in the wage growth distribution being squeezed from the right, with the number of people at the zero-lower bound increases as η declines. With roughly the same number of people experiencing negative wage growth in each experiment, this implies a compression of wages toward the zero-ower bound. Lastly, as mentioned earlier, the size of the demand shock is calibrated to match the increase in unemployment observed in Canada during the Great Recession. As demonstrated in Figure 6c the size of the demand shock also has a role in determining joint dynamics of unemployment and inflation in response to a negative demand shock. As one would expect, larger disruptions to the economy lead to a greater decline in wage growth as agents become increasingly willing to reduce wages as unemployment increases. This is in line with Benigno and Ricci's (2011), who showed that the workers become more flexible in their wage setting behavior when the expected increase in unemployment is large.

Recall that as the elasticity of labour demand η declines, the SRAS curve becomes steeper which pushes the initial transition path upwards. The degree of DNWR determines the extent to which SRAS curve shifts out, with higher values leading to a stronger response in unemployment, and a lessened response in inflation. This explains both the relatively flat initial trajectory as well as the deep decline in waged. Careful analysis suggests that, given the parameter choices listed in Table 1, the lower bound for the percentage of the working population subject to DNWR is approximately 83% - 85%. These values are those necessary, given our parameter choices, to replicate the relatively small decline in wage inflation in response to a negative demand shock during the first few periods. Given that approximately 15% of the population is self-employed, these results suggest 85% also appears to be an appropriate upper limit as well. Thus for the remainder of the analysis, 85% will be used as our benchmark calibration for λ .

5.2 Long Run Phillips Curve

We begin our assessment of the impact DNWR has on the Canadian economy by looking at the LRPC and the sensitivity of sacrifice ratio to changes in the degree of DNWR. Figure 8 plots the LRPC for $\lambda = \{0.7, 0.8, 0.85, 0.90\}$ with the variance of the idiosyncratic shock held constant. As can be seen in Figure 8, the long run Phillips curves are not vertical, but rather become flatter for progressively lower inflation target. Recall that workers are subject to an idiosyncratic labour disutility shock which determines whether they want to increase or decrease their labour supply each period. Households, choose a lower wage rate now, aware of the possibility that sometime in the future they may be bound by DNWR. This lower wage rate causes households to reduce their labour supply, thus leading to an increase in the natural rate of unemployment in the long run.³ Low long-run inflation rates give little relief to workers bound by DNWR. Thus at low inflation targets, a marginal increase in the long-run inflation rate leads to larger increase in employment when compared to same marginal increase at a higher inflation target. Table 2 tabulates the change in unemployment and output in the long run resulting from increase in the inflation target. The rate at which long-run unemployment declines in response to progressively higher inflation targets increases as the degree of DNWR increases. For example, when inflation targets increase from 2%to 3%, the natural rate of unemployment declines by 0.32% when $\lambda = 0.70$ compared to 0.69% when $\lambda = 0.90$. Likewise, for the same increase in inflation targets, output increases by 0.34% when $\lambda = 0.70$, to 0.75% when $\lambda = 0.90$.

5.3 Increasing the inflation Target

Given a consensus in the literature that higher inflation targets 'grease the wheels' of the labour market, we ask the following question: Do higher inflation targets shorten the overall time required for unemployment to returning back to pre-crisis levels? Recall that workers

³The natural rate of unemployment is calculated as the difference between labour supply in the benchmark model listed above, and the labour supply calculated in the model with fully flexible wages.

Table 2

Percentage Increase in Long Run Unemployment				
$\bar{\pi}$	$\lambda=0.70$	$\lambda = 0.80$	$\lambda=0.85$	$\lambda = 0.90$
2 percent to 0 percent	0.67	0.98	1.21	1.52
2 percent to 1 percent	0.33	0.48	0.59	0.74
2 percent to 3 percent	-0.32	-0.46	-0.56	-0.69
2 percent to 5 percent	-0.87	-1.23	-1.48	-1.79
2 percent to 10 percent	-1.87	-2.59	-3.05	-3.61
Increase in Long Run Output				
$\bar{\pi}$				
2 percent to 0 percent	-0.71	-1.05	-1.30	-1.65
2 percent to 1 percent	-0.35	-0.51	-0.64	-0.80
2 percent to 3 percent	0.34	0.49	0.60	0.75
2 percent to 5 percent	0.92	1.32	1.59	1.94
2 percent to 10 percent	1.97	2.76	3.28	3.92

Changes in Unemployment and Output Resulting from changing Inflation Targets The volatility of the idiocyncratic shock is held σ^2 held constant

Each cell represents the percentage change in the natural rate of unemployment (top) and long run output (bottom) resulting from a change in the inflation target listed on the left for the various degrees of DNWR listed at the top of each column. For each estimation, the standard deviation of the idiosyncratic shock is held constant at 0.294.

base their current wage decision on future inflation rates. As discussed in the previous section, higher inflation targets lead to lower rates of unemployment in steady state. However, as we will show, increasing the inflation target does not accelerate the speed to which unemployment returns back to its natural rate following a recession. This turns out to be due to the cyclical component of DNWR increasing with higher inflation targets.

To answer this question Figure 9 plots the impulse response functions (IRFs) of the nominal interest rate, the inflation rate, the percent increase in the number of people bound by DNWR and the unemployment gap to a negative demand shock across various inflation targets. As can be seen in Figure 9, the similarity of the IRFs for unemployment across

inflation targets is striking. There appears to be little evidence that higher inflation targets 'grease the wheels' during a labour market correction. This result appears to be due to risk compensation. When inflation targets are low (0%-2%) it provides little relief to workers who want to lower their current wage rate and work more, but are unable to do so due to DNWR. Higher inflation targets imply that agents can increase their current wage now knowing that future inflation rates will be high enough to force real wage downward if required. As can be seen in Figure 10, the steady state distribution of wage growth moves away from the zero-lower bound, with more people choosing positive wage rates. While it's expected that higher long-run inflation rates would be taken into account when setting nominal wages, the portion of workers at the zero-lower bound decreases by more then had we simply shifted the underlying flexible wage distribution rightward and compressed the fraction of those bound by DNWR to zero. Rather, those that were already increasing their wage rate, increase their wage rate by more with higher inflation targets. Thus, while higher inflation targets elevate the risk associated with being bound by DNWR, agents take this into account and choose a riskier initial wage rate. Likewise, with lower inflation targets, the number of people bound by DNWR increases in steady state, with fewer people moving to the zero-lower bound in response to a negative demand shock. Thus lower inflation targets reduce the cyclical volatility of DNWR.

As Figure 9 demonstrates, the cyclical component of DNWR increases for progressively higher inflation targets. Thus while higher inflation targets provide relief to workers bound by DNWR, the proportion of the population bound by DNWR increases during recessions with higher inflation targets. Thus the entire 'greasing' effect is absorbed by rational workers who exploit the benefit of higher inflation rates. This happens up until the point where the transition path of unemployment across the two inflation targets are virtually identical.

As a counterfactual, Figure 11 reproduces the same IFs listed in Figure 9 when the underlying wage distribution remains unchanged from the benchmark model ($\bar{\pi} = 2\%$). When wage growth decisions are unchanged across inflation targets, the original hypothesis reemerges, with higher inflation targets accelerating the speed at which unemployment returns back to pre-crisis levels.

There is one exception to the argument listed above. While there is no greasing effect across various inflation targets in the short run, there is a one-time reduction in unemployment at the moment a higher inflation target is adopted. With the wage distribution determined prior to the adoption of a higher inflation target, there still would exist a momentary greasing effect from adopting higher inflation targets.

5.4 Policy implications

Now that we have a firm idea regarding the degree at which DNWR impacts the Canadian labour market, we can now move on to a discussion of how it impacts policy decisions. In particular, how sensitive are policy rates to varying degrees of DNWR? In addition, what are the economic consequences of miscalculating the degree of DNWR? To assess the relevance of DNWR in policy decisions, we'll first assess how sensitive the policy rate is to varying degrees of DNWR. We will then move on to an experiment to observe what happens if policymakers either overestimate or underestimate the severity of DNWR when choosing the policy rate.

Figure 12 plots the IRFs for the interest rate, the inflation rate as well as the unemployment gap and the percentage of workers bound by DNWR over a range of values for $\lambda \in \{0.7, 0.8, 0.85, 0.9\}$ in response to a negative demand shock. As demonstrated in Figure 12, higher rates of DNWR lead to an attenuated decline in inflation as well as a larger increase in unemployment in response to a negative demand shock. Since the Taylor rule reacts more to changes in the inflation over changes to output, increasing the degree of DNWR leads to a smaller decline in interest rates. Furthermore, higher rates of DNWR reduce the speed at which inflation, and thus interest rates return back to pre-crisis levels. Lastly, while higher rates of DNWR lead to a larger increase in the unemployment gap, the speed at which the unemployment returns back to pre-crisis levels is accelerated. Thus higher rates of DNWR reduce the half-life of the unemployment gap in response to a negative demand shock. They also lead to a reduction in the volatility of interest rates and inflation and output.

With this information at hand, we can now perform the following experiment: What happens if policymakers miscalculate the number of people unable to adjust wages downward.

Experiment #1:

What if the policymakers miscalculate the degree of DNWR by +/-10% when setting the nominal interest rate?

This experiment goes as follows: Policymakers either overestimate or underestimate the degree of DNWR and choose a policy rate accordingly. At the end of each period, output and inflation are updated to reflect the true data generating process as well as the policy rate decision in the previous step. Policymakers take the realized values for output and inflation as given, chalking up the difference between their estimates and the realized values due to either a miscalculation or measurement error. Thus in the following period policymaker choose an interest rate at this new point based on their estimation for λ and repeat. Table 3 outlines the steps of the thought experiment.

Table 3Steps for Experiment #1

Step 1:	In period t, given the current state of output and inflation, pol- icymakers choose an interest rate based on their estimate for λ and the output, inflation expectations that come with this assumption.
Step 2:	Still in period t, given the policy decision in Step 1, next periods output and inflation are estimated using the correct estimate for λ . Since the steady-state output differs between the two models, the output gap, rather than the output level is used to update output.
Step 3:	In period $t+1$, given the output and inflation rates estimated in Step 2, policymakers again choose an interest rate based on their estimation for λ and the output and inflation expectations that emerge from that assumption.

Figure 13 plots the impulse response functions that results when the degree of DNWR $(\lambda = 0.85 \text{ in our benchmark calibration})$ is either overestimated or underestimated by 10%. These impulse response functions are produced alongside a model simulation when λ is properly calibrated.

When policymakers underestimate the degree of DNWR by 10%, they overestimate the

drop in inflation and cut interest rates to encourage economic growth and attenuate the perceived decline in inflation. Thus policymakers overreact to the negative demand shock and overstimulate the economy, reducing the rise in unemployment and the decline in inflation. As the economy begins to recover and interest rates begin to rise, underestimating the degree of DNWR also causes policymakers to overestimate the speed at which wages and hence inflation adjust back to pre-crisis levels. This accelerates the speed at which interest rates recover, causing unemployment to lag behind the competing scenario where λ is properly calibrated.

When policy rate decisions are based on an overestimation of the degree of DNWR, the opposite holds true. When policymakers overestimate λ by 10%, they underestimate the decline in inflation and thus reduce interest rates by less. This increases the impact of the negative demand shock on unemployment which causes inflation to drop further. As the economy begins to recover, overestimating the degree of DNWR causes policymakers to underestimate the speed at which inflation will adjust back to pre-crisis levels. Thus the speed at which interest rates return back to pre-crisis levels is reduced as policymakers anticipate only a gradual return back to steady state. This accelerates the speed at which unemployment and inflation return back to pre-crisis levels.

What can we learn from this experiment? There appears to be no clear benefit from either under or overestimating the degree of DNWR when measured by either reducing unemployment or reducing disinflation during recessions. However under, rather than overestimating the degree of DNWR appears to closely simulate the time-path observed for inflation and unemployment when the degree of DNWR is properly calibrated. As can be seen in Figure 13, the policy rate implied when policymakers underestimate the degree of DNWR converges with that observed when DNWR is properly calibrated one year earlier than its counterpart. When the degree of DNWR is overestimated, interest rates drop by less and as the economy recovers, the speed at which interest rates rise is also reduced, delaying the speed at which it converges with the policy rate chosen when DNWR is properly calibrated. This delayed convergence has long-lasting repercussions for unemployment and inflation.

6 Conclusion

Tobin (1972) theorized that positive inflation target could 'grease the wheels' of the labour market, and therefore could be used to partially offset the negative effect of DNWR by allowing for greater flexibility in real wages. When dissecting this claim, this paper finds that increasing inflation targets does not accelerate the speed at which unemployment returns back to pre-crisis levels. Rather higher inflation targets lead households, with perfect foresight to choose more aggressive real wage rate. Thus while higher inflation targets allow real wages to decline when nominal wages cannot, real wage rates now on average need to drop by more with higher inflation targets. Thus despite having a highly regulated labour market in Canada, the 'greasing' effect derived from higher inflation targets is almost entirely eroded by the household's wage response. There does however exist a trade-off between output and inflation in the long run, with higher inflation targets leading to a lower natural rate of employment. This paper also explored the economic consequences of miscalculating the degree of DNWR when forming monetary policy. There is no clear benefit from either under or overestimating the degree of DNWR. However, when DNWR is underestimated, the policy rate closely matches the equivalent rate when DNWR is properly estimated. Thus it appears that erring on the low side when estimated the degree of DNWR is preferable. The model presented, while capable of replicating the joint dynamics of unemployment and inflation in Canada, it is not yet capable of reproducing the degree of DNWR observed annually in the micro-level data, further research is required.

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7 Appendix

Figures 1, and 4 calculate wage growth rates using principal component analysis. Figure 14 plots the various components of the estimate along with the principal component growth rate. These 4 components to this analysis include; average hourly wage rates, average weekly wage rates, the median hourly wage rate and the median weekly wage rate. Each of these were obtained from Statistics Canada, Survey of Labour income and Dynamics, where we calculate the average growth rate of each seasonally adjusted quarterly time series from one year prior. As can be seen in Figure A1, a majority of the time series follow a similar pattern with the exception of the annualized growth rate of average hourly wage rates which dropped substantially during the periods following the recession. Thus the principal component analysis provides a more robust measure of wage growth over the time horizon considered. The same methodology was used to calculate the principal component of wage growth for unionized and non unionized workers using data from the Labour Force Survey produced by Statistics Canada.



The unemployment gap is calculated as the national unemployment rate less the natural rate of unemployment. The adjusted nominal wage growth is calculated using principal component analysis to calculate the annual wage growth, less the 10 year ahead forecast expectations. Further details are available in the Appendix. Calculations for the United States comes from Daly and Hobijn (2014).



This graph is calculated by Brouillette, Kostyshyna and Kyui (2015a). This distribution is based on the Survey of Labour Income and Dynamics from 2001-2011.



This graph is calculated by Brouillette, Kostyshyna and Kyui (2015b). This distribution is based on the Major Wage Settlement data from 2001-2015.



The unemployment gap is calculated as the national unemployment rate less the natural rate of unemployment. The adjusted nominal wage growth is calculated by using principal component analysis to calculate the annual wage growth. This series is then adjusted by the 10 year ahead forecast expectations. This analysis is applied to wage rates across the three labour types; those unionized, non-unionized, as well as the sum of the two groups. Data collected from the Statistics Canada's Labour Force Survey.



Figure 6 Short Run Phillips Curves Varying Degrees of DNWR Holding the Natural Rate of Unemployment Constant 2.5 1.5 → Eta =1.1 7 0=chdmcl **Nage Inflation** Lambda = 0.8 → Eta =2.5 0.5 Wage Inflation Lambda=0.85 🔶 Eta =4 -1.5 -0.5 1.5 ➡ Data Lambda=0.9 -0.5 1.5 -1.5 -1 -0.!

-1.5

Unemployment Gap

(a) Variation in DNWR



Unemployment Gap

(b) Variation in Labour Demand Elasticity

(c) Variation in Size of the Demand Shock

For each value for λ and η , the volatility of the idiosyncratic shock is adjusted to keep the natural rate of unemployment fixed at 7%. The natural rate of unemployment is then removed from each of the short run Phillips curves plotted. This is then overlapped with the Canadian wage Phillips curve shown in Figure 1.







Varying the Degree of DNWR λ





The green line indicates the case where the inflation target $\bar{\pi}$ is set equal to 2%. The blue line indicates the case where the inflation target $\bar{\pi}$ is set equal to 1%. Lastly, the red line indicates the case where the inflation target $\bar{\pi}$ is set equal to 5%. The unemployment gap and the percentage of workers with zero wage growth are all measured as the deviation from steady state to highlight the cyclical component.



Figure 10 Density of Log Wage Changes in Steady State Quarterly growth in Log Wages $\bar{\pi}$ increases from 2% to 5%



(c) Unemployment Gap

The green line indicates the case where the inflation target $\bar{\pi}$ is set equal to 2%. The blue line indicates the case where the inflation target $\bar{\pi}$ is set equal to 1%. Lastly, the red line indicates the case where the inflation target $\bar{\pi}$ is set equal to 5%. For the latter two cases the wage distribution is set to match the distribution when $\bar{\pi} = 2\%$ for the lifetime of the demand shock



In each panel $\lambda = \{0.7, 0.8, 0.85, 0.90\}$ are plotted as $\{$ blue, red, green and purple $\}$ respectively. Panel A) plots the interest rates across various measures of λ , measured quarterly. Panel B) plots the inflation rates, which are annualized. Panel C) plots the unemployment gap, measured as unemployment rate less the natural rate of unemployment implied by each value of λ . Last of all, Panel D) plots the increase in the percentage of workers at the zero lower bound, each adjusted by their respective steady state values.



The green line indicates the scenario when policy makers correctly estimate the degree of DNWR in the economy. The red line indicates the outcome when policy makers overestimate λ by 10%. Lastly, the blue line indicates the case when policy makers underestimate λ by 10%.



Data for the annualized growth rates of average hourly wage rates, average weekly wage rates, the median hourly wage rate and the median weekly wage rate are available through Statistics Canada's Survey of Labour income and Dynamics. The common component of each time series is assessed using principal component analysis.



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