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Abstract

This study examines the effect of nominal-wage rigidities on wage growth in Canada using a hazard model and micro data for union contracts. The hazard model is specified in a way that allows considerable flexibility in the shape of the estimated notional wage-change distribution. This notional distribution is compared with the observed distribution to estimate the net effect of downward nominal-wage rigidity and menu costs on wage growth. Estimates from alternative versions of the model suggest that the net effect on the average annual growth rate of wages was in the range of 0.10 to 0.18 percentage points in the unionized private sector during the low-inflation period of the 1990s.

JEL classification: E24, E52, E61
Bank classification: Labour markets; Inflation targets

Résumé

L'auteur examine l'effet de la rigidité des salaires nominaux sur la croissance des salaires au Canada en faisant appel à un modèle de survie et aux microdonnées se rapportant aux conventions collectives. Le modèle de survie est formulé de manière à permettre une très grande souplesse dans la forme de la distribution théorique des variations salariales que l'on tente d'estimer. L'auteur compare la distribution théorique estimée à la distribution observée afin d'évaluer l'incidence nette de la rigidité à la baisse des rémunérations nominales et de la présence de coûts d'étiquetage sur la progression des salaires. Selon les estimations obtenues à partir de différentes variantes du modèle, l'effet net de ces deux facteurs sur le taux de croissance annuel moyen de la rémunération aurait été de l'ordre de 0,10 à 0,18 point de pourcentage dans les entreprises syndiquées du secteur privé durant la période de faible inflation des années 1990.

Classification JEL : E24, E52, E61
Classification de la Banque : Marchés du travail; Cibles en matière d'inflation

1. Introduction

Inflation fell to low levels in many countries during the 1990s. In some cases, the movement to low inflation was accompanied by the adoption of formal inflation targets as the operational framework for monetary policy. These developments have directed attention to determining the level of inflation that will promote the best macroeconomic performance.

As part of this debate, various authors, including Akerlof, Dickens, and Perry (1996) and Fortin (1996), have argued that an economy will function better at some moderate inflation rate than at price stability because nominal-wage rates are downwardly rigid.[1] According to this view, downward nominal rigidity impedes downward adjustments to real wages at low inflation, so targeting a very low inflation rate would raise the average level of unemployment in an economy subject to periodic negative demand shocks. Advocates of this hypothesis conclude that some moderate level of inflation is necessary to facilitate real wage adjustments and minimize the employment costs of binding nominal-wage floors.

There are two critical issues in evaluating the policy implications of the rigidity hypothesis: (i) the empirical significance of downward nominal-wage rigidity, and (ii) the effects on employment of a given amount of rigidity. One line of research on the first issue has been to test the prediction that downward nominal rigidity would make wage freezes more common in periods of lower inflation. Although it is useful to know the frequency of wage freezes, this information is only an imperfect indicator of downward rigidity. In particular, it cannot resolve whether some freezes arise from other factors such as menu costs, nor can it indicate the extent to which wage levels are affected when nominal-wage floors are binding. Deeper analysis of these questions would help to evaluate whether wage rigidity is likely to have significant effects on employment.

The need for more sophisticated tests of nominal-wage rigidity has led to several broad strategies in the literature. One approach is to use some measure of aggregate wage growth to determine whether the shape of the Phillips curve shows evidence of downward nominal-wage rigidity at low levels of inflation. Canadian studies of this type include Dupasquier and Ricketts (1998), Fortin and Dumont (2000), and Farès and Lemieux (2001).

Alternatively, some authors have adopted a microeconometric perspective and test for rigidity using data for individual wage contracts. One way to implement this approach is to compare the observed wage-change distribution and an estimate of the distribution that would have occurred in the absence of rigidity. This strategy was followed by Crawford and Harrison (1998), who

1. See Schultze (1959) and Tobin (1972) for earlier statements of this hypothesis.

estimated a hazard model using data for union wage settlements in Canada.[2] The model used in that study could provide only upper-bound estimates of downward rigidity. The objective of the current paper is to obtain tighter estimates of the impact of rigidity on wage growth using a modified version of the earlier model.

Section 2 describes some basic features of the wage-change distribution to provide some background for the econometric analysis. Sections 3 and 4 present empirical evidence from two alternative versions of the modified hazard model. Section 5 provides conclusions on the impact of rigidity on wage growth in Canada during the 1990s.

2. Stylized Facts from Wage-Change Distributions

The Canadian wage data analyzed in this paper are private sector contracts for unionized bargaining units with at least 500 employees. Wage changes are measured as the average annual percentage change in the base wage rate over the lifetime of the contract. Thus, a wage freeze is defined as a contract with an average annual wage change of zero. This data set has some potential limitations as an indicator of rigidity in the overall economy, since it does not incorporate variable forms of compensation, such as bonuses and profit-sharing, and it excludes small firms and the non-union sector. Information from other micro databases can be used to supplement the evidence from wage settlements.[3]

The objective of the econometric analysis is to distinguish between the observed wage-change distribution and the “notional” distribution that would have occurred in the absence of rigidities. Some stylized facts will help to illustrate the motivation for the econometric models shown in sections 3 and 4. Figure 1 shows the wage-change distributions for three periods corresponding to years of high, moderate, and low inflation as measured by the percentage change in the consumer price index excluding the effect of changes in indirect taxes. The periods are 1978–82 (with an average inflation rate of 10.4 per cent), 1983–91 (average inflation of 3.9 per cent), and 1992–97 (average inflation of 1.6 per cent). Each bar in a histogram shows the percentage of private sector contracts with wage changes lying within an interval of 0.5 percentage points, with the exception of wage freezes, which are shown as wage changes of exactly zero per cent (denoted by the

2. Various other techniques have been used with micro wage data to study downward rigidity. For example, see U.S. studies by Card and Hyslop (1997), Kahn (1997), and McLaughlin (1994, 1999), and Canadian studies by Simpson, Cameron, and Hum (1998), Farès and Hogan (2000), and Crawford and Wright (2001). The Crawford-Wright paper includes a summary of evidence from the Canadian micro literature.
3. Crawford and Harrison (1998) discuss the wage-change distributions from alternative definitions of wage change and different databases.

vertical dashed lines in the figure).[4] Three characteristics of the distributions are highlighted below.

2.1 Frequency of wage freezes

The mean of the notional wage-change distribution depends on factors including the level of inflation, productivity growth, and cyclical demand conditions. Holding the variance of the notional distribution constant, the number of contracts with pressures for nominal-wage cuts will tend to increase as lower inflation reduces the mean wage settlement. If nominal-wage floors are widespread, however, wage freezes will become more common at lower inflation and there will be few rollbacks. The spikes in the histograms at exactly zero per cent show that the incidence of wage freezes does tend to be greatest in periods of low inflation (Figure 1). Wage rollbacks are more common in the low-inflation years, but still affect only 2.4 per cent of private sector contracts.

2.2 Frequency of small wage changes

The combination of an increased frequency of wage freezes and relatively few rollbacks in low-inflation periods is consistent with the predictions of the rigidity hypothesis. When interpreting the evidence in Figure 1, however, it is also important to note the shape of the distribution in the intervals close to zero. In the histogram for the 1992–97 period, the densities initially decline at a relatively smooth rate with movement from the median settlement toward intervals of lower wage growth. Given a smooth distribution for the underlying determinants of wage growth (i.e., the notional distribution), we would expect this pattern of gradual declines to continue in the intervals closest to zero. Instead, there is a sharp decrease in density in the interval representing small wage increases of up to 0.5 per cent, and virtually no density in the interval for small wage decreases of up to 0.5 per cent.[5]

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4. The end points of the intervals exclude the lower bound and include the upper bound (with the exception of the interval to the left of zero). The interval at the upper extreme includes all contracts with an average annual wage change greater than 20 per cent, while the interval at the lower extreme includes all contracts with an average annual wage change of –4 per cent or less.

5. The interval representing wage increases in the range of 1.5 to 2.0 per cent contains 15.3 per cent of all private sector contracts. The percentage of contracts falls gradually to 12.5 per cent in the interval for wage changes of 1.0 to 1.5 per cent, and 11.5 per cent in the interval for 0.5 to 1.0 per cent. In contrast to this smooth rate of decline, the percentage of contracts falls sharply to only 2.6 per cent in the interval containing small wage increases of up to 0.5 per cent, and to only 0.3 per cent in the interval containing small wage decreases of up to 0.5 per cent.

The unusually low densities in the intervals closest to zero indicate that symmetric menu-cost effects may have resulted in a significant number of contracts providing no wage change rather than small wage increases or small wage decreases. If the wage at the end of the previous contract is still broadly appropriate, given current conditions, the employees and firm may settle on a wage freeze to avoid the time and administrative costs of further negotiations over the size of a small wage change. In this respect, note that an adjustment in the hourly wage of 0.5 per cent represents a wage change of only about 10 cents on average (given the average wage level in the wage-settlements database).

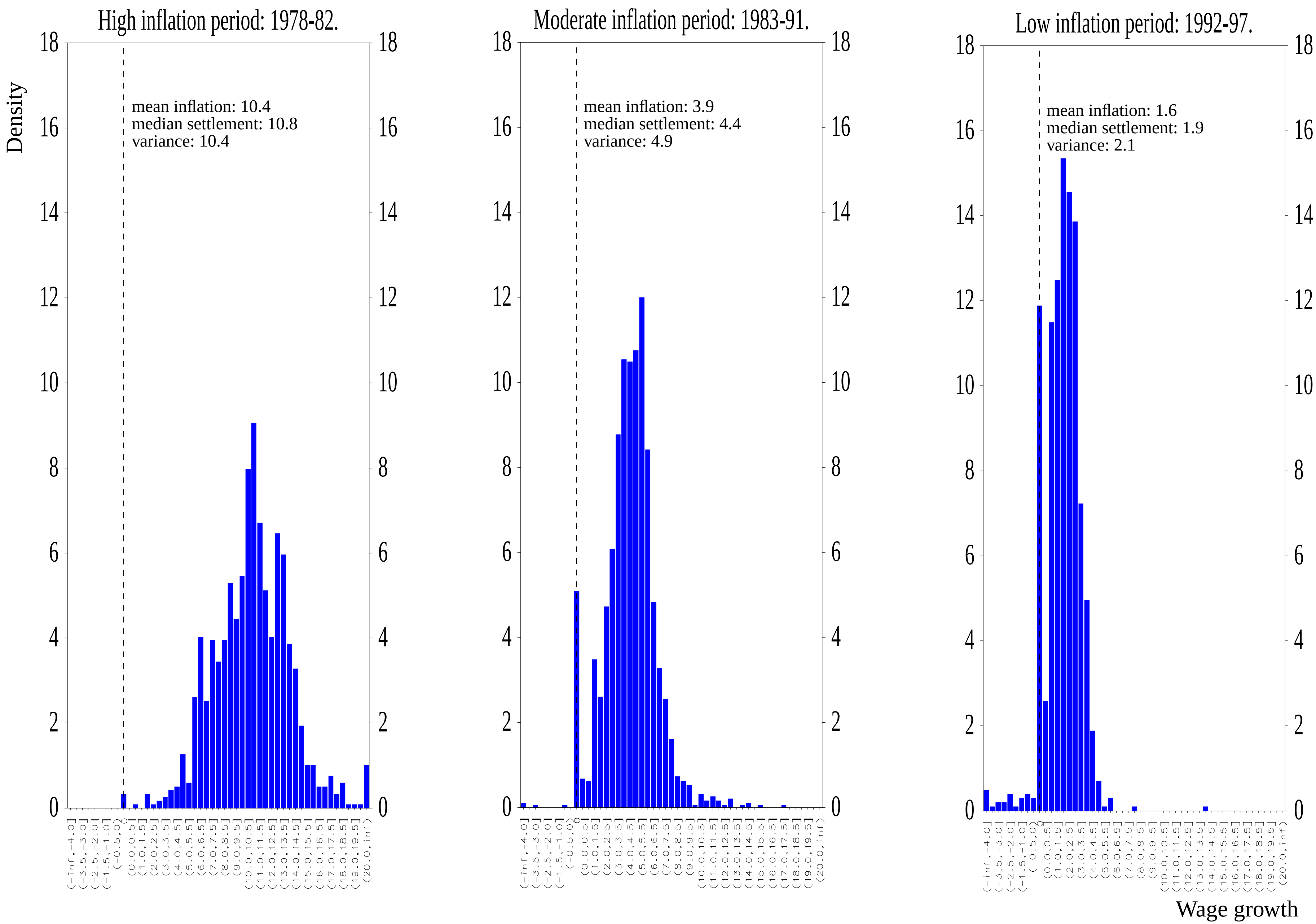
A more formal technique is required to evaluate the empirical importance of these menu-cost effects. Nonetheless, the low densities in intervals close to zero suggest that there could be a significant increase in the number of wage freezes as inflation nears zero, even in the absence of the downward rigidity coming from institutional factors or workers' resistance against pay cuts. The practical implication of this conclusion is that a model that attributes all wage freezes to asymmetric downward rigidity will tend to overstate the effect of rigidity on mean wage growth.

2.3 Intertemporal changes in the variance

The preceding discussion suggests that an econometric model of rigidity should attempt to decompose the total number of wage freezes into those arising from symmetric menu-cost effects and those caused by asymmetric downward rigidity. Figure 1 shows another feature of the wage-change distribution that should be embodied in an empirical model. As stated earlier, if the variance of the notional distribution is constant, the percentage of contracts facing pressures for nominal-wage cuts will tend to increase at lower rates of inflation. However, the variance of the observed distribution is not constant—it was high during the high-inflation period, and then declined in the moderate-inflation period and fell again in the 1990s (Table 1).

It might be argued that this decrease in variance simply reflects a thinning of the density in the left tail of the distribution owing to downward rigidity, rather than a change in the notional distribution. Table 1 reports strong evidence that downward rigidity is not the only reason for the change in variance. While the percentage of contracts lying in the left tail (as measured by the number of contracts at least 2.5 percentage points below the median) did fall significantly over the sample period, a very similar decline occurred on the *right side* of the distribution. Since similar movements occurred on both sides of the distribution, the evidence suggests that much of the decline in the observed variance can be attributed to a decrease in the variance of the notional distribution. Given the positive historical relationship between inflation and the variance of the

Figure 1: Distribution of Wage Settlements, Private Sector



wage-change distribution, constraining the notional variance to be constant would result in an overstatement of the notional density below zero (and the extent of rigidity) in the low-inflation years.

These stylized facts suggest that empirical models should test for a time-changing notional variance and menu-cost effects. Evidence from Tobit models of wage rigidity (Crawford and Wright 2001) shows that models that fail to incorporate these characteristics will significantly overstate the impact of rigidity on wage growth.

Table 1: Private sector wage settlements

Period	Median (per cent)	Variance	Percentage of contracts at least 2.5% from the annual median		
			$\geq 2.5\%$ below median	$\geq 2.5\%$ above median	Total
1978–82	10.8	10.4	14.4	14.7	29.1
1983–91	4.4	4.9	9.5	7.0	16.5
1992–97	1.9	2.1	3.0	1.8	4.8

3. Estimates of Rigidity—Model I

Two versions of a hazard model are used in this paper to estimate the effect of rigidity on wage growth. While each version allows the notional variance to change over time, the versions differ in the way that they attempt to control for rigidity when estimating the notional distribution. This section describes the first of these methods.

3.1 The basic hazard model

The hazard function $h(\Delta w)$ gives the conditional probability of observing a wage change within a given interval:

$$h(\Delta w) = \frac{f(\Delta w)}{[1 - F(\Delta w)]} \tag{1}$$

where $f(\Delta w)$ is the density in a given interval of the wage-change distribution and $F(\Delta w)$ is the cumulative distribution function. The intervals selected for the hazard estimation are called *baseline segments*.

In a proportional hazard model, the hazard function depends on a vector *x* of explanatory variables:

$$h(\Delta w|x) = \exp(x\beta)h_0(\Delta w) \tag{2}$$

where β is a vector of parameters. To be consistent with the terminology in the hazard literature, these explanatory variables will be called *covariates*. If all covariates have a value of zero, the hazard function simplifies to the baseline hazard $h_0(\Delta w)$. Parameters of the baseline hazard are estimated using a separate dummy variable for each of the baseline segments. Inclusion of the time-varying covariates allows the shape of the distribution to change over time.

In equation (2), the parameter for each covariate is constrained to be constant over the entire distribution, so a change in the value of a covariate will shift the entire hazard function up or down relative to the baseline hazard. This constraint could impose inappropriate restrictions on the variance (and other moments) of the estimated wage-change distribution and, therefore, bias the estimates of rigidity. In Crawford and Harrison (1998), the restrictions were relaxed by allowing the effect of a change in covariate to vary over different ranges of the wage-change distribution. Technically, this was accomplished by dividing the distribution into *p* subintervals (called *covariate segments*). For each covariate, a different parameter was estimated for each covariate segment, as shown in equation (3):[6]

$$h(\Delta w|x) = \exp\left(\sum_{i=1}^{p} 1[\Omega_i]x_i(\Omega_i)\beta_i\right)h_0(\Delta w) \tag{3}$$

where $\Omega_i = (\Delta w_L^i, \Delta w_U^i)$ defines the range of covariate segment *i*, $1[\Omega_i]$ is a function equalling 1 if Δw is contained in the set Ω_i and zero otherwise, $x_i(\Omega_i)$ is a 1xk vector of covariates defined over the set Ω_i, and β_i is a kx1 vector of parameters for covariate segment *i*. Thus, the total number of covariate parameters to be estimated is equal to the number of covariates (k) multiplied

6. In principle, the number of covariate segments could be identical to the number of baseline segments. In practice, sufficient additional flexibility is often introduced with the number of covariate segments being less than the number of baseline segments (i.e., the range of an individual covariate segment spans one or more baseline segments). Donald, Green, and Paarsch (1995) discuss this specification of the covariate parameters in a hazard model.

by the number of covariate segments (p). As indicated by equation (1), the wage-change distribution is a transformation of the estimated hazard function.

The hazard function in Crawford and Harrison (1998) was defined in terms of the percentage change in the nominal-wage rate (Δw). In the present study, the wage variable is redefined as the *deviation* of the wage settlement from the median wage change in the current period:

$$h(\Delta w^d | x) = \exp\left(\sum_{i=1}^{p} 1[\Omega_i] x_i(\Omega_i)\beta_i\right) h_0(\Delta w^d) \tag{4}$$

where $\Delta w^d = |\Delta w - \Delta w^m|$ is the absolute value of the deviation of the wage change from the median settlement in period t and Ω_i is defined in terms of deviations. Thus, the modified hazard model describes the conditional probability of observing wage changes a given distance from the median.

This redefinition of the wage variable has two advantages. First, it allows a substantial reduction in the number of parameters to be estimated.[7] Most importantly, specifying the wage variable as the deviation from the median makes it possible to provide point estimates of rigidity. The model in Crawford and Harrison (1998) gave only upper-bound estimates because there was not a well-defined notional distribution when the model was estimated using the level of wage growth.[8]

3.2 Estimating the notional distribution

If rigidity is not modelled explicitly in equation (4), the true parameters of the notional distribution can be identified only if contracts affected by rigidity are excluded from the data used for estimation. This approach is implemented in Model I by assuming that contracts with wage growth greater than the median settlement are unaffected by downward rigidity and menu-cost effects. Therefore, the parameters of the hazard model are estimated using equation (4) and contracts from only the right half of the wage-change distribution. The notional distribution for the left side (the side containing wage freezes) is then constructed for a given year using these parameter estimates and the covariate data for contracts appearing on the left side of the actual

7. Because the level of nominal-wage growth varied over a wide range during the sample period, the model in Crawford and Harrison (1998) contained a large number of baseline segments (45) and, therefore, a large number of parameters for the baseline hazard. The range of observations and the number of parameters can be reduced considerably when the wage variable is measured as deviations from the median.

8. The upper-bound estimates of rigidity were calculated as the difference between the estimated density in the (0, 0.99) interval of the wage-change distribution at 2 per cent inflation and the estimated density in this interval at 6 per cent inflation.

distribution in that year. Provided contract-specific data are used as covariates, Model I does not constrain the notional distribution to be symmetric about the median. As explained below, estimates of the net impact of downward rigidity and menu-cost effects on average wage growth are obtained by comparing the actual left-side data and the estimated notional distribution for the left side.

The assumption in Model I that contracts above the median are unaffected by rigidity rules out a possibility described by Hogan (1997). He suggested that the risk of encountering binding nominal-wage floors in future periods may cause wage increases to be *moderated* at firms unaffected by wage floors in the current period. Since this outcome would result in the current level of wages being lower than would otherwise be the case, forward-looking firms might try to follow this strategy to avoid potential future constraints on their ability to cut the nominal wage. If this behaviour reduces the observed density in the right tail of the wage-change distribution, the methodology of Model I could understate the notional density over the range of wage cuts. However, this effect occurs only to the extent that wage growth is moderated in contracts above the median. Because Model I does not incorporate either of these (offsetting) effects, it should not bias the estimated effect of rigidity on aggregate wage growth.

3.3 Calculating rigidity

In each period, one of the baseline segments in the hazard model corresponds to the interval containing contracts with wage freezes. A key issue is how much of the observed density in this interval can be attributed to downward wage rigidity: some density would be expected even in the absence of downward rigidity, but there may also be *excess density* in this interval arising from symmetric menu-cost effects and asymmetric downward rigidity. The notional distribution constructed from the hazard model provides a way to estimate the excess density in the wage-freeze interval as well as the sources of this excess density.

The methodology adopted for this purpose is explained using the hypothetical case illustrated in Figure 2. Figure 2a shows the distribution for the level of wage change. Consistent with the definition of the wage variable in equation (4), Figure 2b graphs the corresponding distribution of deviations from the median for contracts with wage growth below the median. Thus, the density in the interval at the extreme right in Figure 2b represents contracts with wage increases at or slightly below the median settlement, and movement to the left represents contracts with progressively smaller wage changes (i.e., farther below the median).

Each interval in Figure 2b corresponds to a baseline segment in the hazard model. Assuming that median wage growth is 2.25 per cent, the interval showing *deviations* in the range of 2.0 to

2.49 per cent (indicated by the solid vertical line) represents contracts with wage freezes as well as small wage increases and small wage decreases. For simplicity, the phrase "wage-freeze interval" is used throughout this paper, even though it also covers a range of small wage changes in either direction.[9] Intervals to the right (left) of the wage-freeze interval in Figure 2b contain contracts with wage increases (decreases). The actual distribution of deviations below the median is indicated by the dashed line; the estimated notional distribution is indicated by the dotted line.

Figure 2a: Wage-change distribution (levels)

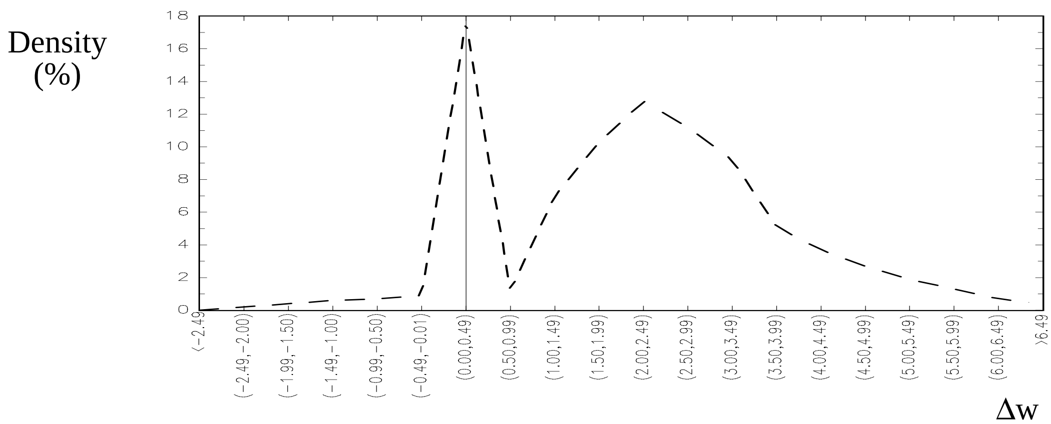
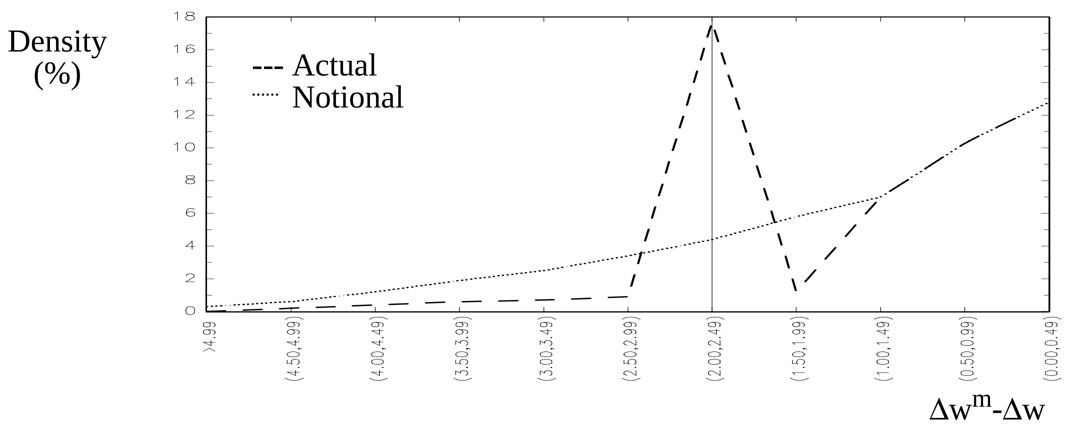


Figure 2b: Deviations below the median



9. In the actual data, almost all contracts in this range are wage freezes. This suggests that the notional density in the wage-freeze interval (which spans a narrow range of only 0.5 per cent) provides a conservative estimate of menu-cost effects.

The actual density exceeds the notional density in the wage-freeze interval in Figure 2b. The difference between these two densities—representing the excess density in the wage-freeze interval—can be decomposed into two components. First, some contracts are wage freezes but would have been wage cuts in the absence of downward rigidity and menu-cost effects. This component is measured by the area between the notional and actual distributions to the left of the wage-freeze interval in Figure 2b. Second, some contracts are wage freezes but would have been wage increases in the absence of menu costs. The percentage of contracts with wage growth pulled down to zero is measured by the area between the notional and actual distributions to the right of the wage-freeze interval. The net effect on mean wage growth from both types of rigidity can be calculated by comparing the actual and notional densities over the entire distribution.

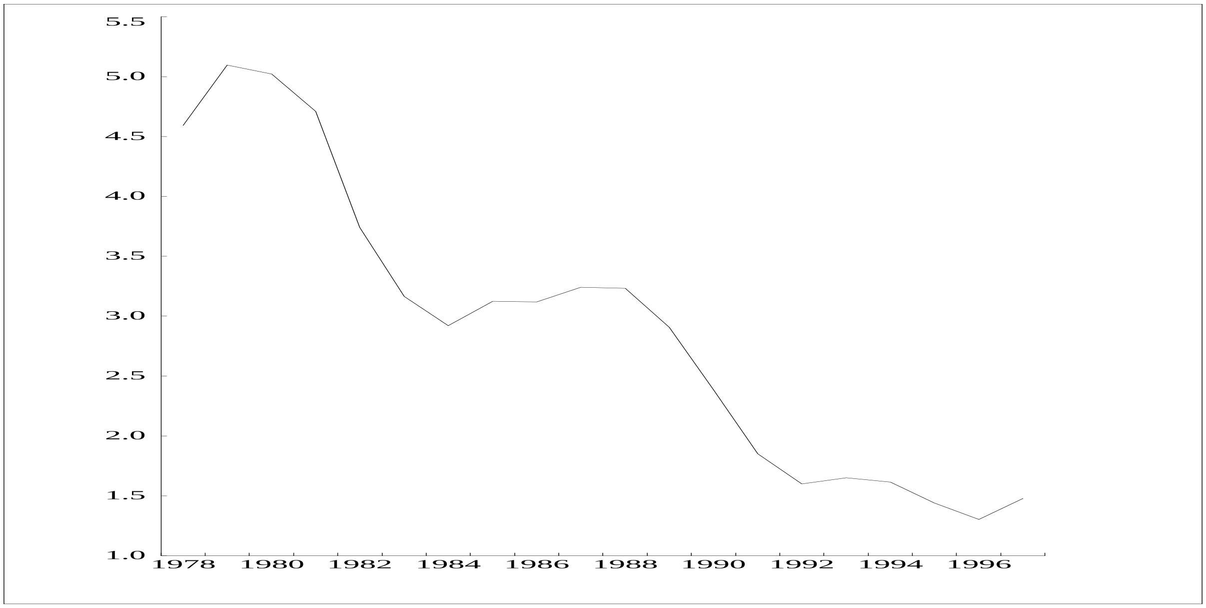
3.4 Data

The hazard model defined by equation (4) is estimated using private sector contracts negotiated during the 1978–97 period. The median wage change varied between 1.4 per cent and 2.6 per cent during the low-inflation years from 1992 to 1997.

Since the wage variable in the hazard model is defined in terms of deviations from the median, variables affecting the dispersion of the wage-change distribution (not the median) are relevant for the covariate vector. The covariate used to estimate Model I is a contract-specific measure of inflation uncertainty which is estimated using parameters from an autoregressive model of inflation with generalized autoregressive conditional heteroscedasticity (GARCH) effects.[10] An n-quarter-ahead forecast of inflation uncertainty (n = contract length) was calculated for each contract using an updated version of a model described in Crawford and Kasumovich (1996). As Figure 3 shows, the average level of inflation uncertainty for contracts signed in a given year trended downward as inflation fell in Canada. A decrease in inflation uncertainty is expected to lower the dispersion of wage changes.

10. Future research could broaden the set of covariates to include variables such as the dispersion of sectoral measures of producer price inflation, productivity growth, and demand conditions. Some preliminary estimations indicated that industry dummy variables (which proxy these sectoral variables) add some explanatory power.

Figure 3: Average inflation uncertainty over contract period



3.5 Empirical results

Each version of the hazard model has eleven baseline segments. The first two segments cover wage deviations up to 0.74 per cent, followed by seven intervals of 0.5 width from 0.75 per cent up to 4.24 per cent, and then intervals of 4.25 to 4.99 per cent and 5.0 to 5.99 per cent.[11] Contracts with deviations from the median greater than or equal to 6 per cent are treated as censored observations.

Because each covariate segment consists of one or more adjoining baseline segments, the number of covariate segments can be less than or equal to the number of baseline segments. The appropriate number of covariate segments was determined by experimentation, leading to five covariate segments for inflation uncertainty.[12]

11. In many of the low-inflation years, a wage freeze would be close to an end point of a baseline segment if all baseline segments had equal widths of 0.5 per cent (as in Figure 2b). More precise estimates of the symmetric menu-cost effects can be obtained if wage freezes are closer to the midpoint of the interval containing freezes. This objective was achieved by having the two baseline segments closest to the median cover the intervals up to (but not including) 0.375 and 0.75 per cent, respectively, and setting the following segments in increments of 0.50 per cent.
12. The five covariate segments for inflation uncertainty cover deviations in the following ranges: (0.0,1.24), (1.25,2.24), (2.25,3.24), (3.25,4.24), and (4.25 and above).

The methodology described in sections 3.2 and 3.3 is now used to calculate the amount of rigidity implied by the estimated hazard models. Before describing the hazard results, estimates of rigidity from symmetrically differenced histograms are provided for comparison.

3.5.1 Symmetrically differenced histograms

Following McLaughlin (1999), a simple non-econometric approach to estimating rigidity is to calculate symmetrically differenced histograms. If the notional distribution is symmetric about the median, and contracts from the right side of the distribution are unaffected by downward rigidity and menu costs, the left side of the notional distribution would be the mirror image of the right side of the actual distribution. Therefore, if we subtract the density a given distance below the median from the density over the same range above the median, the difference is interpreted as an estimate of downward rigidity or menu-cost effects in that interval.

To facilitate comparison with the hazard model results, the symmetrically differenced calculations are based on intervals that are identical to the baseline segments used in the hazard estimation. Table 2 summarizes these calculations in three numbers: (i) excess density in the wage-freeze interval (column (2)), (ii) the difference between the actual and notional densities in intervals containing wage decreases (column (3)), and (iii) the difference between the actual and notional densities in intervals containing wage increases (column (4)). These three numbers sum to zero. Negative values for both (ii) and (iii) would imply that the excess density in the wage-freeze interval originates from *both* sides of zero in the notional wage-change distribution.

Over the 1992–97 period of low inflation, the total density in the intervals containing wage freezes averaged 12.49 per cent (Table 2), whereas the average density over the same range on the right side of the distribution was 5.78 per cent. Thus, conditional on the symmetry assumption, the average level of excess density in the wage-freeze interval is estimated to be 6.71 per cent.

Some of the excess density in the wage-freeze interval represents contracts that are wage freezes but would have been wage cuts in the absence of downward rigidity and menu-cost effects. When the actual right side of the distribution is used to form the notional distribution, we would expect 2.81 per cent of contracts to have wage cuts, whereas the actual number is 2.37 per cent. Therefore, given the assumption of symmetry, only 0.44 per cent of contracts were wage freezes rather than wage cuts (column (3)), which implies that downward nominal-wage rigidity made only a minor contribution to the observed spike at zero in wage-change distributions.

The remainder of the excess density in the wage-freeze interval—6.26 per cent—represents contracts that would have provided wage increases but instead had wage freezes (column (4)). A menu-cost interpretation is suggested by the fact that the unusually low number of wage increases on the left side of the wage-change distribution is coming entirely from the range of wage increases just above the wage-freeze interval (see section A.1 of Appendix A). Since most of the spike at zero is attributed to wage increases that are censored down to zero, the symmetrically differenced histograms imply that the net impact of downward rigidity and menu-cost effects was to *reduce* the average rate of wage growth by 0.05 percentage points (column (5)).

The symmetrically differenced methodology has several limitations. First, the symmetry assumption for the notional distribution may be too restrictive. In addition, any idiosyncratic spikes or outliers on the right side could have an inappropriate influence on the shape of the notional distribution. Nevertheless, the methodology does provide a useful benchmark for comparison with the results from hazard models, which have a more flexible form for the notional distribution.

Table 2: Excess densities and rigidity (1992–97 averages, per cent)

Notional model	Density in wage-freeze (WF) interval	Excess density in wage-freeze interval[a]	Actual density minus notional density below WF interval[b]	Actual density minus notional density above WF interval[c]	Rigidity (net effect on average wage growth)
Symmetric differences	12.49	6.71	–0.44	–6.26	–0.05
Model I	12.49	6.97	–5.93	–1.05	0.10

a. Actual density minus the notional density in the baseline segment containing wage freezes.
b. Sum of differences between actual and notional densities in baseline segments containing wage decreases.
c. Sum of differences between actual and notional densities in baseline segments containing wage increases.

3.5.2 Hazard-model estimates: Model I

Section A.2 of Appendix A reports some characteristics of the hazard model estimated using the methodology described in section 3.2. An important result is that the estimated variance of the notional distribution decreases significantly as the inflation-uncertainty covariate trends downward over the sample period. By reducing the amount of the notional density in the range of wage cuts during the low-inflation 1990s, the downward trend in the variance will reduce the estimates of rigidity relative to a constant-variance scenario.

The second row of Table 2 reports the estimates of rigidity from Model I. The estimated notional distribution suggests that we would have observed 5.52 per cent of contracts in the wage-freeze interval during the low-inflation period in the absence of rigidities.[13] Thus, the estimate of excess density in this interval (6.97 per cent) is quite similar to that from the symmetrically differenced case, although most of the excess density is now attributed to wage cuts that were censored up to zero. According to this model, 1.05 per cent of contracts provided a freeze rather than a pay increase, while 5.93 per cent of contracts contained a freeze rather than a wage cut.

The latter figure cannot be decomposed into the separate contributions from menu-cost effects and downward rigidity without an assumption about the range of wage changes over which symmetric menu costs are operational. However, it is notable that almost half of the 5.93 per cent (or 2.92 per cent) was attributed to the baseline segment containing the smallest wage cuts, so only a small percentage of contracts had wage freezes while facing pressures for significant wage cuts. This feature explains why the estimated net effect of downward nominal rigidity and menu-cost effects on mean wage growth across all contracts is only 0.10 percentage points in Model I. This estimate is similar to the net effect on the average annual wage growth (0.07 percentage points) in the Tobit models reported in Crawford and Wright (2001).

4. Estimates of Rigidity—Model II

In Model I, the notional distribution was identified by estimating the parameters of the hazard model using contracts from only the right side of the wage-change distribution. The left side of the notional distribution was constructed using these parameter estimates and covariate data for contracts from the left side. An alternative approach, developed in this section, is to model the effects of rigidity directly in equation (4).

4.1 Estimating the notional distribution

Figure 4 explains the methodology of Model II. Figures 4a and 4c show the observed distributions of the level of wage growth for two representative years (1995 and 1996, respectively). The dashed vertical lines indicate the interval containing the median wage settlement. Figures 4b and 4d graph the distributions of deviations from the median for contracts with wage growth below the median (i.e., the *left sides* of the distributions in Figures 4a and 4c). Thus, the density in the interval at the extreme right in these figures represents contracts with wage increases at or slightly

13. As noted in footnote 9, the notional density in the wage-freeze interval (5.52 per cent) can be interpreted as a conservative estimate of the contribution of menu costs to the number of wage freezes. Menu-cost effects may also occur in the neighbouring intervals.

below the median settlement, and movement to the left represents contracts with progressively smaller wage changes.

When the wage variable is defined in terms of deviations from the median, the baseline segment containing wage freezes (denoted by the solid vertical line in Figure 4b or 4d) will be further to the left in a year with a higher median wage settlement. For example, the median settlement was 1.5 per cent in 1995, so the interval containing deviations in the 1.25 to 1.74 per cent range is the baseline segment which includes wage freezes in that year. In contrast, the median settlement was 2.0 per cent in 1996, so wage freezes in that period will be incorporated in the density for the baseline segment (1.75, 2.24) in Figure 4d. Intervals to the right (left) of the wage-freeze intervals in Figures 4b and 4d contain contracts with wage increases (decreases).

The graphs for both 1995 and 1996 show a significant increase in density in the interval containing wage freezes, and low density in the intervals on either side of the wage-freeze interval. The spike in the wage-freeze interval could reflect downward nominal-wage rigidity, but the low densities immediately on either side of that interval suggest that symmetric menu-cost effects also contribute to the spike. Thus, a baseline segment that is a given distance below the median may have an unusually high density if it includes wage freezes in the current period, whereas the same baseline segment may have an unusually low density in a different period when it includes contracts with small wage increases or decreases. For example, the density for deviations in the range (1.25,1.74) is 14.0 per cent in 1995 when that interval contains wage freezes (Figure 4b), but only 4.3 per cent the following year when it contains small wage increases (Figure 4d).

The intertemporal variation in which baseline segment contains wage freezes can be exploited to identify the effects of rigidity. When the wage data are deviations from the median, and the level of median wage growth is in the range (1.25,1.74) as in 1995, the density may be unusually high in the baseline segment for deviations in the range (1.25,1.74) because it contains contracts with wage freezes in that period. Similarly, the density may be unusually high for deviations in the baseline segment (1.75,2.24) when median wage growth is in the range (1.75,2.24) as in 1996. Therefore, to model asymmetric downward rigidity and menu-cost effects, a set of covariate dummy variables is defined such that a particular dummy has a value of one for years when median wage growth is within a specified range, and zero otherwise.[14] The ranges of covariate segments for each of these dummy variables are specified in a way that allows the model to

14. A total of three rigidity/menu-cost dummy variables were included for years with the median wage change ranging from 1.25 to 1.74, 1.75 to 2.24, and 2.25 to 2.74, thereby covering all of the low-inflation years in the sample period.

capture positive spikes in whatever baseline segment contains wage freezes in the current period as well as unusually high (or low) densities elsewhere in the distribution.[15] Since the determinants of notional wage growth are modelled through the other covariates, the left side of the notional wage-change distribution is constructed using all parameters except those for the rigidity/menu-cost dummy variables and covariate data for contracts on the left side.

15. Four covariate parameters are estimated for each of these dummy variables: (i) one for the baseline segment that includes wage freezes, (ii) one for the baseline segments that include wage cuts, (iii) one for the baseline segment that includes small wage increases, and (iv) one for the baseline segments that include larger wage increases. Using a year such as 1995 for illustration (Figure 4b), these parameters would cover the following ranges, respectively: (i) the eighth baseline segment (i.e., (1.25,1.74)), (ii) all intervals to the left of segment 8, (iii) segment 9 (i.e., (0.75,1.24)), and (iv) the two segments at the extreme right (closest to the median). The ranges would be shifted to the right (left) for a year with a lower (higher) level of median wage growth.

Figure 4a: Wage-change distribution (levels)

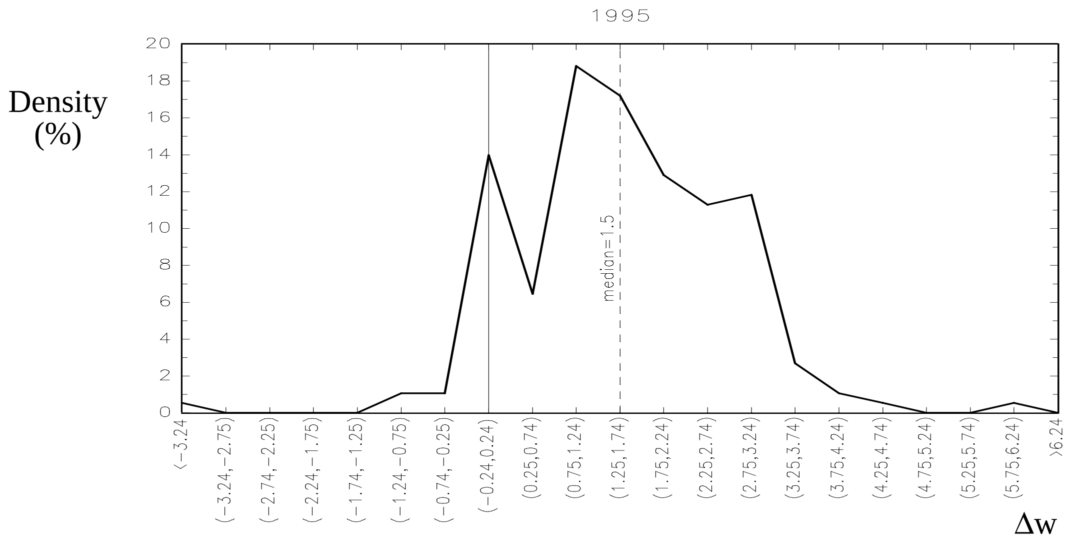


Figure 4b: Deviations below the median

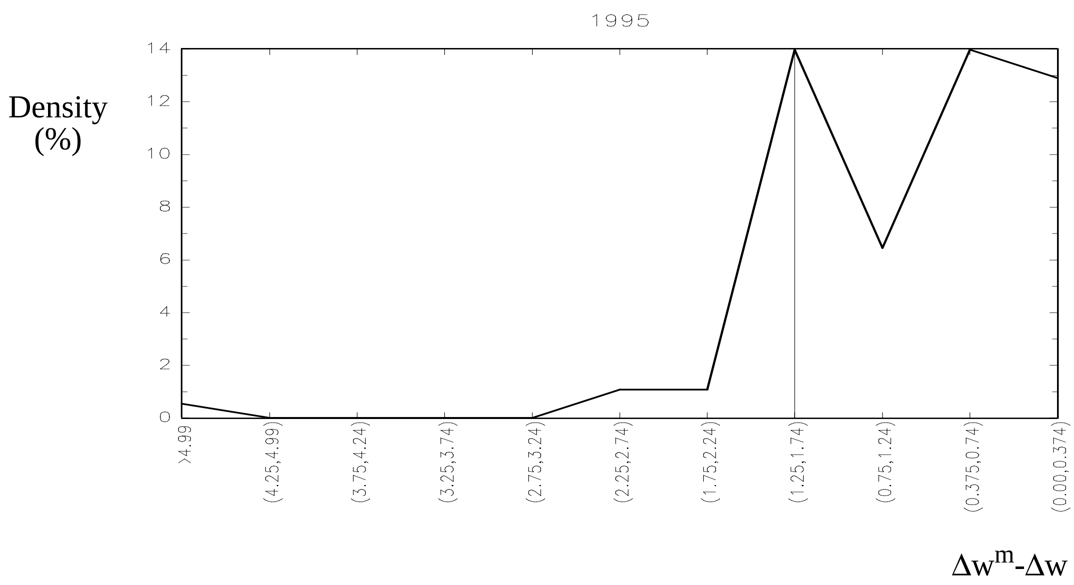


Figure 4c: Wage-change distribution (levels)

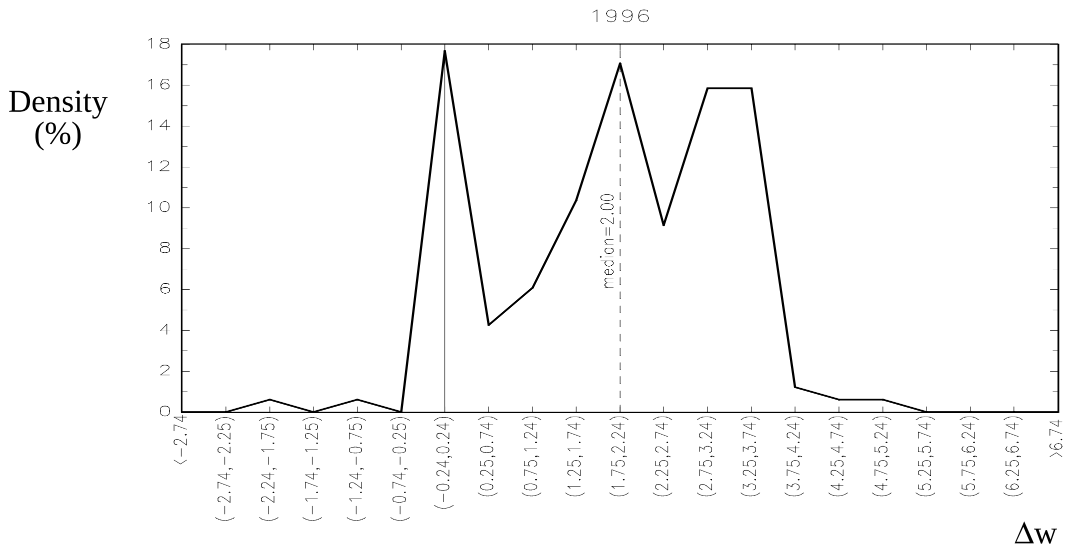
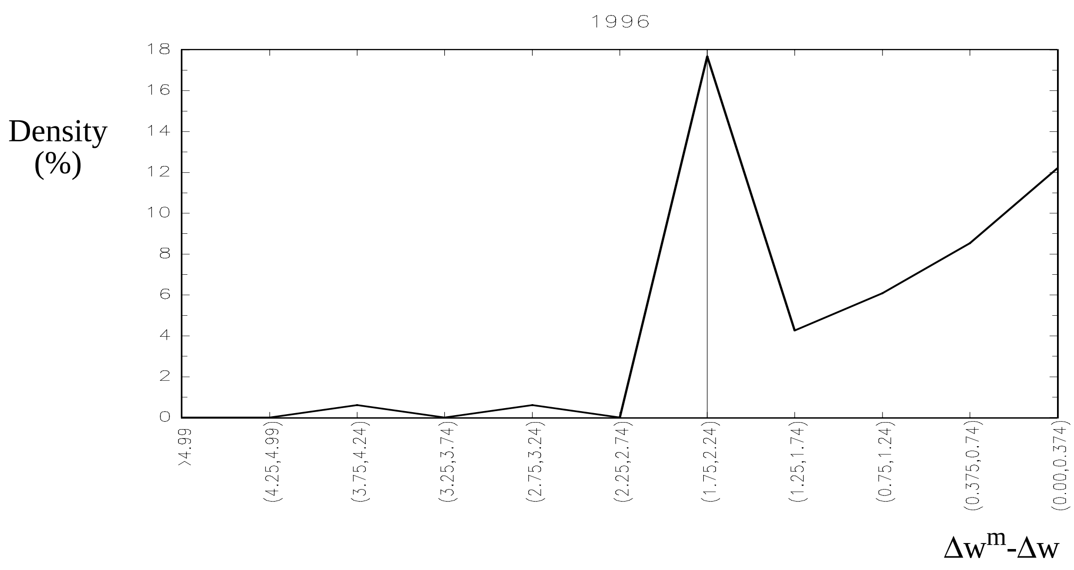


Figure 4d: Deviations below the median



Model II could be applied to data from only the left side of the wage-change distribution. However, data from the right side also contain information on changes over time in the dispersion of the underlying distribution, and inclusion of those data makes it easier to differentiate between the notional distribution and rigidity effects. Therefore, data from both sides of the distribution are used to estimate parameters of the hazard model, with the rigidity/menu-cost dummy variables applying only to contracts from the left side of the distribution. The net effect of downward rigidity and menu costs is estimated by comparing the actual and notional distributions.

Kahn (1997) also tested whether there is unusual density a given distance below the median. Using dummy variables and OLS regressions, she examined whether the proportion of workers receiving pay changes within different (one-percentage point) intervals below the median varies over time, depending on whether an interval contains a pay freeze, pay cuts, or pay changes "close" to zero in a given year. Kahn's model constrains the variance of the notional distribution to be constant over time, whereas the hazard model does not impose this restriction. This characteristic of the Kahn methodology means that it may not adequately differentiate between the notional density and the effects of rigidity.

4.2 Empirical results

The third row of Table 3 lists results when Model II is used to estimate the hazard parameters. Consistent with the results of section 3, the notional variance in Model II decreases as inflation uncertainty falls. However, the estimated notional distribution is flatter than in Model I, so the estimated effect of rigidity on average wage growth increases to 0.18 percentage points in Model II. The higher estimate of rigidity reflects differences in two parts of the distribution. First, Model II implies that a higher proportion of contracts would have had wage cuts in the absence of rigidities. Second, unlike the other models, the actual density in the range of wage increases tends to be *greater* than predicted by the notional distribution (by 1.53 per cent on average).

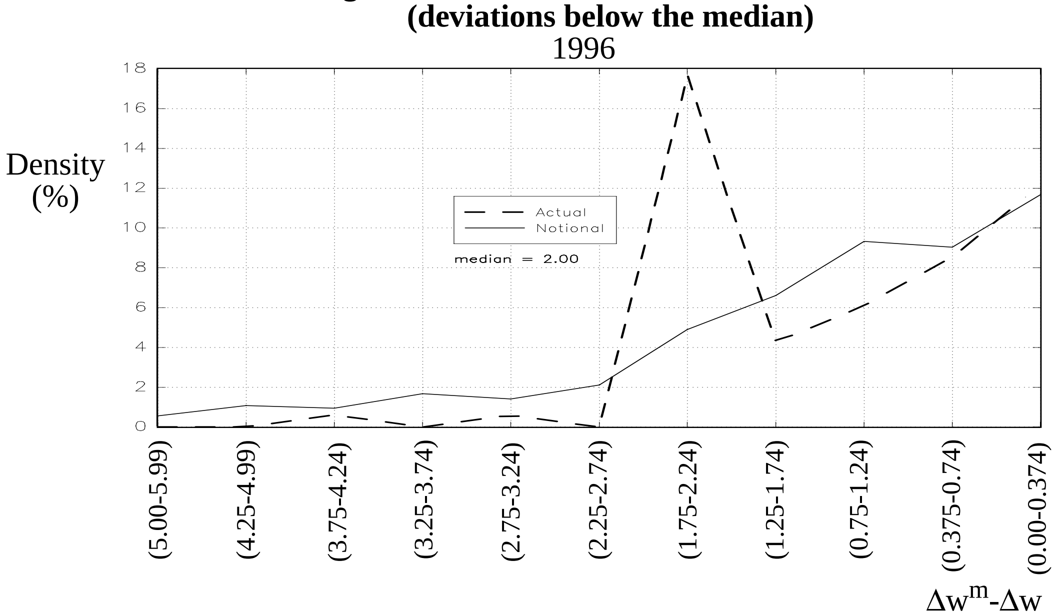
To understand the latter effect, and its impact on the estimate of rigidity, it is useful to contrast the distributions from two years. First, the patterns in 1996 are consistent with the expected outcomes in the presence of downward rigidity and menu-cost effects. Figure 5 shows the actual and notional densities of deviations below the median. Since the median settlement was 2.0 per cent in that year, the baseline segment corresponding to deviations in the (1.75, 2.24) range is the wage-freeze interval. In 1996, the excess density in the wage-freeze interval originates from both directions. There are fewer contracts than predicted by the notional distribution in the first intervals to the right of the wage-freeze interval (consistent with menu costs pulling some small wage increases down to zero), and the notional density is very similar to the actual density in the two intervals at the extreme right which include contracts with higher wage increases.

Table 3: Excess densities and rigidity (1992–97 averages, per cent)

Notional model	Density in wage-freeze (WF) interval	Excess density in wage-freeze interval[a]	Actual density minus notional density below WF interval[b]	Actual density minus notional density above WF interval[c]	Rigidity (net effect on average wage growth)
Symmetric difference	12.49	6.71	–0.44	–6.26	–0.05
Model I	12.49	6.97	–5.93	–1.05	0.10
Model II	12.49	7.12	–8.64	1.53	0.18

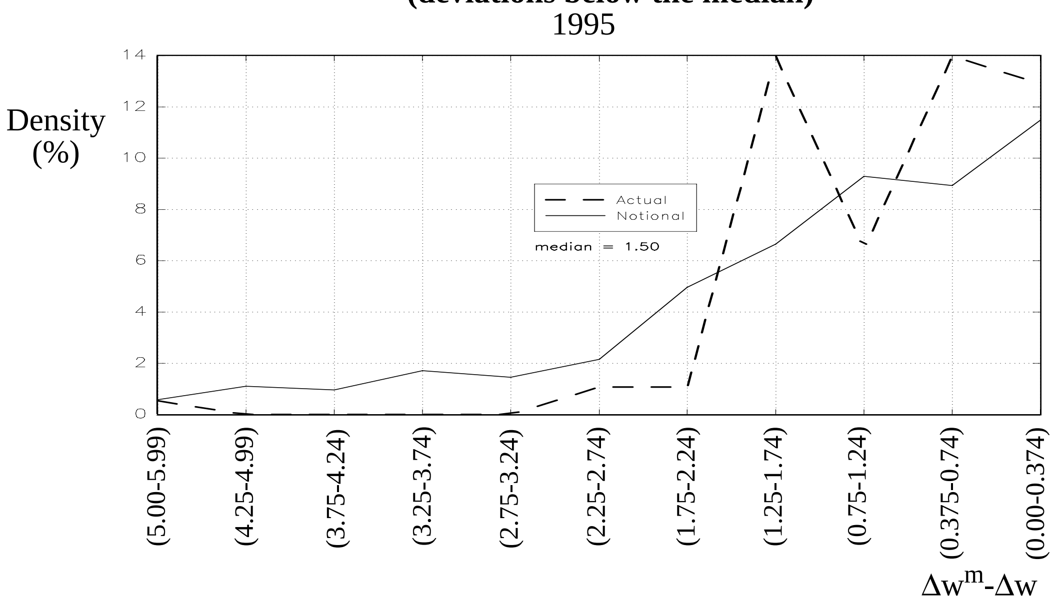
a. Actual density minus the notional density in the baseline segment containing wage freezes.
b. Sum of differences between the actual and notional densities in baseline segments containing wage decreases.
c. Sum of differences between the actual and notional densities in baseline segments containing wage increases.

Figure 5: Actual and Notional Densities
(deviations below the median)



In contrast, the patterns in most of the other years during the low-inflation period are not fully consistent with the expected outcomes with downward rigidity and menu-cost effects. Figure 6 shows this tendency using 1995 as a representative year. The median settlement was 1.5 per cent in that year, so the baseline segment corresponding to deviations in the (1.25, 1.74) range is the wage-freeze interval. Contrary to expectations, overall there is *more* density to the right of the wage-freeze interval than predicted by the estimated notional distribution, and this unexpected density is coming from the two segments at the extreme right (i.e., the intervals representing contracts with wage increases closest to the median). Since downward rigidity gives wage freezes rather than wage cuts, and menu-cost effects give wage freezes rather than small wage increases or decreases, we would expect the actual and notional densities to be similar over the intervals containing higher wage increases (for which menu costs should not have a big effect). The finding that the actual number of contracts with wage increases near the median tends to *exceed* the notional densities suggests that Model II overstates the effect of rigidity.

Figure 6: Actual and Notional Densities
(deviations below the median)



One explanation for this pattern is that Model II does not reflect the full extent of the decrease in the notional variance in the low-inflation years. While the inflation-uncertainty variable helps to explain much of the downward trend in variance, other factors that contributed to the decline may have been excluded from the current model (for example, changes in the dispersion of sectoral measures of output growth, productivity growth, or producer price inflation).[16] In this case, the estimated variance of the notional distribution would be too high, and Model II would overstate

16. The unexpectedly high density just below the median in Figure 6 may reflect skewness in the true notional distribution that is not fully captured by the current set of covariates. Starting in 1987, there is a strong tendency for the actual data for wage growth to have a greater density immediately below the median than immediately above the median. Since this trend began before the low-inflation period, it may have been caused by a change in the shape of the notional distribution rather than some form of rigidity. McLaughlin (1999) reports the same tendency in U.S. panel data from the early 1970s to the early 1990s.

the effect of rigidity on wage growth. Future research could include additional covariates to examine this possibility.

5. Conclusions

This study has presented estimates of wage rigidity from a hazard model that allows considerable flexibility in the shape of the notional distribution. A comparison of the observed wage-change distribution and the estimated notional distribution provides an estimate of the net effect of downward nominal rigidity and menu costs on wage growth. Estimates from alternative versions of the model suggest that the net effect of downward rigidity and menu costs on the average annual growth rate of wages was in the range of 0.10 to 0.18 percentage points in the unionized private sector during the low-inflation period of the 1990s. The lower end of this range is very close to the estimate from Tobit models with a time-changing notional variance and menu-cost effects (Crawford and Wright 2001).

The wage settlements data used in this study measure changes in the base wage rate, and exclude all employees in the non-union sector and unionized workers at smaller firms. This raises the question of whether wage settlements are representative of the flexibility of total labour compensation in the aggregate economy. Evidence from other Canadian micro databases was examined in Crawford and Harrison (1998). On balance, informal comparisons of the frequencies of wage freezes and rollbacks in those data sets suggest that the wage settlements data probably overstate the extent of rigidity in the aggregate economy.

Finally, it appears that menu-cost effects make a significant contribution to the spike at zero in wage-change distributions. For both the symmetrically differenced and hazard estimates, close to one-half of the observed density in the interval containing wage freezes (spanning a narrow range of 0.50 per cent) is predicted by the estimated notional distribution. The role of menu costs is even greater if we consider a broader measure that takes into account the densities in the baseline segments closest to the wage-freeze interval.

Bibliography

Akerlof, G., W. Dickens, and G. Perry. 1996. "The Macroeconomics of Low Inflation." *Brookings Papers on Economic Activity* 1: 1–59.

Card, D. and D. Hyslop. 1997. "Does Inflation Grease the Wheels of the Labour Market?" In *Reducing Inflation: Motivation and Strategy*, edited by C.D. Romer and D.H. Romer, 71–114. Chicago: University of Chicago Press.

Crawford, A. and A. Harrison. 1998. "Testing for Downward Rigidity in Nominal Wage Rates." In *Price Stability, Inflation Targets, and Monetary Policy*, 179–218. Proceedings of a conference held by the Bank of Canada, May 1997. Ottawa: Bank of Canada.

Crawford, A. and M. Kasumovich. 1996. "Does Inflation Uncertainty Vary with the Level of Inflation?" Bank of Canada Working Paper No. 1996–9.

Crawford, A. and G. Wright. 2001. "Downward Nominal-Wage Rigidity: Micro Evidence from Tobit Models." Bank of Canada Working Paper No. 2001–7.

Donald, S., D. Green, and H. Paarsch. 1995. "Differences in Earnings and Wage Distributions Between Canada and the United States: An Application of a Semi-Parametric Estimator of Distribution Functions with Covariates." Discussion Paper No. 95–34, University of British Columbia.

Dupasquier, C. and N. Ricketts. 1998. "Non-Linearities in the Output-Inflation Relationship: Some Empirical Results for Canada." Bank of Canada Working Paper No. 1998–14.

Farès, J. and S. Hogan. 2000. "The Employment Costs of Downward Nominal-Wage Rigidity." Bank of Canada Working Paper No. 2000–1.

Farès, J. and T. Lemieux. 2001. "Downward Nominal-Wage Rigidity: A Critical Assessment and Some New Evidence for Canada." In *Price Stability and the Long-Run Target for Monetary Policy*, 3–31. Proceedings of a conference held by the Bank of Canada, June 2000. Ottawa: Bank of Canada.

Faruqui, U. 2000. "Employment Effects of Nominal-Wage Rigidity: An Examination Using Wage Settlements Data." Bank of Canada Working Paper No. 2000–14.

Fortin, P. 1996. "The Great Canadian Slump." *Canadian Journal of Economics* 29: 761–87.

Fortin, P. and K. Dumont. 2000. "The Shape of the Long-Run Phillips Curve: Evidence from Canadian Macrodata, 1956–1997." Working Paper. Département des sciences économiques, Universite du Québec à Montréal (June).

Hogan, S. 1997. "What Does Downward Nominal-Wage Rigidity Imply for Monetary Policy?" Bank of Canada Working Paper No. 1997–13.

Kahn, S. 1997. “Evidence of Nominal Wage Stickiness from Microdata.” *American Economic Review* 87: 993–1008.

McLaughlin, K. 1994. “Rigid Wages?” *Journal of Monetary Economics* 34: 383–414.

———. 1999. “Are Nominal Wage Changes Skewed Away From Wage Cuts?” *Federal Reserve Bank of St. Louis Review* May/June: 117–132.

Schultze, C. 1959. “Recent Inflation in the United States.” Study No. 1, prepared for the Joint Economic Committee of the U.S. Congress, Washington, D.C.

Simpson, W., N. Cameron, and D. Hum. 1998. “Is Hypoinflation a Good Policy?” *Canadian Public Policy* 24: 291–308.

Tobin, J. 1972. “Inflation and Unemployment.” *American Economic Review* 62: 1–18.

Appendix A

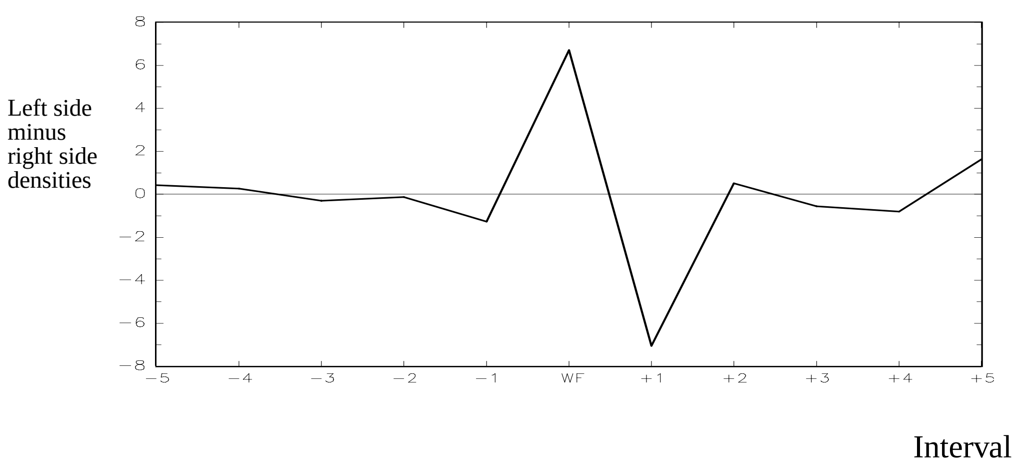
A.1 Symmetrically differenced histograms

This section presents more details regarding the symmetrically differenced histograms discussed in section 3.5. Each interval in the differenced histogram would be zero if the wage-change distribution is symmetric about the median. A positive (negative) value indicates greater (less) density on the left side of the distribution than on the right side. The ranges of intervals are identical to those for the baseline segments used in the hazard models.

Figure A1 shows the average annual values for the symmetrically differenced histograms during the 1992–97 period. The data point at the far left is the difference between the left and right sides of the distribution over the intervals farthest from the median (i.e., the difference between the densities in the left and right tails). Movement to the right in Figure A1 corresponds to a comparison of densities that are increasingly closer to the median. The interval "WF" shows the excess density in the interval containing wage freezes.

Figure A1 has two equally prominent features. There is a pronounced positive spike in the interval containing wage freezes, and a negative spike over the range containing small wage increases (denoted by +1). There is little difference in the intervals containing wage cuts (intervals –1 to –5). Conditional on the assumption of symmetry, this evidence suggests that menu costs are the major cause of wage freezes.

Figure A1: Symmetric differences (annual averages, 1992–97)

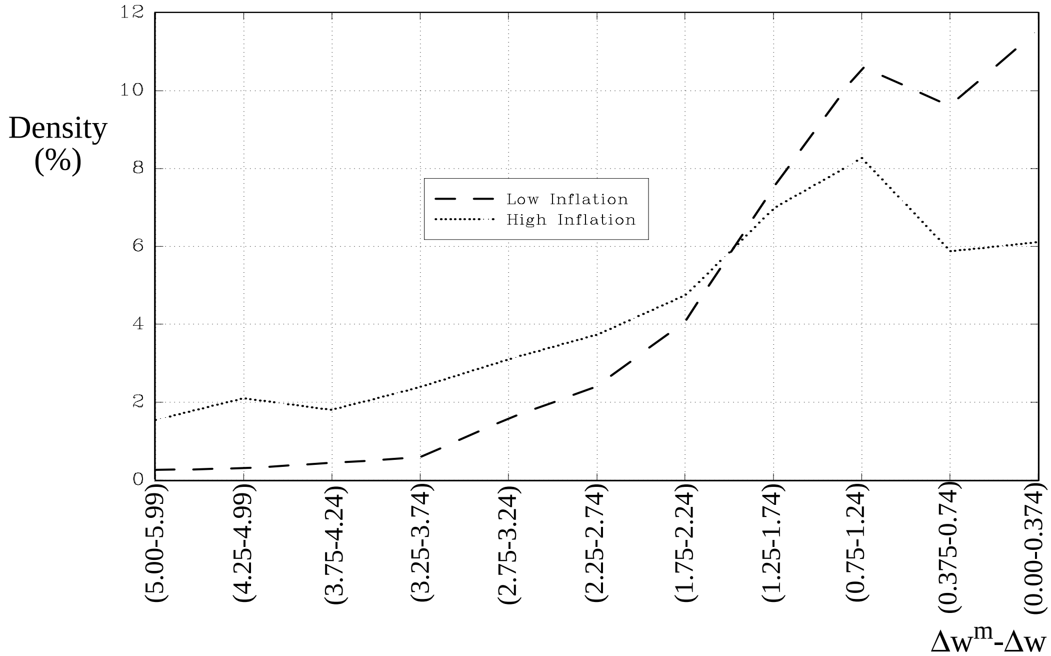


A.2 Effect of changes in covariates

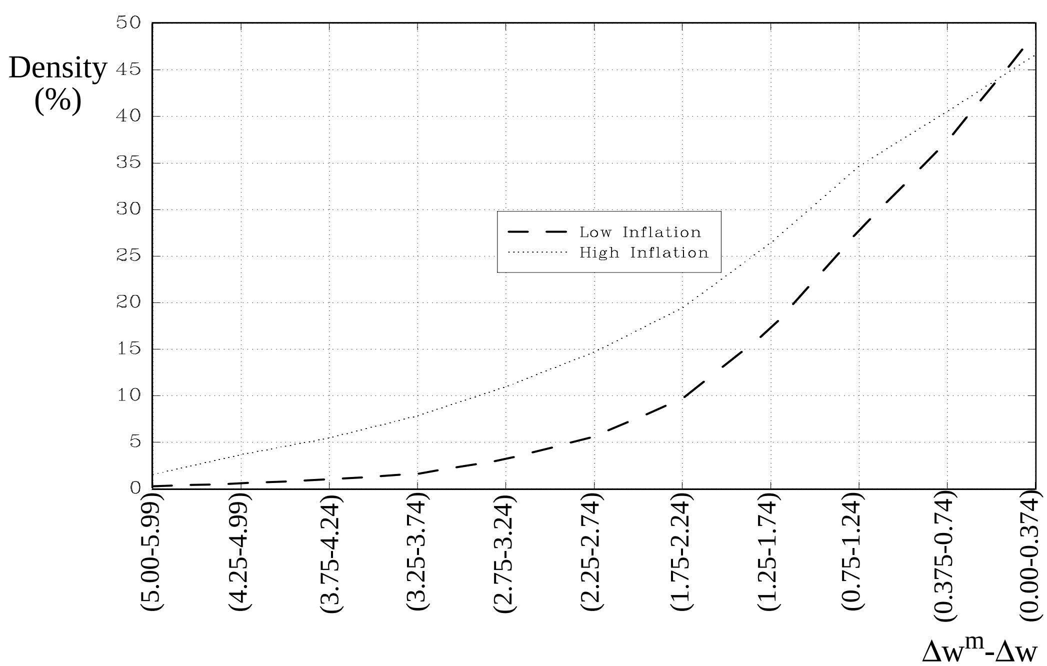
This section describes how the shape of the notional distribution varies with changes in the inflation-uncertainty covariate. Figure A2 graphs the estimated densities and cumulative distributions when the hazard Model I from section 3 is evaluated at the mean levels of inflation uncertainty during the high-inflation and low-inflation subperiods.[1] The estimated notional distribution has a much lower variance in the low-inflation period: about 15 per cent of contracts are at least 2.25 per cent below the median settlement in the high-inflation scenario in Figure A2, compared to only 5 per cent in the low-inflation example. This result highlights the importance of having a specification that permits the variance of the notional distribution to be time-varying. Constraining this variance to be constant would cause the notional density below zero (and downward rigidity) to be overstated in low-inflation years.

1. The tendency in Figures A2 and A3 for estimated densities to decrease in the two baseline segments at the extreme right reflects the smaller range of those intervals (see footnote 11 in the main text).

Figure A2: Estimated notional distribution (deviations below the median)



Cumulative distribution (deviations below the median)



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