Minimum wage indexation regimes: Evidence on wage setting in Brazil*

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October 22, 2025

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Abstract

We present new evidence on wage stickiness in a developing country and the nature of wage setting in the context of an inflation-indexed minimum wage. Specifically, we study Brazil between 2015-2017 where the minimum wage is indexed once a year to past inflation. We document that workers exposed to the policy experience more rigid nominal wages. This includes workers who earn more than the current minimum wage but less than the upcoming one, suggesting that firms anticipate the policy. We augment a standard New Keynesian model with heterogeneous labor to study how an inflation shock affects the economy in the presence of this type of time-dependent and backward-looking minimum wage indexation policy. In our calibration, a future increase in the nominal minimum wage lowers output today and increases demand for unexposed workers relative to exposed ones.

*We are grateful to David Autor, Martin Beraja, Simon Jaeger, and Christian Wolf for their support and guidance at every stage of this project. We thank Constanza Abuin, Daron Acemoglu, Bautista Bassi, Pedro Martinez-Bruera, Tomas Caravello, Alberto Cavallo, Viola Corradini, Tishara Garg, Deivy Houeix, Martina Uccioli, Rafael Veiel, and Ivan Werning as well as participants of the MIT Labor and Macroeconomics lunches for their helpful comments and feedback.

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1 Introduction

It is well established that monetary policy and other nominal shocks have real effects on output. A key mechanism by which this happens is the presence of nominal rigidities. Several authors have indirectly documented their importance by measuring the impact of monetary policy in differently rigid environments (Olivei and Tenreyro, 2007). However, while ample direct evidence has been collected in the past 20 years on the nature of pricing rigidities (Nakamura and Steinsson, 2013), the direct evidence on wage rigidities is more limited. This is partly due to a lack of high frequency micro data on wages and partly due to the fact that there is a widely accepted consensus that wages update once a year (Taylor, 2016). In addition, wages are more likely than prices to be at least partly determined by government policy. Therefore, it can be inappropriate to make absolute statements about the nature of wage setting without examining the broader institutional context (Tito, 2011).

We address this gap by directly measuring nominal wage rigidity vis a vis an inflation-indexed minimum wage in the Brazilian context. Indexation happens annually in January and is foreseeable. To measure how wage setting varies under the policy, we leverage variation in worker-level and state-level exposure to it. Since our data is available at a monthly frequency, we are also able to study how wage setting evolves before the indexation event itself. Then, we explore the aggregate implications of our findings in a New Keynesian model with high and low skill workers where the latter earn an inflation-indexed minimum wage that updates once a year.

Empirically, we show that exposed workers experience greater earnings stickiness throughout the year but much more flexible earnings at the turn of the year relative to unexposed workers. The difference cannot be explained by a worker's relative position in the earnings distribution, nor by their personal characteristics such as age, education, or economic sector. We also find evidence consistent with firm's wage setting behavior anticipating the indexation event.

To study this policy's effect on the economy as a whole, we augment a New Keynesian model with two worker types and a time-dependent, backward-looking, inflation-indexed minimum wage. The model shows that output and inflation may fall today in anticipation of an indexation event in the future. In our calibration, this happens despite a fall in the nominal interest rate. In addition, the policy has the expected distributional effects. Low skill worker's real wages rise and their employment falls relative to high skill workers. Firms that are more low-skill intensive set higher prices and have lower output relative to those that are more high-skill intensive.

The empirical analysis focuses on two minimum wage increases in January 2016 and

January 2017. First, we analyze wage setting non-parametrically. In this exercise, exposed workers are defined as those that currently earn less than the future minimum wage. We find that exposed workers experience a lower frequency of earnings adjustments between February and November relative to unexposed workers on the order of xx%. This relationship flips at the turn of the year when the indexation event takes place.

Additionally, we find evidence that this stickiness is consistent with firm's wage setting behavior anticipating the indexation event. A straightforward explanation for greater earnings stickiness throughout the year would be if exposed workers' competitive wages lay below the mandated minimum wage and were therefore bound by it. However, this cannot be the full story since workers earning more than the current minimum but less than the following year's minimum also have more rigid earnings throughout the year. Furthermore, this behavior cannot be explained by a worker's relative position in the earnings distribution since the wage setting of unexposed workers at the top behaves similarly to that of unexposed workers closer to the minimum wage. It also cannot be explained by firm-level differences in exposure since unexposed workers have similar earnings rigidity regardless of their firm type. In this exercise, exposed firms are those that hire at least one exposed worker. Overall, the evidence points instead towards firms anticipating the upcoming increase.

Second, building on the intuition in the non-parametric analysis, we compare workers in the same earnings percentile across differently exposed states. Exposure is now measured as the state-level bindingness of the minimum wage, also known as the Kaitz Index. We find that a one standard deviation increase in the Kaitz index is associated with a 9 percentage point decline in the likelihood of a sustained earnings increase for workers in the second earnings decile throughout the year. In contrast, they are 25 percentage points more likely to experience a sustained earnings increase at the turn of the year. High earners, who are not exposed to the policy regardless of the state they live in, are a placebo test. As expected, their earnings rigidity exhibits almost no difference across more versus less exposed states.

Next, we estimate the worker-level version of the same regression. This allows us to control for additional individual-level characterstics such as age, gender, education, region, and sector. We find similar results. Workers at the second decile of earnings in more exposed states are less likely to experience an earnings adjustment relative to workers in the same decile in unexposed states, and relative to workers in other deciles regardless of bindingness.

Motivated by these facts, we incorporate this type of minimum wage policy into a New Keynesian model to study its effects on output, inflation, and employment. In the model we assume the extreme of the empirical findings: low skill labor is paid exactly the minimum wage which is rigid unless an indexation event occurs, and high skill labor is paid a completely flexible competitive wage. There is a representative household that supplies both high and low skill labor. The production side of the economy is composed of n competitive input firms, a continuum of monopolistically competitive intermediate firms, and a representative final good firm. The input firms hire high and low skill labor in different proportions, and sell their production at marginal cost to intermediate firms. Intermediate firms face nominal rigidities in price setting.

Due to the nominal price rigidities faced by intermediate firms, there is an aggregate price Phillips curve to which the minimum wage is indexed. In the model, a period is defined at the quarterly level. The minimum wage updates once a year during the first quarter. This introduces a non-linearity in the model since the indexation rule is time-dependent. We follow Olivei and Tenreyro (2007) and solve the model using the nonlinear algorithm proposed by Fuhrer and Bleakley (1996).

In this setup, we study the impact of an inflationary shock to the Phillips curve. We assume that the shock occurs at the end of a given period, when all the other outcomes for that period have been determined. Consistent with the findings in Olivei and Tenreyro (2007), its effects are stronger when they occur right after the first quarter, since the nominal minimum wage stays fixed for longer. Since the nominal minimum wage is the only outcome that depends on past inflation, the effects we observe in the model are the direct result of anticipating this indexation event. A future increase in the nominal wage raises future marginal costs by raising the low skill real wage. This lowers output and raises inflation in the future. In our calibration, the future decline in output dominates the dynamics of output, inflation and employment in the present. Both output and inflation fall today, despite a contemporaneous decline in the nominal interest rate. While inflation recovers, output remains permanently lower.

The mechanics of the policy also mean that the inflationary shock has distributional effects. Low skill worker's real wages rise and therefore their employment declines relative to high skill workers. Low-skill intensive input firm's marginal costs rise by more, resulting in higher prices and lower output for them relative to the high-skill intensive firms.

Overall, the model highlights two important dynamics that arise from the introduction of a backward-looking and time-dependent inflation-indexed minimum wage when there are inflationary shocks. First, output and inflation fall in anticipation of the future nominal minimum wage increase. Second, there are important distributional effects. Minimum wage workers enjoy higher real wages but lower employment. Firms that are exposed to the minimum wage raise their prices and lower their output.

Literature: This paper contributes to three main strands of the literature. These are the literature on nominal wage rigidities and how it mediates shocks, the literature on indexation, and the literature on minimum wage policies.

The literature that directly measures nominal wage rigidities has mostly focused on developed economies. Some prominent examples include Le Bihan et al. (2012) who, using a large representative survey in France, find that the frequency of nominal wage adjustments is 38% at the quarterly frequency. Using the Survey of Income and Program Participation (SIPP), Barattieri et al. (2014) find a range between 21.1-26.6% for the probability that a US worker will experience a wage change in a given quarter. Finally, Sigurdsson and Sigurdardottir (2011) find that the frequency of monthly wage changes is 10.8% in Iceland. On average, these papers find that the monthly frequency of wage adjustment is approximately 10%. Our findings contribute to the literature on nominal wage rigidity by providing, to our knowledge, the first direct evidence of high-frequency micro-wage setting behavior in a large developing country. In our context, the average frequency of adjustments is approximately 20% throughout the year, and much higher at the turn of the year.

There is also a literature that studies the importance of nominal wage rigidities by evaluating the impact of monetary policy in differently rigid environments. Olivei and Tenreyro (2007) leverage variation in wage rigidity over time in the US. Based on suggestive evidence from different surveys they argue that wage contracts are more likely to adjust at the end of the fiscal year. Consistent with this fact, they find that monetary policy shocks have less impact on output when they take place right before this period of contract renewal and a larger one when they occur right after it. Minton and Wheaton (2022) leverage variation in wage rigidity across US states. They argue that states with a more binding minimum wage will have more rigid wages. Consistent with this, they find that employment responds more to monetary policy shocks in states with a relatively higher minimum wage. Finally, Faia and Pezone (2024) leverage variation in wage rigidity across firms in Germany. They find that firm's stock prices and employment respond more to monetary policy shocks in firms with more rigid wages as measured by their collective bargaining activity. Our paper relates most closely to Minton and Wheaton (2022) in that it leverages variation in wage rigidity arising from the minimum wage. However, we focus on inflationary shocks instead of monetary policy shocks, and on the dynamics that arise specifically from the anticipation of a minimum wage increase.

Research on wage indexation was very popular in the late 20th century. Seminal papers include Gray (1976) and Fischer (1977). They argue that indexation protects workers from nominal shocks but exposes them to real ones since it mechanically preserves the real wage. However, as highlighted by Jadresic (1996), this conclusion depends on the specific indexation rule used. Recent theoretical work has focused on determining what are the optimal indexation rules. Carrillo et al. (2022) find that workers prefer to index to past inflation when real shocks dominate, but they prefer to index to trend inflation when nominal shocks dominate. Recent empirical work has focused on evaluating indexation schemes in practice. For example, Manacorda (2004) finds that the *Scala Mobile* indexation scheme in Italy had a significant impact on wage inequality. Bijnens et al. (2023) finds that a temporary suspension of wage indexation in Belgium had positive employment effects in 2015. Our paper contributes to this literature by emphasizing that indexation events generally occur sporadically, and not continuously. Therefore, it is important to study how wage setting and other outcomes evolve in between and vis a vis indexation events.

While economy-wide indexation is less prevalent than in the late 20th century, the policy survives in many places in the form of partial indexation schemes. Jaeger et al. (2024) highlight the importance of two wage setting institutions that often embed indexation policies. These are collective bargaining agreements and the minimum wage. Koester and Grapow (2021), who provide a recent survey of the prevalence of different wage indexation policies in the euro area, find that 18% of euro area private sector workers work in countries where the minimum wage is indexed to inflation. The partial nature of these schemes allow researchers to leverage differential exposure to it within the same economy to identify its effects. Our paper fits into this tradition, and brings in evidence from a developing country context. We highlight the distributional impact of such policies, both for the workers that are directly affected by them and for firms that are differentially exposed to them.

Finally, our paper also contributes to the literature on the minimum wage. The vast majority of it focuses on the effect of unexpected and large increases in the minimum wage (Dube and Lindner, 2024). This is largely because in this context it is easier to identify its causal effects. However, there is a broad swath of both local and national governments, such as California, France, and Canada, that have adopted or are moving towards adopting some form of inflation-indexed minimum wage policy (Karlamangla, 2024; Campbell, 2024). Thus, it is important to study them, despite the identification challenges that arise from the fact that increases are foreseeable.

Outline: Our paper proceeds as follows. Section 2 provides background on the Brazilian minimum wage policy. Section 3 describes the data and presents descriptive evidence, including the non-parametric analysis. Section 4 analyzes how wage setting varies based on the bindingness of the minimum wage at the state- and worker-level in a regression framework. Section 5 presents the model and discusses the implications of a backward-looking time-dependent inflation-indexed minimum wage for the propagation of inflationary shocks. Section 6 concludes.

2 Background

2.1 The minimum wage in Brazil

Brazil has a long history of actively using minimum wage policy. There has been a nationwide minimum wage since 1984 which is closely watched because it also establishes the floor for pensions, welfare payments, and unemployment benefits. However, its use as an index for other contracts is forbidden.

There are two other main wage-setting institutions that we set aside primarily because the national minimum wage acts as a wage floor for both of them. These are (1) individual state's minimum wages, and (2) collective bargaining agreements. So far, five states set their own higher minimum wages[1]. However, their application is irregular both in terms of who it applies to, and when they are updated. Collective bargaining agreements are negotiated and therefore respond endogeneously to the specific conditions of the sector or firm to which they apply. In contrast, the national minimum wage is updated on a regular schedule and applies to all full time workers. It does not take any individual sector or firm's characteristics into account.

Prior to 2008, the minimum wage was determined via negotiations between trade union centrals and the central government. As part of his platform, President Lula proposed that minimum wages should automatically adjust every January based on a rule that accounted for inflation over the previous 12 months and GDP growth with a two-year lag. This rule was signed into law in 2011 and used until 2019. A notable exception occurred in 2017 and 2018 when the two-year lag of GDP growth was negative. In these cases, the law was interpreted to mean that the minimum wage would only ever *increase* (and never decrease) based on these two factors. After 2019, the new government reverted to updating the minimum wage exclusively based on inflation. However, they maintained the regularity of updating it every January.

Every year at the beginning of September, the Brazilian government publishes its own forecast of the following year's minimum wage as part of its annual budget law (Lei Orcamentaria Anual, or LOA). This is necessary since so many social programs and other government payouts are tied to the minimum wage. While the minimum wage increase is already predictable since it relies on a fixed and transparent formula, this is yet another instance where the public is made aware of the expected upcoming increase.

[1]These are Rio de Janeiro, Rio Grande do Sul, Paraná, Sao Paulo and Santa Catarina.

2.2 The analysis period: July 2015-June 2017

For data access reasons, our analysis focuses on the period between January 2015 and December 2017. It encompasses two minimum wage hikes which we examine separately. In January of 2016, the monthly minimum wage for full-time workers rose from 788R$ to 880R$, implying an 11.67% increase. This was the result of an 11.27% inflation rate in 2015, and a 0.5% real GDP growth rate in 2014. The forecast that was published in the annual budget law proposal of September 2015 was 865R$. In January of 2017 the minimum wage rose to 937R$, a 6.5% increase from the year prior. It reflected the 6.6% inflation rate in 2016 but, as explained above, it disregarded the -3.5% real GDP growth rate in 2015. The government's forecast published in September 2016 as part of the annual budget law proposal was 945R$.

3 Data and Descriptive Evidence

3.1 Data on Earnings and Employment

We obtain labor market data from RAIS (*Relaçao Anual de Informacões Sociais*). This is an employer - employee matched annual mandatory survey for all registered firms in Brazil. We create two different datasets. One is at the worker-level and the other is at the state-level. In our sample we restrict to private sector workers with a standard 44 hour workweek aged 18 to 54, employed by firms with more than 5 workers. The final worker-level sample contains approximately 4 million workers per year, and there are 27 states.

In addition to a worker's characteristics such as age, gender, race and education, we observe their earnings in two ways. First, firms directly report a worker's annual average monthly earnings. For worker l in year t, we label this variable $\hat{y}_t^l$. Second, firms also report worker's monthly earnings in each month. For worker l in month m and year t we label this variable as y_{mt}^l. Firms are required to report how much they effectively pay each worker, including overtime but excluding the 13th salary.

In our dataset, sometimes a worker's directly reported annual average monthly earnings $\hat{y}_t^l$ does not match the annual average predicted by averaging monthly earnings y_{mt}^l. This is likely due to measurement error in the monthly earnings, not in the directly reported annual average, since it is the latter that dictates eligibility for welfare benefits. See appendix B.1 for a fuller discussion. To address this issue, we restrict the sample to workers whose directly reported annual average monthly earnings are consistent with their monthly earnings.

Wage rigidity. In the analysis, we measure how wage rigidity varies with exposure to the minimum wage. This requires us to measure wage changes at the worker level. To proxy for wage changes, we rely on sustained positive changes in earnings. This is a suitable proxy for two reasons. First, sustained earnings changes are less likely to reflect transitory changes in earnings due to factors such as changes in hours worked, or one-off bonus payments. Second, it is illegal for firms to unilaterally lower a worker's nominal wages. We define a sustained earnings increase as a month-to-month increase in earnings that is at least maintained the following month regardless of whether a worker switches employers.

Summary Statistics. To get a better understanding of the characteristics of workers exposed and unexposed to the minimum wage, table 1 describes workers along the wage distribution for the 2015-2016 sample.[2] We use their annual average monthly earnings in 2015 $\hat{y}_t^l$, to sort them. Each column corresponds to one of three groups: those earning less than the following year's minimum wage, those earning less than two multiples of the following year's minimum wage, and those earning more than that.

Workers who earn less than the following year's minimum wage are surprisingly similar to those who earn up to two times the minimum wage. They are more likely to work in services, have a high school degree or less, and work in smaller establishments. In contrast, workers who earn more than two times the minimum wage are more likely to work in manufacturing, have a college degree, and work in larger establishments. Overall, as wages increase the likelihood of living in the northeast (southeast) decreases (increases).

[Table 1 about here.]

3.2 Non-parametric analysis

[Figure 1 about here.]

We start with a non-parametric analysis of wage-setting at the worker level. The objective is twofold. First, to understand whether the minimum wage matters for wage setting beyond its mechanical binding effect. Second, to understand whether other factors that are correlated with the minimum wage, but are not the policy itself, may explain this behavior.

We measure wage-setting using the frequency of sustained earnings increases. It is defined as the share of workers who experience a sustained earnings increase in a given month. For example, if 20% of workers experience a sustained earnings increase each month, this implies that the average duration between sustained earnings increases is 5 months. A higher frequency of sustained earnings increases implies more flexible wages, while a lower frequency implies more rigid wages.

Figure 1 plots the frequency of sustained earnings increases for four types of workers at the monthly level. Each worker-type has varying degrees of exposure to the minimum wage.

[2] See appendix B.2 for the table corresponding to the 2016-2017 sample.

To capture possible anticipation, we focus on the period before each minimum wage increase. Panel 1a reports the results for 2015, while panel 1b reports the results for 2016.

Workers are classified into one of four types based on the first observation of their monthly nominal earnings. On the one hand, "Binding MW" and "Non-binding MW" workers are both exposed to the minimum wage increase in the sense that they earn less than the following year's minimum wage. The difference between them is that binding MW workers (orange line) earn exactly the current minimum wage while non-binding MW workers (red line) earn more than it.

"Mid-wage" and "High-wage" workers are both unexposed to the minimum wage increase in the sense that they earn more than the following year's minimum wage. Mid-wage workers (green lines) earn less than two multiples of next year's minimum wage while high-wage workers (blue lines) earn more than that. These unexposed worker types are additionally sorted into one of two firm types: exposed or unexposed. Exposed firms (solid lines) employ at least one exposed worker, while unexposed firms (dashed lines) employ none.

The most important fact that emerges from figure 1 is that exposed workers experience significantly more rigid wages throughout the year than unexposed workers. This is true in both sample periods. In general, binding MW and non-binding MW workers experience a frequency of sustained earnings increases of around 12-14% throughout most of the year, while mid-wage and high-wage workers experience a frequency of around 18-20%. This relationship flips at the turn of the year, when exposed workers are much more likely to experience a sustained earnings increase than unexposed workers.

To make progress on what may explain the correlation of minimum wage exposure and wage rigidity, we compare wage setting behavior across worker types. The first explanation we consider is that the policy generates wage setting power for firms. Then, we evaluate in turn whether it is the worker's level of earnings or their firm type that drives the results instead.

The behavior of the non-binding MW workers suggests that firms have greater wage setting power over workers that are exposed to the upcoming minimum wage increase. Since this worker type's competitive wage lies above the current minimum wage, it cannot be that the rigidity of their earnings is explained by the policy's bindingness. Instead, what separates them from unexposed workers and ties them to binding MW workers, is the fact that they will be affected by the upcoming minimum wage increase. Although we remain agnostic as to why exposure lends wage-setting power to firms, the empirical patterns are consistent with this being true.

We compare the wage setting behavior of mid-wage relative to high-wage workers to show that a worker's level of earnings does not drive the difference in earnings rigidity.

While these two groups have significantly different earnings levels, they exhibit a strikingly similar frequency of earnings changes. This is especially meaningful given that these two types of workers are very different in terms of their characteristics, as reported in table 1.

Finally, we contrast workers in different firm types to explore whether firm characteristics explain the results. We find that mid-wage and high-wage workers at both exposed and unexposed firms have a similar earnings rigidity. This implies that firm characteristics that may be correlated with firm-level exposure do not drive the result. It further supports the hypothesis that worker-level exposure is the most important determinant of earnings rigidity.

4 Wage Setting and Minimum Wage Bindingness

Exposure to the minimum wage may by correlated with wage setting practices for reasons other than the policy. So, we estimate a regression version of the non-parametric analysis to better address possible unobserved confounders. The biggest concern is that differential wage-setting across exposed and unexposed workers is due to a worker's relative position in the earnings distribution and not their exposure to the minimum wage. These two characteristics are correlated since it is low-wage workers that are exposed to the policy. The comparison of mid-wage and high-wage workers in the non-parametric analysis begins to address this concern by showing that the earnings rigidity of unexposed workers is similar at different points in the earnings distribution. However, it is not conclusive because there may be a non-linear relationship between a worker's position in the earnings distribution and how their wages are set.

To directly address this concern we rely on two empirical strategies. First, we directly compare wage-setting within the same earnings percentile across states where the minimum wage is more versus less binding. This allows us to isolate the effect of minimum wage bindingness from a worker's relative position in the earnings distribution. Throughout the year, we find that workers at the 2nd decile of earnings have a 9pp lower frequency of adjustment in areas with a one standard deviation more binding minimum wage. At the turn of the year, they have a 25pp higher frequency of adjustment in areas with a one standard deviation more binding minimum wage.

Second, we estimate a worker-level version of the same regression. This allows us to control for additional individual-level characterstics such as age, gender, education, region, and sector. We find similar results.

4.1 State-level Analysis

Econometric Framework

To correlate the minimum wage with the frequency of sustained earnings increases, we estimate a state-level two-way fixed effects model relying on state-level variation in minimum wage exposure. Since figure 1 shows that wage-setting behaves differently throughout the year versus at the turn of the year, we estimate the model separately for the period between February to November and the period from December to January. We pool the data prior to each minimum wage increase from the 2015-2016 and 2016-2017 samples.

We measure state-level minimum wage exposure using the Kaitz index (Lee, 1999; Autor et al., 2016). The Kaitz index in year t and state s is defined as the difference between the log minimum wage in year t and the log median wage in state s and year t: $Kaitz_{st} = log(mw_t) - log(\hat{y}_{st}^{median})$. The measure captures how binding the minimum wage is in each state.

We specify the model as follows:

$$F_{smt}^{d} = \sum_{k=1}^{10} \beta^{d}(\mathbb{1}_{d=k} \times Kaitz_{st}) + \rho_d + \gamma_{sd} + \delta_{td} + \epsilon_{smtp} \quad (1)$$

Where F_{smt}^{d} is the frequency of sustained earnings increases in state s at month m-event window t for earnings decile d. ρ_d are decile fixed effects. γ_{sd} are state-decile fixed effects and δ_{td} are event-window-decile specific time fixed effects. The sample includes all workers in firms with more than 5 employees. In each sample, workers are categorized into each earnings decile based on their first observed monthly earnings. Standard errors are clustered at the state level.

We control for unobserved state-level characteristics that are fixed over time with state-level-decile specific fixed effects. An important example is sectoral composition. If poorer states also have a greater share of their economic activity in a specific area, such as agriculture, then wage-setting practices specific to that economic activity will correlate with the minimum wage. However, since we do not expect aggregate sectoral composition to change significantly over the short two-year period under consideration, the fixed effects will account for this correlation.

The event-window-decile specific time fixed effects account for aggregate shocks that are common across states but may correlate with the bindingness of the minimum wage. Since the bindingness is constant within each event-window, only event-window specific time fixed effects are necessary. An important example of an aggregate shock this accounts for is the inflationary environment. Since inflation mechanically leads to a higher minimum wage, it is also associated with greater bindingness. The fixed effects account for any correlation between such aggregate shocks and wage setting practices.

Thus, this design allows us to compare workers in the same position of the earnings distribution in states where the minimum wage is more versus less binding. The coefficients of interest are the β^d coefficients which isolate the effect of minimum wage bindingness accounting for permanent differences across states within each event window and decile and across event windows within each state and decile. Higher earnings deciles are a natural placebo group for lower earnings deciles since the minimum wage is less likely to matter for them, regardless of the state-specific minimum wage bindingness.

Engbom and Moser (2022) also use an empirical strategy that relies on the Kaitz index in the context of Brazil. They study the correlation between the minimum wage and wage inequality. They do two things differently. First, they find that the minimum wage has positive and significant spillovers up to the 90th percentile of the earnings distribution. Thus, they argue that a Kaitz index built around the 90th percentile of earnings instead of the median is more appropriate. We conduct the analysis using this version of the Kaitz index and find similar results. Second, they include a quadratic term of the Kaitz index to capture non-linear effects of minimum wage bindingness. Our results are robust to this specification as well.

Results

Figure 2 shows the results from estimating equation 1 for each time period. Panel 2a plots each β^d coefficient from pooling the months between February and November, while panel 2b reports the β^d coefficients from pooling together December and January. The standard deviation of the Kaitz index is 0.1. Thus, $\beta^d \times 0.1$ describes the percentage point change in the frequency of sustained earnings increases when the minimum wage bindingness increases by one standard deviation.

Panel 2a shows that workers at the bottom of the wage distribution have more rigid earnings in states where the minimum wage binds more. The negative and significant β^2 coefficient implies that a one standard deviation increase in the Kaitz index is associated with a 9 percentage point decrease in the frequency of sustained earnings increases for workers at the 2nd decile of the earnings distribution. This effect is economically significant. Given that the average frequency of sustained earnings increases for these workers is 12.6%, this implies a 71% decrease relative to the mean.

Panel 2b shows that this relationship flips at the turn of the year. Workers at the bottom of the earnings distribution have more flexible earnings in states where the minimum wage binds more. The positive and significant β^2 coefficient implies that a one standard deviation increase in the Kaitz index is associated with a 25 percentage point increase in the frequency of sustained earnings increases for workers at the 2nd earnings decile. Given that the average frequency of sustained earnings increases for these workers is 61.3%, this implies a 40% increase relative to the mean.

In both panels, the effect on deciles higher up in the distribution is basically insignificant. This is consistent with higher earnings deciles not being exposed to the minimum wage regardless of the state-level minimum wage bindingness.

Overall, both the direction and magnitude of the results for the lower earnings deciles and the higher earnings deciles are consistent with the non-parametric evidence presented in figure 1. They provide further evidence that nominal wage setting is more rigid for workers exposed to the minimum wage between February and November, but more flexible at the turn of the year.

[Figure 2 about here.]

4.2 Worker level Analysis

Econometric Framework

To further address concerns about unobserved confounders, we estimate a worker-level version of equation 1. This allows us to control for other worker-specific characteristics in addition to their earnings decile. We proceed by regressing a dummy variable indicating whether a worker l experiences a sustained earnings increase on the interaction of the Kaitz index with the worker's state-specific earnings decile.

$$D^F_{lsmt} = \sum_{k=1}^{10} \lambda^d \left(\mathbb{1}_{d=k} \times Kaitz_{st}\right) + \rho_d + \gamma_{sd} + \delta_{td} + X'_l + \epsilon_{lsmt} \tag{2}$$

Where D^F_{lsmt} is a dummy variable that equals one if worker l in state s at month m event-window t experiences a sustained earnings increase. As before, ρ_d are earnings decile fixed effects, γ_{sd} are state-decile fixed effects and δ_{td} are event-window-decile specific time fixed effects. X'_l is a vector of worker-specific controls. This includes age, education, gender, sector, and region. The sample includes all workers in firms with more than 5 employees. Standard errors are clustered at the state level.

The coefficient of interest is λ^d. It describes how the likelihood of a sustained earnings increase differs for each earnings decile d in states where the minimum wage is more versus less binding.

Results

Figure 3a plots the λ^d coefficients from estimating equation 2 pooling together the months between February and November. The blue circles represent the coefficients from a baseline regression that includes controls for age, education, and gender. The orange triangles represent the coefficients from a regression that additionally includes sector and region fixed effects. The results are practically unchanged between the two specifications.

[Figure 3 about here.]

The results are consistent with the state-level analysis. Workers at the 2nd earnings decile in states where the minimum wage binds more are less likely to experience a sustained earnings increase relative to workers in the first earnings decile. The point estimates imply that a 2nd earnings decile worker in a state where the minimum wage binds by 1 standard deviation more, is 9pp less likely (32pp more likely) to experience a sustained earnings increase throughout the year (at the turn of the year).

5 Model

In this section, we present a minimum wage augmented New Keynesian model where the minimum wage is indexed to past inflation and updates once every four quarters. The model is based on Glover (2016) but extended to include n input firms that combine high and low skill labor differently. Thus, these input firms are differently exposed to the minimum wage and will aid us in understanding the distributional impact of minimum wage hikes. We use the model to understand how such a minimum wage policy affects the propagation of an exogenous shock to inflation on output and employment.

5.1 Model Setup

Formally, our economy is composed of n competitive input firms, a continuum of monopolistically competitive intermediate goods producers, a representative final good producer, and a representative household that provides both high and low skill labor. Input firms produce competitively using high and low skill workers and differ in their relative demand for each type of labor. The monopolistically competitive intermediate goods firms produce differentiated output using the n inputs. Then, a competitive final good producer aggregates the intermediate goods. The household supplies its labor freely across sectors. Low skill labor is remunerated by the minimum wage, while high skill labor is compensated by a competitive wage rate.

Households and Wage Setting

A representative household derives utility from consumption, C_t, and disutility from labor. It supplies both high and low skill labor, denoted by H_t and L_t, freely across sectors. Their disutility of labor is given by ψ_H and ψ_L respectively. ν is the inverse Frisch elasticity. High skill labor is paid a competitive high-skill wage, denoted W_{Ht}, and low skill labor is paid the minimum wage, denoted W_{Lt}. Following Glover (2016), we incorporate the minimum wage by imposing an upper-bound constraint on low-skill labor. Additionally, households have access to a bond market. Households maximise:

$$\max_{C_t,H_t,L_t,B_{t+1}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{C_t^{1-\sigma}}{1-\sigma} - \psi_H \frac{H_t^{1+\nu}}{1+\nu} - \psi_L \frac{L_t^{1+\nu}}{1+\nu} \right] \tag{3}$$

subject to:

$$P_t C_t + B_{t+1} = B_t R_{t-1} + W_{Ht} H_t + W_{Lt} L_t + \Gamma_t \tag{4}$$

$$L_t \leq \bar{L}_t \tag{5}$$

As in Glover (2016) and Schmitt-Grohé and Uribe (2016), the minimum wage constraint on low-skill labor is exogenous. This implies that low-skill labor is demand-determined. We define the stochastic discount factor as $Q_{t+k|t} = \beta(C_{t+k}/C_t)^{-\sigma}$. Optimization determines high skill labor supply and intertemporal substitution of consumption as follows

$$\frac{W_{Ht}}{P_t} = \psi_H H_t^{\nu} C_t^{\sigma} \tag{6}$$

$$1 = R_t \mathbb{E}_t \left[Q_{t+1|t} \frac{P_t}{P_{t+1}} \right] \tag{7}$$

Minimum Wage Policy

The minimum wage is indexed to past inflation and updates once every four quarters. The minimum wage rule is given by

$$W_{Lt} = \begin{cases} W_{L,t-1} + \pi_{t-1} + \pi_{t-2} + \pi_{t-3} + \pi_{t-4} & \text{if } t \text{ is the first quarter,} \\ W_{L,t-1} & \text{otherwise} \end{cases} \tag{8}$$

Firms and Price Setting

Final good producer

A competitive final good firm aggregates intermediate goods $Y_t(j)$ using a CES aggregator. The profit maximisation problem is

$$\max_{Y_t(j)} P_t Y_t - \int_0^1 P_t(j) Y_t(j) dj \quad \text{s.t. } Y_t = \left(\int_0^1 Y_t(j)^{\frac{1}{\lambda^p}} dj \right)^{\lambda^p} \tag{9}$$

Where P_t is the final good price index, $P_t(j)$ is the price of intermediate good j, and $\lambda^p > 1$ is the elasticity of substitution across intermediate goods. Profit maximisation yields the standard expression for demand of variety j in terms of overall demand for the final good, price of variety j, and the final good price.

$$Y_t(j) = \left(\frac{P_t(j)}{P_t} \right)^{\frac{\lambda^p}{1-\lambda^p}} Y_t \tag{10}$$

Imposing zero profits, the final price index given by:

$$P_t = \left(\int_0^1 P_t(j)^{\frac{1}{1-\lambda^p}} dj \right)^{1-\lambda^p} \tag{11}$$

Intermediate goods producers

A continuum of monopolistically competitive intermediate goods producers indexed by $j \in [0, 1]$ use inputs $\{X_{it}(j)\}_{i=1,...,n}$ from each input firm to produce a differentiated good $Y_t(j)$ using a constant returns to scale technology. Their profit maximisation problem is given by

$$\max_{\{X_{it}(j)\}_{i=1,...,n}} P_t(j) Y_t(j) - \sum_{i=1}^{n} P_{it} X_{it}(j) \quad \text{s.t. } Y_t(j) = \prod_{i=1}^{n} X_{it}(j)^{\lambda_i} \tag{12}$$

Where the elasticity of substitution across inputs is given by λ_i such that $\sum_{i=1}^{n} \lambda_i = 1$. The cost of each input i, given by P_{it}, dictates its relative demand by each intermediate producer. It is given by

$$\frac{X_{i't}(j)}{X_{it}(j)} = \frac{P_{it}}{P_{i't}} \tag{13}$$

Intermediate producer j's absolute demand for input i will depend on overall demand for variety j. The nominal marginal cost $MC^{(n)}$ faced by intermediate producer j will also be equal across intermediate producers and is given by

$$MC^n = \prod_{i=1}^{n} \lambda_i^{-\lambda_i} P_{it}^{\lambda_i} \tag{14}$$

Price Setting

We assume that the intermediate goods producers are subject to a a Calvo-style friction and can only change their prices infrequently. Each period, a fraction $1 - \xi_p$ of firms can reset their price. Intermediate good producer j sets its price $P_t(j)$ to maximise profits as follows

$$\max_{P_t(j)^*} \sum_{k=0}^{\infty} \xi_p^k \mathbb{E}_t \left\{ Q_{t+k|t} \left(P_t(j)^* Y_{t+k|t}(j) - TC^n_{t+k|t}(Y_{t+k|t}(j)) \right) \right\} \tag{15}$$

subject to

$$Y_{t+k|t}(j) = \left(\frac{P_t(j)^*}{P_{t+k}} \right)^{\frac{\lambda_p}{1-\lambda_p}} Y_{t+k} \qquad \forall k \tag{16}$$

Where $Q_{t+k|t}$ is the stochastic discount factor for nominal payoffs. And $Y_{t+k|t}(j)$ denotes demand for output in period $t+k$ of firm j that last reset its price in period t. Note that, given our assumptions, all intermediate firms that re-optimize will set the same price.

Input goods producers

Each input firm, indexed by $i \in \{1, ..., n\}$, produces and input X_{it} competitively using a CES aggregate of high and low skill labor. They maximise profits subject to their production function:

$$\max_{L_{it}, H_{it}} P_{it} X_{it} - W_{Lt} L_{it} - W_{Ht} H_{it} \quad \text{s.t. } X_{it} = \left[\alpha_i \theta L_{it}^{\frac{\eta-1}{\eta}} + (1-\alpha_i) H_{it}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \tag{17}$$

η is the elasticity of substitution between labor types, θ governs the efficiency of low skill workers relative to high skill workers and is always less than 1. α_i is the share of low skill workers (per efficiency units) used in production, it is input firm-specific.

The solution to the input firm problem gives demand for each type of labor H_{it} and L_{it} as a function of wages, and the quantity of input produced as follows

$$L_{it} = \left[\frac{(W_{Ht}\theta\alpha_i)^{\eta-1}}{(\theta\alpha_i)^{\eta}W_{Ht}^{\eta-1} + (1-\alpha_i)^{\eta}W_{Lt}^{\eta-1}} \right]^{\frac{\eta}{\eta-1}} X_{it} \tag{18}$$

$$H_{it} = \left[\frac{((1-\alpha_i)W_{Lt})^{\eta-1}}{(\theta\alpha_i)^{\eta}W_{Ht}^{\eta-1} + (1-\alpha_i)^{\eta}W_{Lt}^{\eta-1}} \right]^{\frac{\eta}{\eta-1}} X_{it} \tag{19}$$

Finally, this implies that marginal cost for input producers can be expressed as a function of wages as follows

$$MC_{it} = W_{Lt}W_{Ht} \left[(\theta\alpha_i)^{\eta}W_{Ht}^{\eta-1} + (1-\alpha_i)^{\eta}W_{Lt}^{\eta-1} \right]^{\frac{1}{1-\eta}} \tag{20}$$

Since input producers are competitive, we have that $P_{it} = MC_{it}$.

Policy and Market Clearing

The central bank sets the nominal interest rate $\tilde{R}_t$ according to a Taylor-type reaction function:

$$\tilde{R}_t = \rho\tilde{R}_{t-1} + (1-\rho)(\phi_\pi\hat{\pi}_t + \phi_y\hat{y}_t) \tag{21}$$

where ϕ_π and ϕ_y are the Taylor rule coefficients for inflation and output, respectively.

Market clearing gives us the final equilibrium conditions that must hold in the model. First, the final goods market clearing condition states that the supply of final good Y_t equals the demand from households C_t.

$$Y_t = C_t \tag{22}$$

Input market clearing requires that the supply of each input X_{it} equal total demand from all the intermediate goods producers.

$$X_{it} = \int_0^1 X_{it}(j)dj \qquad \forall i \in \{1, ..., n\} \tag{23}$$

Finally, the labor market clears for each labor type. All the supply of high and low skill labor from households equals demand for each of the labor types from the inputs goods producers.

$$L_t = \sum_{i=1}^{n} L_{it}, \quad H_t = \sum_{i=1}^{n} H_{it} \tag{24}$$

Equilibrium

An equilibrium is prices $\{P_t(j), MC_t^n, \{P_{it}\}_{i=1}^n, W_{Lt}, W_{Ht}, R_t\}$ and quantities $\{Y_t, C_t, Y_t(j),$ $\{X_{it}\}_{i=1}^n, \{X_{it}(j)\}_{i=1}^n, H_t, L_t, \{H_{it}\}_{i=1}^n, \{L_{it}\}_{i=1}^n, B_t\}$ such that, given the exogenous processes and government policy, all agents are optimizing and all markets clear.

5.2 Model Solution and Calibration

To solve the model, we set N=2 and log-linearize the equilibrium conditions around the steady-state. The full set of equations is presented in Appendix C. Special attention should be given to the minimum wage indexation rule which is described by the following law of motion:

$$w_t^{min} = \left(1 - \sum_{k=1}^{4} q_{kt} * a_k\right) * (w_{t-1}^{min} + \pi_{t-1} + \pi_{t-2} + \pi_{t-3} + \pi_{t-4}) \tag{25}$$

$$+ \left(\sum_{k=1}^{4} q_{kt} * a_k\right) * w_{t-1}^{min} \tag{26}$$

where $(1-a_k)$ is the fraction of workers whose wage adjusts in each quarter k with $k = 1, ..., 4$, and q_{kt} are dummy variables that take on the value of one when period t is equal to quarter k. As in Olivei and Tenreyro (2007), this implies that wage setting is time-dependent. Therefore, the system is nonlinear and we use the nonlinear solution method of Fuhrer and Bleakley (1996) to solve the model.

Table 2 presents the calibration of the model. We set the minimum wage to update once a year in the first quarter. Accordingly $1-a_k$, the probability that the minimum wage resets in quarter k, is equal to 1 if $k = 1$ and equal to 0 if $k \neq 1$. The parameter α_i governs the level of exposure of input firm i to the minimum wage. We set $\alpha_1 < \alpha_2$ such that input firm 1 is more high skill intensive relative to input firm 2. In the linearized conditions, α_i enters the parameter s_L^i which describes the share of firm-level output paid to low skill labor. We set $s_L^1 = 0.1$ and $s_L^2 = 0.9$.

The remaining parameters are standard in the New Keynesian literature. The discount factor β is equal to $1.04^{-\frac{1}{4}}$ which corresponds to an annualized real interest rate of 4%. The intertemporal elasticity of substitution σ is equal to 2, the inverse frisch elasticity ν is equal to 1, the price stickiness parameter ξ_p is equal to 0.35, and the taylor rule coefficients ϕ_π and ϕ_y are equal to 2 and 0.6 respectively.

[Table 2 about here.]

5.3 Propagation of an inflationary shock

Figures 4 to 7 present impulse response functions to a 25 basis point increase in aggregate inflation on other aggregate and input-firm specific outcomes. The aggregate outcomes are the nominal minimum wage, aggregate inflation, aggregate output, the nominal interest rate, and real wages. The input-firm specific outcomes are employment, output and prices. Recall that in our calibration there are two input firms, where input firm 1 is high-skill intensive while input firm 2 is low skill intensive. Each figure separately plots the response to four different realizations of the shock, each taking place in a different quarter. We assume that the shock takes place at the end of period t, after all variables for that period have been determined.

Figure 4b presents the IRF of the nominal minimum wage in response to the inflationary shock. As expected, the nominal minimum wage evolves as a step function. Following the shock, it updates every first quarter by the amount of accumulated inflation in the past four periods. The first increase we observe takes place in the fifth quarter, which corresponds to the first "first quarter" after the shocks.

Figure 4a describes the behavior of aggregate inflation. Due to the timing of the shocks, the initial increase in inflation has no contemporaneous effect on other variables. So, the shock to inflation will only have a direct effect on outcomes that depend on past inflation. The nominal minimum wage is the only outcome that does so. The first indexation event after the shock takes place in the fifth quarter, so all the effects we observe are the result of it's anticipation.

As is usual in New Keynesian frameworks, the two forward looking variables are aggregate output and aggregate inflation. Aggregate output depends directly on future output because of consumption smoothing, and directly on future inflation through its dampening effect on the real interest rate. Aggregate inflation depends directly on future inflation due to nominal price rigidities. Price setters incorporate their expectation of inflation into today's prices since they do not know whether they will be able to re-adjust their prices in the future. However, it also depends indirectly on future output through the marginal cost. Lower output in the future lowers output today which lowers input demand and ultimately input prices. Lower input prices translate into lower marginal costs. Finally, the nominal interest rate will react to contemporaneous inflation and output through the taylor rule. It will rise in response to higher inflation, and fall in response to lower output.

Now turning to the indexation event, and how it filters through the economy, what happens is the following: an increase in the nominal minimum wage directly raises the real wage of low skill workers. This raises concurrent marginal costs, and therefore aggregate inflation. The input-firm level marginal cost rises by more for firms that are more low-skill intensive. Thus, input firm 2's prices will rise relative to input firm 1. This has two effects on output. First, overall demand falls due to the price increase, and second, demand for input firm 2's output falls relative to input firm 1. Finally, the overall decline in demand indirectly lowers the real wages of high skill workers.

As described above, the future increase in inflation and decline in output in response to the nominal minimum wage indexation event will affect outcomes in the economy today. Higher future inflation unambiguously raises inflation today, while in combination with lower output it will have an ambiguous effect on output today. Therefore, the response of the nominal interest rate is also ambiguous. If the impact of lower output is greater than the impact of higher inflation, then the nominal interest rate will fall. If the impact of higher inflation is greater, it will rise.

Figure 4 suggests that in this calibration, the impact of lower future output dominates. Figures 4c and 4a show that output and inflation fall in response to the anticipated indexation event. The nominal interest rate reacts contemporaneously by falling (Figure 4d), but it is not sufficient to overturn the negative impact of lower future output. Ultimately, while inflation returns to its steady state level, the nominal minimum wage is permanently higher and output remains permanently lower.

There are also important distributional consequences. Figure 5 shows that low skill real wages are permanently higher while high skill real wages are permanently lower. Figure 6 shows that the resulting low skill employment decline is larger in magnitude than the corresponding high skill employment increase. Consequently, figure 7 output is lower (higher) and prices are higher (lower) in input firm 2 (1).

Overall, the analysis shows that staggered and backward looking indexation rules have significant effects even before the indexation event takes place. In particular, it has a strong negative effect on output which consequently lowers inflation. Since the policy only affects one portion of the population, it also has important distributional effects. Specifically, workers exposed to the indexation event experience an increase in their real wages and a decline in their employment relative to unexposed workers. The effects are stronger the further away in time the occurence of the shock is from the indexation event. It is important to note that this analysis does not incorporate any contemporaneous effects of the initial shock. Arguably, since an inflationary shock likely has a contemporaneous dampening effect on low skill real wages in this environment, its possible that some of these conclusions would be overturned.

[Figure 4 about here.]

[Figure 5 about here.]

[Figure 6 about here.]

[Figure 7 about here.]

6 Conclusion

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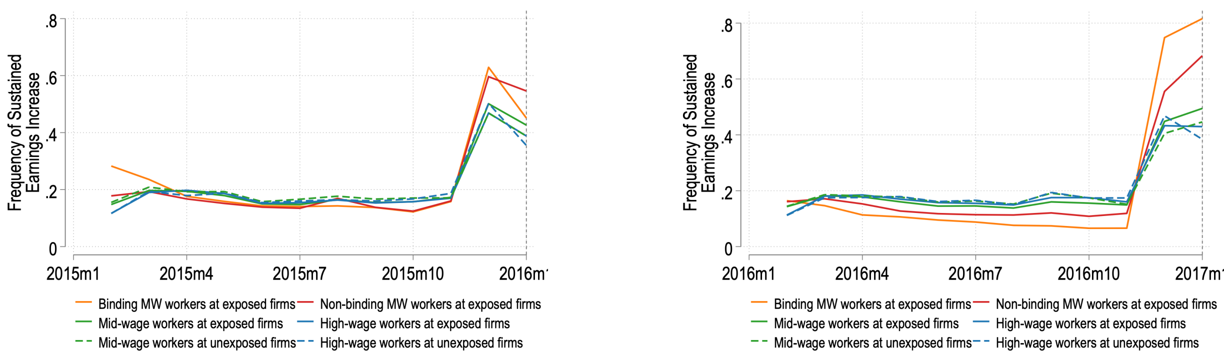
Figures

Figure 1: Non-parametric Frequency of Sustained Earnings Increases

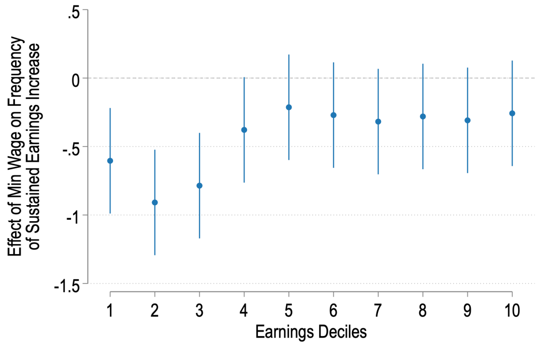
(a) 2015-2016 (b) 2016-2017



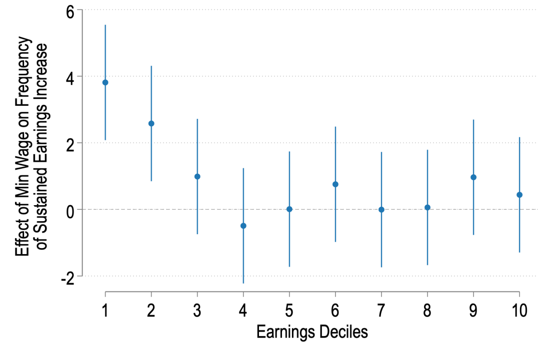
Notes: This figure presents non-parametric evidence on the frequency of sustained earnings increases at the worker-level. The frequency of sustained earnings increases is defined as the share of workers with a month-to-month earnings increase that is at least maintained the following month. Workers are classified when they enter the sample. Binding MW workers are those that earn exactly the curent minimum wage. Non-binding MW workers are those that earn more than the current min wage but less than the following year's min wage. Mid-wage workers are those that earn more than the following year's minimum wage but less than two multiples of it. High-wage workers are those that earn more than two multiples of the following year's minimum wage.

Figure 2: State-level Regressions

(a) February-November



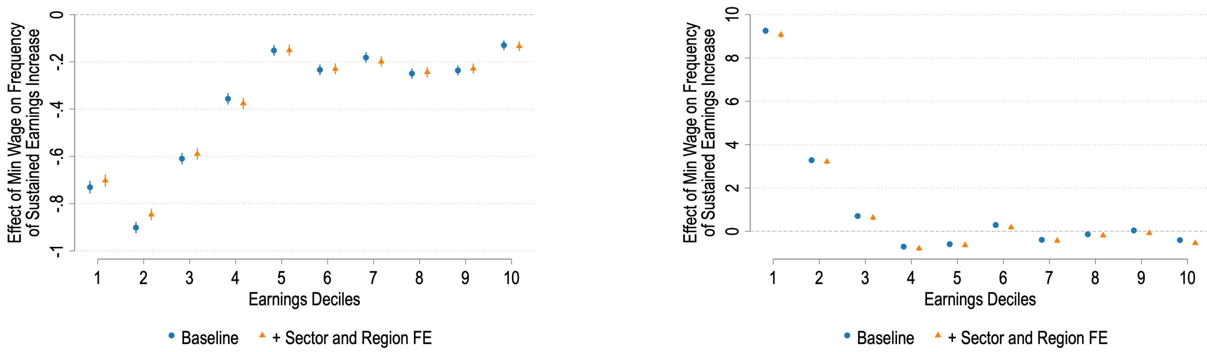
(b) December-January



Notes: This figure plots the β^d coefficients from estimating equation 1 of the frequency of sustained earnings increases on the Kaitz index at each earnings decile, controlling for state-decile and time-decile fixed effects. The frequency of sustained earnings increases is defined as the share of workers with a month-to-month earnings increase that is at least maintained the following month. Standard errors clustered at the state level.

Figure 3: Worker Level Regression

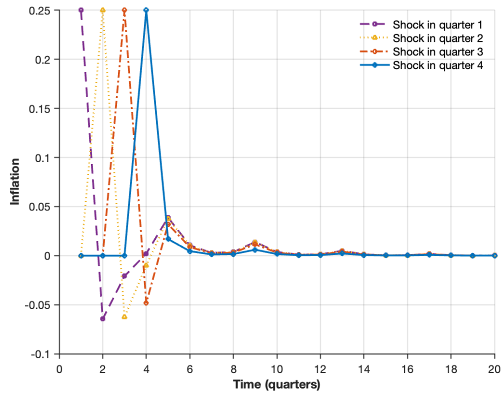
(a) February-November (b) December-January



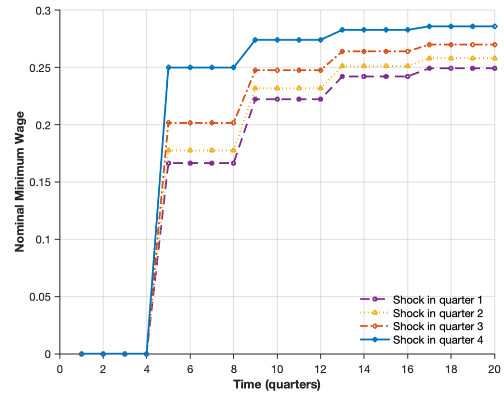
Notes: The blue circles represent the λ^d coefficients from a single worker-level regression described by equation 2. Specifically, the coefficients describe the change in the probability that a worker experiences a sustained earnings increase at each earnings decile as the state-level bindingness of the minimum wage increases. We control for worker characteristics such as age, education, gender and earnings deciles. The orange triangles represent the same λ^d coefficients from a regresssion that additionally controls for industry and region fixed effects.

Figure 4: Impulse Response Functions of Inflation, Nominal Minimum Wage, Output, and Nominal Interest Rate

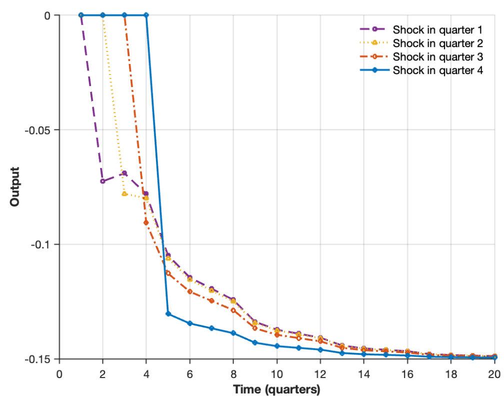
(a) Inflation



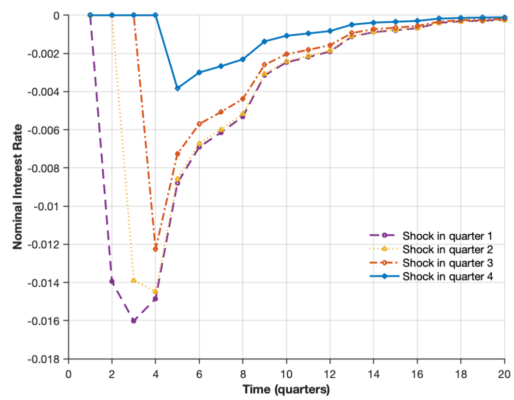
(b) Nominal Minimum Wage



(c) Output



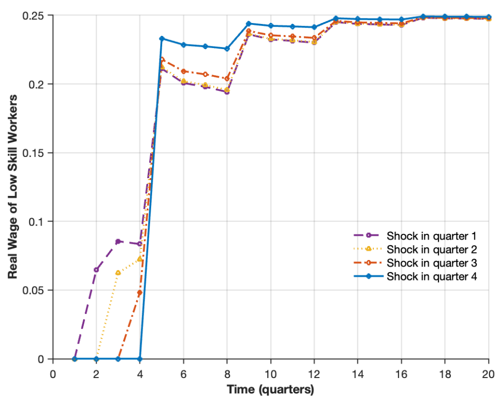
(d) Nominal Interest Rate



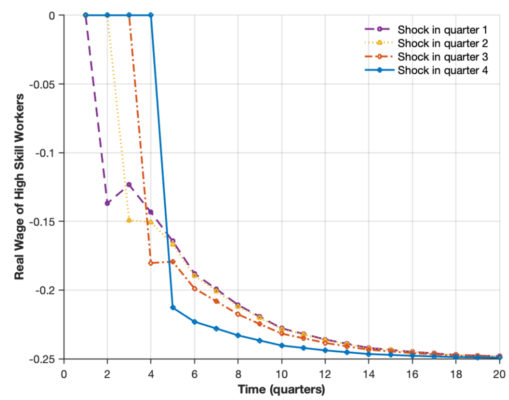
Notes: This figure plots the four impulse responses to a 25 basis point increase in aggregate inflation in the first, second, third and fourth quarters separately. We assume the shock occurs at the end of the quarter, when the other variables have already been determined.

Figure 5: Impulse Response Functions of High and Low Skill Real Wages

(a) Low Skill Real Wage



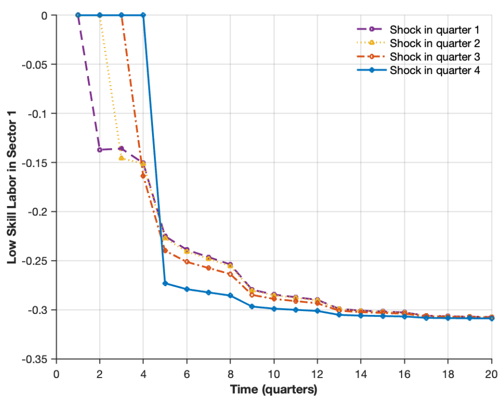
(b) High Skill Real Wage



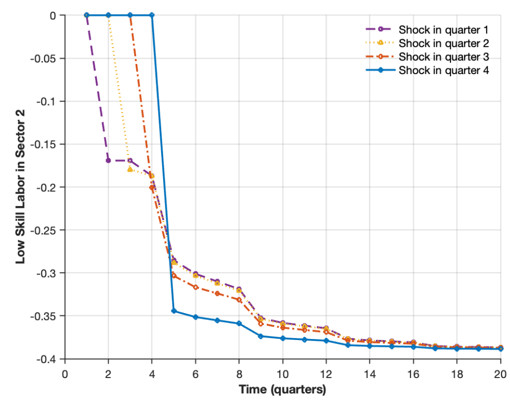
Notes: This figure plots the four impulse responses to a 25 basis point increase in aggregate inflation in the first, second, third and fourth quarters separately. We assume the shock occurs at the end of the quarter, when the other variables have already been determined.

Figure 6: Impulse Response Functions of Input Firm's High and Low Skill Labor

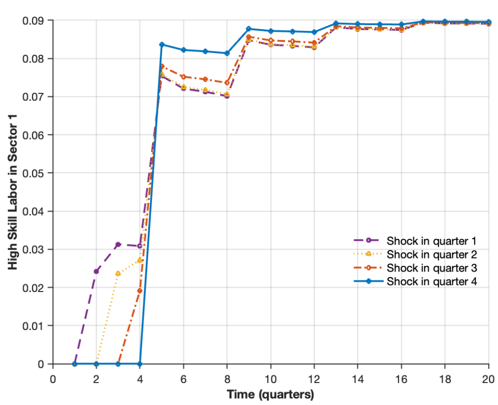
(a) Low Skill Labor in Input Firm 1



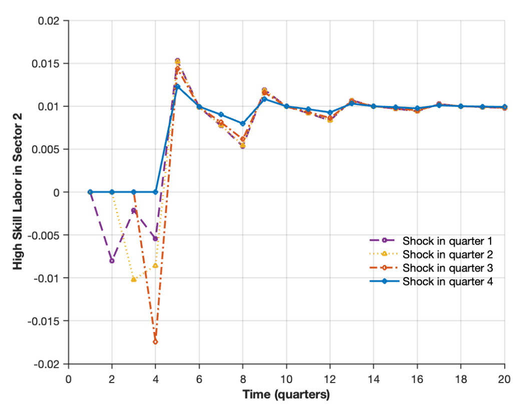
(b) Low Skill Labor in Input Firm 2



(c) High Skill Labor in Input Firm 1



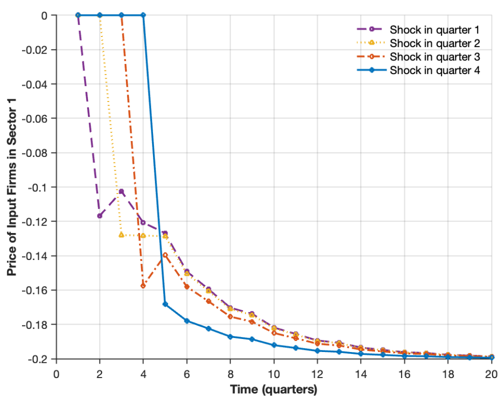
(d) High Skill Labor in Input Firm 2



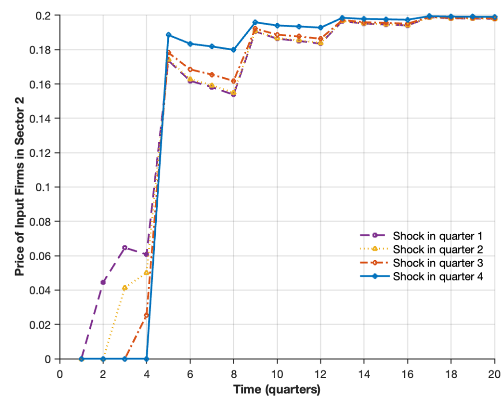
Notes: This figure plots the four impulse responses to a 25 basis point increase in aggregate inflation in the first, second, third and fourth quarters separately. We assume the shock occurs at the end of the quarter, when the other variables have already been determined. Input firm 1 is more high skill intensive while input firm 2 is more low skill intensive.

Figure 7: Impulse Response Functions of Input Firm's Price and Output

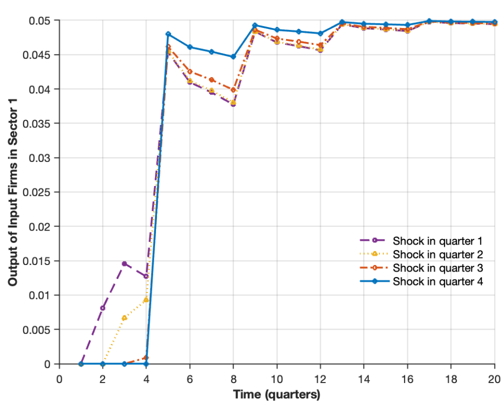
(a) Price of Input Firm 1



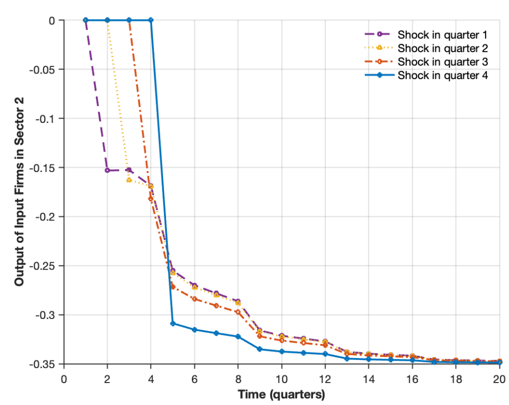
(b) Price of Input Firm 2



(c) Output of Input Firm 1



(d) Output of Input Firm 2



Notes: This figure plots the four impulse responses to a 25 basis point increase in aggregate inflation in the first, second, third and fourth quarters separately. We assume the shock occurs at the end of the quarter, when the other variables have already been determined. Input firm 1 is more high skill intensive while input firm 2 is more low skill intensive.

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C.1 Summary Statistics by Earnings Percentiles (2016) A12

Tables

Table 1: Summary Statistics by Earnings Percentiles (2015)

	$\hat{y}_t < mw^{t+1}$	$mw^{t+1} < \hat{y}_t < 2 \cdot mw^{t+1}$	$2 \cdot mw^{t+1} < \hat{y}_t$
Observations	1000101	6288112	3068607
Female	0.45	0.40	0.23
Age	32.19	34.07	37.80
Education			
Less than High School	0.53	0.43	0.29
High School	0.45	0.52	0.45
More than High School	0.02	0.05	0.27
Establishment Size			
Small (<20)	0.19	0.22	0.16
Medium (20–250)	0.37	0.39	0.41
Large (>250)	0.44	0.39	0.44
Regions			
North	0.08	0.05	0.05
Northeast	0.37	0.16	0.10
Southeast	0.37	0.51	0.57
South	0.08	0.19	0.20
Centerwest	0.09	0.08	0.08
Sectors			
Agr. and Mining	0.17	0.08	0.05
Manuf. and Constr.	0.30	0.31	0.41
Services	0.53	0.60	0.52

Table 2: Model Calibration

Parameter	Description	Value	Source
β	Discount factor	0.99	Standard
σ	Intertemporal elasticity of substitution	2.0	Standard
ν	Inverse Frisch elasticity	1.0	Standard
ϕ_π	Taylor rule inflation coefficient	2.0	Standard
ϕ_y	Taylor rule output coefficient	0.6	Standard
ξ_p	Price stickiness parameter	0.35	Standard
λ	Elasticity of substitution across input goods	0.5	Standard
η	Elasticity of substitution between labor types	0.8	Standard
s_L^1	Low skill labor share in input firm 1	0.1	Assumed
s_L^2	Low skill labor share in input firm 2	0.9	Assumed
$1-a_1$	Probability that minimum wage resets in quarter 1	1	Assumed
$1-a_2, 1-a_3, 1-a_4$	Probability that minimum wage resets in quarter 2, 3, 4	0	Assumed

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A Appendix: Institutional Details

B Appendix: Data

B.1 Measurement Error in Earnings and Treatment

There are two versions of RAIS. One of them is publicly available,[3] and the second is accessed through a data use agreement with the Ministry of Labour. The public version of RAIS tracks workers within a year, but not across them. For this reason, we aggregate this dataset to the region-industry level when conducting the analysis across years. We call this the de-identified dataset. In contrast, the private version identifies workers and firms with their national identification numbers. For firms, this number is known as the CNPJ, and for workers it is known as CEP. We refer to it as the identified dataset.

The key information in RAIS is a worker's earnings, which is recorded in two ways. First, firms report earnings for worker l in year t in each month m, y^l_{mt}. The survey required this information for the first time in 2015. From this, we can calculate the predicted annual average monthly earnings as $\hat{y}^{l,pred}_t = \frac{\sum_{m=1}^{m=12} y^l_{mt}}{12}$. Second, firms also directly report a worker's annual average monthly earnings $\hat{y}^l_t$. By common sense, the predicted average should coincide with the reported average: $\hat{y}^{l,pred}_t = \hat{y}^l_t$. We tag the workers for whom it does as having verified earnings.

Appendix Figures

Figure C.1 reports, for each dataset, the percent of observations with verified earnings. For the de-identified data (orange line), the percent of verified earnings is close to 100% up until the COVID pandemic in 2020. Then, it falls to roughly 80% and subsequently climbs back up to approximately 90%. The identified data suffers from measurement error in the earnings data to a much greater extent (blue line). There, the percent of verified earnings oscillates between 70% and 50%. Moreover, there is a striking seasonal pattern. The value jumps in January, and then falls steadily until December. Within a year, the percent of

[3]We access the public version of RAIS through Base dos Dados, https://basedosdados.org/.

verified earnings can vary across months because of workers' entry into and exit out of the formal labor market.

Appendix Figures

Given this evidence, figures C.2 and C.3 focus on the prevalence of measurement error in the identified data. Figure C.2 compares, for workers whose earnings are unverified, the distribution of their directly reported annual average monthly earnings $\hat{y}_t^l$ in blue, with the distribution of their predicted annual average monthly earnings $\hat{y}_t^{l,pred}$ in red. In all three years, the distribution of $\hat{y}_t^{l,pred}$ exhibits a long left tail. This reveals that when monthly earnings are mis-reported, they are consistently recorded to be "too low".

Appendix Figures

Figure C.3 compares the distribution of treatment for workers with verified earnings in blue, with the distribution of treatment for workers with unverified earnings in red. Treatment is calculated as the predicted earnings increase due to the minimum wage: $ln(mw_{t+1}) - ln(\hat{y}_t^l)$. The figure restricts to workers whose treatment value is greater than zero. Although different in magnitude, the value of treatment across the two sets of workers is distributed similarly. This suggests that using the directly reported annual average monthly earnings $\hat{y}_t^l$ to calculate treatment ameliorates any concerns that it may be affected by measurement error in the earnings variable.

B.2 Summary Statistics by Earnings Percentiles

Table C.1 reports the summary statistics by earnings percentiles for the sample 2016-2017. It is similar to Table 1, which reports the same statistics for the year 2015. Appendix Tables

C Appendix: Model with 2 Input Firms

The system of log-linearized equations is giving by:

<u>Household Block</u>

$$\text{Intertemporal Euler equation :} \qquad y_t = y_{t+1} - \frac{1}{\sigma}\left(r_t - \pi_{t+1}\right)$$

$$\text{High-skill wage determination :} \qquad w_t^H = \nu h_t + \sigma y_t$$

Firm Block

$$\text{New Keynesian Phillips Curve}: \quad \pi_t = \frac{(1-\xi_p\beta)(1-\xi_p)}{\xi_p}mc_t + \beta\pi_{t+1} + \varepsilon_t^{\pi}$$

$$\text{Cost minimization condition}: \quad x_t^2 - x_t^1 = q_t^1 - q_t^2$$

$$\text{Final goods production function}: \quad y_t = \lambda x_t^1 + (1-\lambda)x_t^2$$

$$\text{Marginal cost of final goods producers}: \quad mc_t = \lambda q_t^1 + (1-\lambda)q_t^2$$

$$\text{Sector 1, low-skill labor demand}: \quad w_t^L = q_t^1 + \frac{1}{\eta}\left(x_t^1 - l_t^1\right)$$

$$\text{Sector 1, high-skill labor demand}: \quad w_t^H = q_t^1 + \frac{1}{\eta}\left(x_t^1 - h_t^1\right)$$

$$\text{Sector 2, low-skill labor demand}: \quad w_t^L = q_t^2 + \frac{1}{\eta}\left(x_t^2 - l_t^2\right)$$

$$\text{Sector 2, high-skill labor demand}: \quad w_t^H = q_t^2 + \frac{1}{\eta}\left(x_t^2 - h_t^2\right)$$

$$\text{Sector 1 - marginal cost}: \quad q_t^1 = s_{L,1}w_t^L + (1-s_{L,1})\,w_t^H$$

$$\text{Sector 2 - marginal cost}: \quad q_t^2 = s_{L,2}w_t^L + (1-s_{L,2})\,w_t^H$$

Market Clearing Conditions

$$\text{Goods market clearing condition}: \quad y_t = c_t$$

$$\text{High-skill labor market}: \quad h_t = H_1 h_{1,t} + H_2 h_{2,t}$$

Policy block and Definitions

$$\text{Monetary policy}: \quad r_t = \phi_\pi \pi_t + \phi_y y_t$$

$$\text{Inflation}: \quad \pi_t = p_t - p_{t-1}$$

$$\text{Low skill real wage}: \quad w_t^L = w_t^{min} - p_t$$

$$\text{Law of motion min wage}: \quad w_t^{min} = \left(1 - \sum_{k=1}^{4} q_{kt} * a_k\right) * \left(w_{t-1}^{min} + \pi_{t-1} + \pi_{t-2} + \pi_{t-3} + \pi_{t-4}\right) + \left(\sum_{k=1}^{4} q_{kt} * a_k\right) * w_{t-1}^{min}$$

Note that the parameters s_L^1 and s_L^2 govern the share of low skill labor in each input firm. They represent the share of output of firm i that is attributable to low skill labor. They are given by:

$$s_L^i = \frac{(\theta\alpha_i)L_i^{\frac{\eta-1}{\eta}}}{(\theta\alpha_i)L_i^{\frac{\eta-1}{\eta}} + (1-\alpha_i)H_i^{\frac{\eta-1}{\eta}}} \tag{27}$$

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Figures

Figure C.1: Percent of verified earnings over time

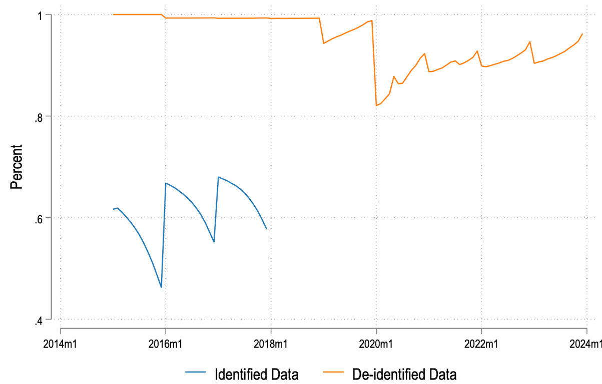
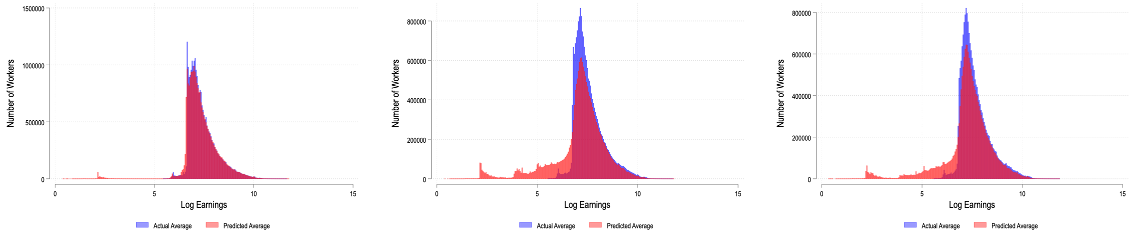
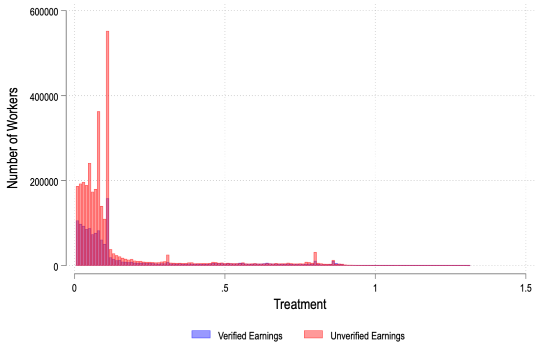


Figure C.2: Distribution of Measurement Error in Earnings (Identified Data)

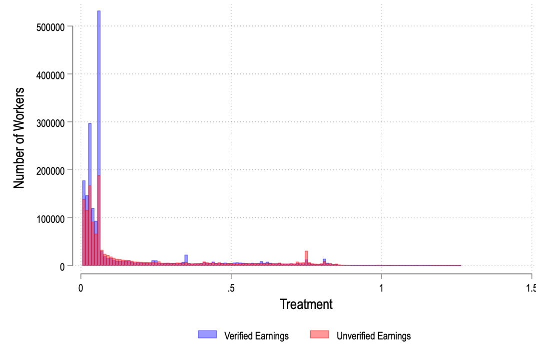


(a) 2015 (b) 2016 (c) 2017

Figure C.3: Distribution of Measurement Error in Treatment (Identified Data)



(a) 2015



(b) 2016

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Tables

Table C.1: Summary Statistics by Earnings Percentiles (2016)

	$\hat{y}_t < mw^{t+1}$	$mw^{t+1} < \hat{y}_t < 2 \cdot mw^{t+1}$	$2 \cdot mw^{t+1} < \hat{y}_t$
Observations	1035718	6928745	3252501
Female	0.42	0.40	0.24
Age	33.41	34.51	38.15
Education			
Less than High School	0.49	0.40	0.26
High School	0.47	0.53	0.45
More than High School	0.04	0.07	0.28
Establishment Size			
Small (<20)	0.26	0.26	0.18
Medium (20–250)	0.32	0.36	0.40
Large (>250)	0.42	0.38	0.42
Regions			
North	0.08	0.05	0.04
Northeast	0.41	0.18	0.10
Southeast	0.36	0.50	0.58
South	0.07	0.18	0.20
Centerwest	0.09	0.09	0.08
Sectors			
Agr. and Mining	0.22	0.09	0.06
Manuf. and Constr.	0.24	0.27	0.38
Services	0.53	0.63	0.55