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Asymmetric Business Cycles in Segmented Labour Markets*

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Abstract

We document the presence of asymmetric business cycles in both regular and contract labour markets in India and investigate the role of nominal wage rigidities and labour adjustment costs in accounting for these asymmetries. Using data from Annual Survey of Industries, we find that (i) the growth rate of output is negatively skewed, (ii) the growth of regular employment is negatively skewed while that of contract employment is positively skewed, (iii) the nominal wage growth of regular workers is positively skewed while that of contract workers is negatively skewed. We show that a standard business cycle model augmented with asymmetric wage adjustment cost for both regular and contract labour coupled with symmetric labour adjustment cost for regular workers does a good job of explaining the asymmetries in both output and employment cycles. We also find that the presence of contract labour relaxes the constraint of downward nominal wage rigidity, and hence decreases the optimal level of grease inflation required in the economy.

JEL codes: E24, E32, J42

Keywords: Asymmetry; Wage Rigidity; Segmented Markets; Optimal Inflation.

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1. Introduction

Despite the rapid development of emerging market business cycle models over the past decade, our understanding of labour market dynamics and their role in business cycle fluctuations in these countries is limited.[1] Importantly, insufficient attention has been given to the role of dual labour markets, even though this duality is often a distinctive characteristic of labour markets in EMEs. For instance, in 2015-16, the proportion of contract labour as a share of manufacturing work is substantial at 35.6% in India.

This observation raises empirical as well as theoretical questions. Empirically, does contract employment exhibit any particular pattern across the business cycle in India? And are the wage and employment dynamics distinct from those exhibited by the permanent or regular workers? If so, how does it impact the business cycles in India? Theoretically, what should be the modifications in the current framework for studying business cycles to account for large proportions of contract employment and their business cycle properties. And how does our understanding of the propagation mechanisms of business cycles change with such a modified framework? This paper aims to provide answers to these questions.

Industrial relations in India are largely governed by the Industrial Disputes Act (IDA) of 1947. This legislation is applicable to the regular workers, while the contract workers do not come under the ambit of this law. The provisions under IDA are quite stringent and impose several restrictions on firms regarding employment conditions (like work hours, leave and holidays), compensation paid to workers (like wages and pension), layoff, retrenchments and closures.[2] Since the IDA regulations do not cover contract workers, they usually receive lesser wages than permanent workers and are outside the coverage of trade unions. Hence, contract workers provide the firms an option of hiring and firing workers without being subject to provisions of law. Empirically, there is growing evidence to suggest that the higher flexibility of the contract labour has resulted in their increased share in the labour force (Saha et al. (2013),

[1]See the works of Neumeyer and Perri (2005), Uribe and Yue (2006), Aguiar and Gopinath (2007), Mendoza (2010), Garcia-Cicco et al. (2010), Chang and Fernández (2013) among others.

[2]Chapter VB of the IDA authorises labour courts and tribunals to set aside any discharge or dismissal referred to them as unjustified. If a unit employs more than 100 workers, retrenchment requires seeking authorisation from the state government, and this is rarely granted (Saha (2006)).

Chaurey (2015)).

Our interest in this paper is to examine the implications of this segmented labour market featuring both regular and contract workers on business cycles in India. We begin by systematically documenting the employment and wage dynamics exhibited by regular and contract workers using data on manufacturing firms from the Indian Annual Survey of Industries (ASI) for the period 1998-1999 to 2015-2016.

This empirical exercise reveals two interesting features in the data. First, the growth rate of employment and wages of contract workers is more volatile than that of regular workers. Second, employment and wage growth of both regular and contract workers exhibit asymmetric fluctuations over the business cycle. Specifically, we find that the employment cycle of regular workers is negatively skewed while their nominal wage growth is positively skewed. Regular employment tends to decline faster than increase over the business cycle, while the nominal wages of regular workers adjust upwards more rapidly than downwards. These empirical patterns are consistent with other developed economies as reported by Abbritti and Fahr (2013).

The distinctive feature of Indian business cycles is the dynamics of contract employment and wages. We find that the employment of contract workers is positively skewed while their nominal wages is negatively skewed over the business cycle. This is exactly opposite to the behaviour of regular employment and wages. While the fall in regular employment is at a faster rate than its rise, contract employment on the other hand, expands at a faster rate and falls sluggishly.

To address these empirical findings, we extend the standard New Keynesian framework to include dual labour markets, asymmetric wage adjustment costs and symmetric labour adjustment cost for regular workers. The model economy is composed of households, a labour packer, intermediate good firms, a final good firm and the central bank. Monopolistically competitive households receive utility from consumption of the final good, supply differentiated regular and contract labour to a labour packer and have access to complete markets. Importantly, wage setting by the households is subjected to asymmetric wage adjustment costs that are calibrated to capture the distinctive wage dynamics of regular and contract labour.

The labour packer bundles the differentiated regular and contract labour into a composite labour input and sells it to intermediate firms. In aggregating differentiated regular labour, the packer faces a symmetric labour adjustment cost. Lechthaler and Snower (2008) show that introducing labour adjustment costs into New Keynesian models helps capture the hiring and firing costs associated with employment. Consistent with the provisions of the IDA, we apply these costs only to regular workers and not to the contract workers. Intermediate goods producers use composite labour input to produce differentiated goods and face price adjustment costs. The final good producer aggregates the intermediate goods and sells the composite good in a perfectly competitive market. Finally, the central bank implements monetary policy by setting the short-term interest rate according to a Taylor-type feedback policy rule.

We calibrate the asymmetric wage adjustment costs of both regular and contract workers to reflect the contrasting asymmetries in their nominal wage dynamics. Upon matching the data moments, we find that our model is successful in generating a negatively skewed regular employment and a positively skewed contract employment as observed in the data. Following a negative productive shock, the nominal wages and hence the real wages of contract workers declines immediately while that of regular workers does not reduce by much, as they are subject to convex adjustment costs. This causes a sharp contraction in regular employment but a mild decline in contract employment. On the other hand, following a positive productivity shock, regular wages increases rapidly while there is a muted response in contract wages. This makes hiring contract workers more profitable compared to the regular workers, leading to a sharp expansion in contract employment and a more moderate increase in regular employment. This mechanism generates a negatively skewed regular labour and a positively skewed contract labour over the cycle.

Using the calibrated parameter values, we solve for the optimal inflation that maximizes the households' welfare. Following Kim and Ruge-Murcia (2009), we define the optimal level of grease inflation as the extra inflation obtained under asymmetric vis-à-vis symmetric wage adjustment costs.[3] The optimal grease inflation in an one-sector version of our model containing only regular workers is 0.066%. Introducing contract labour into our model reduces the optimal grease inflation to 0.003%. Thus,

[3]In his presidential address to the American Economic Association, Tobin (1972) argued for a positive rate of inflation to overcome the constraints imposed by the downward nominal wage rigidity.

if the Indian economy just had regular workers facing downwardly rigid wages, the planner has to generate an extra inflation of 0.066% to aid the labour market adjustment. However, with the introduction of contract labour with opposing asymmetry, the optimal grease inflation declines to 0.003%. In sum, the presence of contract labour eases the pressure to generate higher inflation following productivity shocks.

Our work in this paper is related to multiple strands of literature. There is a growing body of literature that studies business cycle asymmetries for advanced economies (see Ball and Mankiw (1994); McKay and Reis (2008); Görtz and Tsoukalas (2013)). The paper closest to our study is Abbritti and Fahr (2013). They argue that the presence of downward nominal wage rigidities can lead to asymmetries in business cycle fluctuations. We extend this study by incorporating segmented labour markets with contrasting dynamics in the context of an emerging economy, namely India. In addition, we also study the effect of contract labour on the optimal level of grease inflation in the economy. Our paper also contributes to the burgeoning literature focusing on dual labour markets and business cycles in emerging economies. Some of the papers like Bosch and Esteban-Pretel (2012), Restrepo-Echavarria (2014), and Fernández and Meza (2015) study business cycles in the presence of dual labour markets. Our work adds to this literature by focusing on the role that segmented labour markets plays in explaining business cycle asymmetries.

This paper is organized as follows. Section 2 presents stylized facts concerning business cycle asymmetries in labour markets. Section 3 describes the model framework. Section 4 presents the calibration strategy. The main results of the paper are presented in Section 5. Section 6 solves for the optimal inflation under Ramsey optimisation, and section 7 concludes.

2. Empirical Evidence

In this section, we document the business cycle facts for India using data from Annual Survey of Industries. Primarily, we show that the growth rate of employment for regular workers is negatively skewed while that of contract workers is positively skewed. On the other hand, the growth rate of nominal wages for regular workers is positively skewed while that of contract workers is negatively skewed.

2.1 Annual Survey of Industries

Annual Survey of Industries (ASI) is an yearly census of registered manufacturing plants in India. Conducted by the National Sample Survey Office (NSSO), all registered manufacturing plants with more than 100 workers (census scheme) are surveyed yearly. In addition, one-fifth of the smaller registered plants are randomly sampled every year (sample scheme).

In order to construct the aggregate data, we use the data cleaning procedure adopted by Allcott et al. (2016). We first remove all the observations that have an invalid state code. Next, we only consider factories that were open in that assessment year. And finally, we remove all the firms that have non-manufacturing NIC codes. More details on the data preparation can be found in the Appendix A.1. At the end of this procedure, we have data on about 680,000 firms for the period of 1998-99 to 2015-16. We use the sampling weights provided by the ASI to construct the aggregate data.

Following Hsieh and Klenow (2009) and Allcott et al. (2016), we measure output by the revenue earned by firms. We use Consumer Price Index of Industrial Workers (CPI-IW) as our measure of price level. One of the important advantages of ASI is, it provides labour market information separately for both regular and contract workers. We measure employment by total number of regular and contract workers employed by the firms. Similarly, our measure of nominal wage is nominal wage per man-day for both regular and contract workers. We use the annual growth rates of these macroeconomic variables to calculate the business cycle statistics.

2.2 Cyclicality

We start our empirical results with the cyclicality of labour market variables provided in Table 1. We find that employment is procyclical for both regular and contract workers. The correlation of contract employment is higher than the regular employment, implying that the contract employment traces the business cycle more closely compared to the regular employment. We also find a positive correlation between contract and regular employment which indicates that both regular and contract employment behave as complements and not as substitutes in the economy.

Table 1
Cyclicality of Annual Growth Rates

	Regular Labour	Contract Labour
$\rho(x, Output)$	0.35	0.78
$\rho(x, Regular\,Labour)$	1	0.26

Note: Cyclicality of annual growth rates obtained from Annual Survey of Industries 1998-99 to 2015-16. Labour is the total number of regular and contract workers employed. Output is total revenue earned by firms deflated by the Consumer Price Index of Industrial workers (CPI-IW).

Table 2
Standard Deviation of Annual Growth Rates

Output	0.073	
Price	0.027	
	Regular Labour	Contract Labour
Employment	0.043	0.065
Nominal Wage	0.035	0.048
Real Wage	0.026	0.033

Note: Standard Deviations of annual growth rates obtained from Annual Survey of Industries 1998-99 to 2015-16. Labour is the total number of regular and contract workers employed. Nominal wages is the nominal compensation per manday. Price is Consumer Price Index of Industrial workers (CPI-IW). Real wages are nominal wages deflated by the price level. Output is total revenue earned by firms deflated by the price level.

2.3 Standard Deviations

Table 2 documents the standard deviations of annual growth rates of output and labour market variables. The output volatility is much higher in India than other developed countries. This confirms the findings of Aguiar and Gopinath (2007) and emerging market business cycle research in general. Moreover, the volatility of contract employment is about 50% higher than that of regular employment. Another interesting finding is the wages (both in real and nominal terms) of contract workers is also more volatile compared to the wages of regular workers. This seems to indicate that the labour market of contract workers is more flexible compared to the regular

Table 3
Skewness of Annual Growth Rates

Output	−0.037	
Price	0.504	
	Regular Labour	Contract Labour
Employment	−0.434	0.546
Nominal Wage	0.430	−0.610
Real Wage	0.128	−0.414

Note: Skewness of annual growth rates obtained from Annual Survey of Industries 1998-99 to 2015-16. Labour is the total number of regular and contract workers employed. Nominal wages is the nominal compensation per manday. Price is Consumer Price Index of Industrial workers (CPI-IW). Real wages are nominal wages deflated by the price level. Output is total revenue earned by firms deflated by the price level.

workers, both in terms of labour adjustment and wage-setting process.

2.4 Skewness

Having documented the (co-)movement of output and labour market variables over the business cycle, we now show the asymmetric nature of their adjustments. Table 3 reports the skewness of annual growth rates of output and labour market variables, which is the main interest of our study. We find that the employment of regular workers is negatively skewed while both their nominal and real wages are positively skewed. This finding indicates that, over the business cycle, regular employment tends to fall faster than it increases while the wages of regular workers adjusts upwards more rapidly than downwards. We also find that output growth is negatively skewed. These empirical patterns are consistent with those in other developed economies such as France, Germany, US, UK and the Euro area as documented by Abbritti and Fahr (2013).

The remarkable feature of Indian business cycles is the dynamics of contract employment and wages. We find that the employment of contract workers is positively skewed while their nominal (and real) wages is negatively skewed. This is exactly opposite to the behaviour of regular employment and wages. While the regular employment contracts at a faster rate compared to its expansion, contract employment on the other hand, expands at a faster rate than its decline. A positive nominal wage skewness for regular workers is suggestive of downward nominal wage rigidity, while we observe the opposite for contract workers. These skewness measures indicate the underlying dichotomy that exists between regular and contract labour markets.

In the next section, we build a model to investigate the role of nominal wage rigidities and labour adjustment cost in explaining the asymmetric movements of output and employment over the business cycle.

3. Model Framework

We extend the workhorse New Keynesian model with wage and price rigidities to include segmented labour markets, asymmetric wage adjustment costs and labour adjustment cost for regular workers. Our objective is to capture the contrasting nominal wage rigidities associated with both regular and contract labour and examine its implications for asymmetric business cycles in India.

3.1 Labour Packer

A continuum of infinitely lived identical households populates the economy, indexed by $i \in [0, 1]$ and each household has a continuum of members. Within each household, a fraction s of its members participates in regular employment while the remaining fraction $(1 - s)$ participates in contract employment. Each household supplies differentiated regular $(n_t^r(i))$ and contract $(n_t^c(i))$ labour to the intermediate goods firms. We make use of the concept of a "labour packer" (or a union) which combines different types of labour into a composite labour service, which is then leased to the firm at a wage rate W_t. The labour aggregation takes place in two stages. In the first stage, the packer solves a simple optimization problem to determine the demand for each differentiated type of regular $n_t^r(i)$ and contract labour $n_t^c(i)$, respectively. The aggregate demand for regular (sn_t^r) and contract $\big((1-s)n_t^c\big)$ labour is given by

$$sn_t^r = \left(\int_0^s n_t^r(j)^{\frac{\varepsilon_w - 1}{\varepsilon_w}} dj\right)^{\frac{\varepsilon_w}{\varepsilon_w - 1}}, \tag{1}$$

$$(1-s)\, n_t^c = \left(\int_s^1 n_t^c(j)^{\frac{\varepsilon_w - 1}{\varepsilon_w}} dj\right)^{\frac{\varepsilon_w}{\varepsilon_w - 1}}, \tag{2}$$

where n_t^r and n_t^c are the average demand for regular and contract labour, respectively. The profit maximization problem for the competitive labour packer is given by

$$\max_{n_t^r, n_t^c} W_t^r \left(\int_0^s n_t^r(j)^{\frac{\varepsilon_w - 1}{\varepsilon_w}} dj\right)^{\frac{\varepsilon_w}{\varepsilon_w - 1}} + W_t^c \left(\int_s^1 n_t^c(j)^{\frac{\varepsilon_w - 1}{\varepsilon_w}} dj\right)^{\frac{\varepsilon_w}{\varepsilon_w - 1}}$$
$$- \left(\int_0^s W_t^r(j) n_t^r(j) dj\right) - \left(\int_s^1 W_t^c(j) n_t^c(j) dj\right).$$

Here, $\varepsilon_w > 1$ is the elasticity of substitution between different varieties of labour and j indexes the differentiated labour inputs which populate the unit interval. The first-order conditions for the problem yield the following demand conditions for regular and contract labour:

$$n_t^r(i) = \left(\frac{W_t^r(i)}{W_t^r}\right)^{-\varepsilon_w} sn_t^r, \qquad n_t^c(i) = \left(\frac{W_t^c(i)}{W_t^c}\right)^{-\varepsilon_w} (1-s)\, n_t^c, \tag{3}$$

where W_t^r and W_t^c denote the aggregate wage for regular and contract workers, and is given by

$$W_t^r = \frac{1}{s^{\frac{1}{\varepsilon_w}}} \left(\int_0^s W_t^r(j)^{1-\varepsilon_w} dj\right)^{\frac{1}{1-\varepsilon_w}},$$

$$W_t^c = \frac{1}{(1-s)^{\frac{1}{\varepsilon_w}}} \left(\int_0^s W_t^c(j)^{1-\varepsilon_w} dj\right)^{\frac{1}{1-\varepsilon_w}}.$$

In the second stage, the packer determines the demand for the aggregate amount of regular and contract labour. Here, the packer aggregates regular and contract labour using a CES aggregator to produce a composite labour service h, defined as

$$h_t = \left[\gamma^{\frac{1}{\delta}} \left(sn_t^r\right)^{\frac{\delta-1}{\delta}} + (1-\gamma)^{\frac{1}{\delta}} \left(\left(1-s\right) n_t^c\right)^{\frac{\delta-1}{\delta}}\right]^{\frac{\delta}{\delta-1}}, \tag{4}$$

where γ captures the difference in productivity between regular and contract labour while δ denotes the elasticity of substitution between them.

To capture the cost imposed by IDA on hiring and firing of regular workers, we introduce a per unit labour adjustment cost which the labour packer incurs in order to adjust the employment of regular workers. Contract workers who do not come under the ambit of the labour laws are not subject to these adjustment costs. Following Lechthaler and Snower (2008), these frictions are modeled by a simple quadratic labour adjustment cost given by

$$C(n_t^r) = \frac{\kappa^r}{2}(n_t^r - n_{t-1}^r)^2. \tag{5}$$

The competitive labour packer chooses the aggregate regular (n_t^r) and contract (n_t^c) labour by minimizing the total cost.

$$\min_{n_t^r, n_t^c} W_t^r s n_t^r + sC(n_t^r) + W_t^c \left(1-s\right) n_t^c,$$

subject to the labour aggregator (4). Optimization yields the following aggregate demand conditions for regular and contract labour

$$sn_t^r = \gamma \left(\frac{W_t}{\tilde{W}_t^r}\right)^{\delta} h_t, \qquad (1-s)\, n_t^c = (1-\gamma) \left(\frac{W_t}{W_t^c}\right)^{\delta} h_t, \tag{6}$$

where $\tilde{W}_t^r = W_t^r + C_t'(n_t^r)$ represents the total cost of employing regular workers and the aggregate wage index W_t is given by

$$W_t = \left[\gamma \left(\tilde{W}_t^r\right)^{1-\delta} + (1-\gamma) \left(W_t^c\right)^{1-\delta}\right]^{\frac{1}{\delta-1}}. \tag{7}$$

3.2 Household

Each household i maximizes its lifetime utility given by

$$U = \mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{c_t(i)^{1-\sigma}}{1-\sigma} - \frac{n_t^r(i)^{1+\rho}}{1+\rho} - \frac{n_t^c(i)^{1+\rho}}{1+\rho} \right], \tag{8}$$

where $c_t(i)$ is the consumption of the final good. As monopolistic competitors, households choose their wages and supply differentiated regular $(n_t^r(i))$ and contract $(n_t^c(i))$ labour to the intermediate goods sector. Importantly, nominal wages $W_t^r(i)$ and $W_t^c(i)$ set by the households for regular and contract sectors are subject to asymmetric wage adjustment costs. Following Kim and Ruge-Murcia (2009) and Abbritti and Fahr (2013), we model the wage adjustment cost for a j worker, where $j \in \{r, c\}$ as

$$\Phi_t^j = \phi_w^j \left(\frac{\exp(-\psi^j(\Omega_t^j - 1)) + \psi^j(\Omega_t^j - 1) - 1}{(\psi^j)^2} \right), \tag{9}$$

where Ω_t^j denotes the wage inflation of j worker. The parameter ϕ_w^j captures the degree of convexity and ψ^j the degree of asymmetry in the adjustment cost. When $\psi^j > 0$, a wage increase faces linear costs while a wage decrease is subjected to convex costs. Hence, a decrease in nominal wage is costlier than a corresponding increase. On the other hand, if $\psi^j < 0$, an increase in nominal wage is more expensive compared to a decrease, since now wage increase is subjected to convex costs.[4] This functional form captures the contrasting nominal wage rigidities of regular and contract labour, which coupled with labour adjustment costs are the key mechanisms through which the model can explain the observed business cycle asymmetries in the data.

To smooth consumption, households can use one-period nominal risk-free bond B_t, which pays a nominal interest rate of i_t. Using income earned from wages, interests and profits, households finance their current period's consumption and the next period's bond holdings. The household's budget constraint is therefore given by

$$c_t(i) + \frac{B_{t+1}(i)}{P_t} \leq (1 + i_{t-1}) \frac{B_t(i)}{P_t} + \frac{W_t^r(i) n_t^r(i)(1 - \Phi_t^r(i))}{P_t} + \frac{W_t^c(i) n_t^c(i)(1 - \Phi_t^c(i))}{P_t} + \frac{\Pi_t}{P_t}, \tag{10}$$

[4] Refer to Kim and Ruge-Murcia (2009) for a discussion on the attractiveness of this functional form.

where Π_t is the total profit in the intermediate good sector and P_t is the aggregate price index. In each period households maximize their utility by choosing $c_t(i)$, $B_{t+1}(i)$, $W_t^r(i)$ and $W_t^c(i)$ subject to the labour demand condition (1) and the budget constraint (10). The first order conditions are as follows:

$$c_t^{-\sigma}(i) = \eta_t, \tag{11}$$

where η_t is the Lagrangian multiplier associated with the household's budget constraint. Equation (11) implies that at an optimum, the marginal utility of consumption is equal to the marginal utility of wealth.

$$i_t = \frac{1}{\beta} E_t \left[\frac{P_{t+1}}{P_t} \frac{\eta_t}{\eta_{t+1}} \right]. \tag{12}$$

Equation (12) is the standard Euler equation that equalises the cost of postponing consumption with its expected marginal benefit. The wages of regular workers $W_t^r(i)$ satisfy

$$\begin{aligned} &\frac{(n_t^r(i))^{1+\rho}}{W_t^r(i)} \varepsilon_w + E_t \beta \frac{\eta_{t+1}}{P_{t+1}} \left[\left(\frac{W_{t+1}^r(i)}{W_t^r(i)} \right)^2 n_{t+1}^r(i) (\Phi_{t+1}^r(i))' \right] + \\ &(1-\varepsilon_w)\eta_t \frac{1}{P_t}(1-\Phi_t^r(i)) n_t^r(i) - \frac{W_t^r(i)}{W_{t-1}^r(i)} (\Phi_t^r)' \frac{\eta_t}{P_t} n_t^r(i) = 0. \end{aligned} \tag{13}$$

Equation (13) equates the cost of raising wages to its benefits. The costs include the wage adjustment cost and a decrease in the hours worked as firms substitute towards cheaper input. On the other hand, the gains include higher hourly wage income and a reduction in future expected wage adjustment cost. Analogously, the wages of contract workers $W_t^c(i)$ satisfy

$$\begin{aligned} &\frac{(n_t^c(i))^{1+\rho}}{W_t^c(i)} \varepsilon_w + E_t \beta \frac{\eta_{t+1}}{P_{t+1}} \left[\left(\frac{W_{t+1}^c(i)}{W_t^c(i)} \right)^2 n_{t+1}^c(i) (\Phi_{t+1}^c(i))' \right] + \\ &(1-\varepsilon_w)\eta_t \frac{1}{P_t}(1-\Phi_t^c(i)) n_t^c(i) - \frac{W_t^c(i)}{W_{t-1}^c(i)} (\Phi_t^c)' \frac{\eta_t}{P_t} n_t^c(i) = 0. \end{aligned} \tag{14}$$

3.3 Final Good Firm

There is a final good firm which aggregates the intermediate goods $y_t(z)$ according to a CES technology and sells the composite good y_t in a perfectly competitive market. The final good is given by

$$y_t = \left(\int_0^1 (y_t(z))^{\frac{\varepsilon_p - 1}{\varepsilon_p}} \, dz \right)^{\frac{\varepsilon_p}{\varepsilon_p - 1}}, \tag{15}$$

where $\varepsilon_p > 1$ is the elasticity of substitution between the intermediate goods. The demand function faced by an intermediate firm is given by

$$y_t(z) = \left(\frac{P_t(z)}{P_t} \right)^{-\varepsilon_p} y_t. \tag{16}$$

The aggregate price index P_t is given by

$$P_t = \left(\int_0^1 (P_t(z))^{(1-\varepsilon_p)} \, dz \right)^{\frac{1}{1-\varepsilon_p}}. \tag{17}$$

3.4 Intermediate Goods Firm

3.4.1 Marginal Cost

The intermediate goods sector is characterized by monopolistically competitive firms, where each firm produces a differentiated good $z \in [0, 1]$ using the production function

$$y_t(z) = a_t (h_t(z))^{1-\alpha}, \tag{18}$$

where $y_t(z)$ is the output of firm z, $h_t(z)$ is the aggregate labour input for firm z, and α is the production function parameter. a_t is the exogenous productivity shock that follows an AR(1) process

$$\ln a_t = \rho_a \ln a_{t-1} + \varepsilon_t^a. \tag{19}$$

Intermediate producers face a common wage W_t. They cannot adjust their prices costlessly to maximize their profit in each period, but will always act to minimize their cost subject to the constraint of producing enough to meet the demand. Each firm minimizes its total cost given by

$$\min_{h_t(z)} W_t h_t(z), \tag{20}$$

subject to the production technology (18). The first-order conditions of the problem provide an expression for the marginal cost given by

$$MC_t(z) = \frac{W_t}{a_t(1-\alpha)(h_t(z))^{-\alpha}}, \tag{21}$$

where $MC_t(z)$ is the marginal cost of the intermediate firm z.

3.4.2 Profit Maximization

Monopolistically competitive firms choose their price and maximize the discounted sum of real profits

$$\mathrm{E}_0 \sum_{t=1}^{\infty} \frac{\beta^t \eta_t}{P_t} \left[P_t(z)(1-\Gamma_t^z) y_t(z) - W_t h_t(z) \right], \tag{22}$$

subject to the downward-sloping demand function of the final good producer (16) and a price adjustment cost Γ_t^z similar to Rotemberg (1982), given by

$$\Gamma_t^z = \frac{\phi_p}{2} \left[\pi_t(z) - 1 \right]^2, \tag{23}$$

where $\pi_t(z)$ refers to the price inflation and ϕ_p captures the cost of price adjustment. The first order condition yields the standard price Phillips curve for the firm and is given by

$$\frac{1}{P_t} \left[(1-\epsilon_p)(1-\Gamma_t^z) y_t(z) - \Gamma_t^{z\prime} \frac{P_t(z)}{P_{t-1}(z)} y_t(z) + \frac{1}{P_t(z)} y_t(z) \epsilon_p MC_t(z) \right] + \\ E_t \left[\beta \frac{\eta_{t+1}}{\eta_t} {\Gamma_{t+1}^z}' \frac{y_{t+1}(z)}{P_{t+1}} \left(\frac{P_{t+1}(z)}{P_t(z)} \right)^2 \right] = 0. \tag{24}$$

3.5 Monetary Policy and Resource Constraint

The central bank implements monetary policy by setting the short-term interest rate according to a Taylor-type feedback rule, where the nominal interest rate responds to its own lagged value and any deviation of inflation from its steady state, that is,

$$\ln(i_t/i) = \phi_i \ln(i_{t-1}/i) + \phi_\pi \ln(\pi_t/\pi), \tag{25}$$

where i and π refer to the steady state values of interest rate and inflation, respectively.

Since households are assumed to be identical, under a symmetric equilibrium, all households make the exact same choices and therefore the i subscripts can be dropped without loss of generality. Analogously, all firms are identical and hence would charge the same price and produce the same quantity. This implies that substituting profits of the intermediate firm into the household budget constraint and assuming without loss of generality that bonds are in net-zero supply, we get the aggregate resource constraint as follows:

$$c_t = \frac{W_t^r s n_t^r (1-\Phi_t^r)}{P_t} + \frac{W_t^c (1-s) n_t^c (1-\Phi_t^c)}{P_t} + (1-\Gamma_t^z) y_t - \frac{W_t h_t}{P_t}. \tag{26}$$

4. Calibration

We calibrate the parameters of the model to quantitatively investigate the impact of nominal wage rigidities on business cycle asymmetries. Table 4 shows the values chosen for the parameters externally.

The discount factor β is set to reflect a real interest rate of 4%. The share of regular workers s and their relative income share γ are directly obtained from the ASI data. The elasticity of substitution between regular and contract workers δ is set to 1.03 following the findings of Basu et al. (2018). Following Anand and Prasad (2010), the elasticity of substitution among differentiated goods ϵ_p is chosen to be 10. The price adjustment cost parameter ϕ_p is taken as 100 to match the Calvo parameter of 0.25,

Table 4
Externally Chosen Parameters

Parameter description		Value	Source
Price adjustment	ϕ_p	100	Corresponds to Calvo parameter of 0.25
Relative income share	γ	0.61	Annual Survey of Industries
Elasticity of substitution of labour	δ	1.03	Basu et al. (2018)
Share of labour in production function	α	0.29	Annual Survey of Industries
Discount factor	β	0.96	Real interest rate of 4%
Inter-temporal elasticity of consumption	σ	2	Anand and Prasad (2010)
Persistence of productivity shock	ρ_a	0.85	Annual Survey of Industries
Elasticity of substitution among goods	ϵ_p	10	Anand and Prasad (2010)
Elasticity of substitution among labour	ϵ_w	7	Laxton and Pesenti (2003)
Share of regular labour	s	0.72	Annual Survey of Industries
Inverse of Frisch elasticity	ρ	2	Banerjee and Basu (2017)
Interest rate coeff. in Taylor rule	ϕ_i	0.86	Banerjee and Basu (2017)
Inflation coeff. in Taylor rule	ϕ_π	1.47	Banerjee and Basu (2017)
Standard deviation of productivity shock	σ_a	0.05	Annual Survey of Industries

which represents a mean price duration of about 1 quarter.[5,6] Following the findings of Banerjee and Basu (2017), the monetary policy rule parameters, namely the elasticity of interest rate with respect to inflation ϕ_π, and lagged interest rates ϕ_i are set at 1.47 and 0.86, respectively. We estimate the TFP shock process using Solow residuals to obtain a persistence ρ_a of 0.85 and a standard deviation σ_a of 0.05.

We calibrate the parameters of asymmetric wage adjustment costs and labour adjustment cost by matching the model generated moments with their corresponding data counterparts. Table 5 shows the calibrated values of the cost parameters. The wage rigidity parameters of regular workers ϕ_w^r and contract workers ϕ_w^c are chosen to match the standard deviations of the corresponding nominal wage inflation. The wage asymmetry parameters of regular labour ψ^r and contract labour ψ^c are chosen to match the corresponding skewness of the nominal wage growth. The asymmetry parameter of regular wages ψ^r is calibrated to be positive, meaning that any increase in regular wages faces a linear cost while a decrease is subject to convex costs, leading

[5]Refer to Table 1 in Khan (2005) for converting the price adjustment cost parameter to the corresponding Calvo parameter.

[6]According to Banerjee and Basu (2017), the commodity-wise monthly CPI data for the industrial workers in India shows that the average price duration is around 1 quarter.

Table 5
Calibration Targets of Benchmark Model

Parameter			Performance		
Description		Value	Target to Match	Data	Model
Regular Labour					
Wage rigidity	ϕ_w^r	5100	Std. dev. of nominal wage growth	0.035	0.032
Wage asymmetry	ψ^r	15600	Skewness of nominal wage growth	0.430	0.461
Labour adjustment	κ^r	0.40	Std. dev. of employment growth	0.043	0.047
Contract Labour					
Wage rigidity	ϕ_w^c	4700	Std. dev. of nominal wage growth	0.048	0.046
Wage asymmetry	ψ^c	-18500	Skewness of nominal wage growth	-0.610	-0.614

to a slow downward adjustment of wages for regular workers. On the other hand, the asymmetry parameter of contract wages ψ^c is calibrated to be negative, thus penalizing any wage increase with a convex cost. The labour adjustment cost parameter of the regular workers κ^r is calibrated to match the standard deviation of its employment growth.

5. Results

We discuss the performance of our benchmark model with asymmetric wage adjustment and symmetric labour adjustment costs in accounting for the business cycle dynamics. We also compare this with other competing versions of the model to show that our benchmark model does a better job of matching the data.

5.1 Cyclicality

Table 6 compares the empirical cyclicality with the cyclicality obtained from different model formulations. *Asym* refers to our benchmark setup which uses asymmetric wage adjustment costs to capture the contrasting wage dynamics between regular and contract labour, and labour adjustment cost for regular workers. *No LAC* is same as our benchmark model but with no labour adjustment cost, while *Sym* uses

Table 6
Cyclicality of annual growth rates

	Data	Asym	No LAC	Sym	1-Sec
$\rho(Y, reg)$	0.35	0.51	0.48	-0.15	0.56
$\rho(Y, cont)$	0.78	0.62	0.37	0.16	-
$\rho(reg, cont)$	0.26	0.04	-0.24	0.94	-

Note: Cyclicality of annual growth rates in the ASI data from 1998-99 to 2015-16 along with the model specifications. *Asym* is the benchmark model with asymmetric wage adjustment costs and symmetric labour adjustment cost for regular workers. *No LAC* is similar to our benchmark specification, but with no labour adjustment cost. *Sym* models wage adjustment using symmetric adjustment costs, and *1-Sec* is the one sector version of the benchmark with just regular workers. The adjustment costs are recalibrated to make the model results comparable.

symmetric costs to capture the wage changes for both regular and contract workers. Finally, *1-Sec* is a one-sector version of our benchmark model containing only regular workers. We recalibrate the adjustment cost parameters of all the models to make them comparable. The resulting parameter values of different models are given in appendix C .

The cyclicality in the data exhibits three empirical regularities namely, (a) both regular and contract labour are procyclical, (b) contract labour is more cyclical compared to regular labour, (c) regular and contract employment move together over the cycle. The model having only asymmetric wage adjustment costs with no labour adjustment cost, succeeds in generating procyclical regular and contract labour. However, it fails on the other two fronts as the model produces regular labour to be more cyclical than the contract and they move in opposite directions over the cycle. The model with symmetric adjustment costs generates countercyclical regular employment which is at odds with the data. The benchmark model with both asymmetric wage adjustment and labour adjustment costs succeeds in capturing all the three aspects of the data and it is the only model that does so.

Table 7
Standard deviation of annual growth rates

	Data	Asym	No LAC	Sym	1-Sec
Output	0.073	0.071	0.065	0.036	0.075
Price	0.027	0.009	0.009	0.007	0.015
Regular Labour					
Employment	0.043	0.047	0.043	0.039	0.073
Nominal Wages	0.035	0.032	0.036	0.031	0.033
Real Wages	0.026	0.035	0.036	0.032	0.028
Contract Labour					
Employment	0.065	0.058	0.052	0.090	-
Nominal Wages	0.048	0.046	0.045	0.052	-
Real Wages	0.033	0.043	0.045	0.050	-

Note: Standard deviations of annual growth rates in the ASI data from 1998-99 to 2015-16 along with the model specifications. *Asym* is the benchmark model with asymmetric wage adjustment costs and symmetric labour adjustment cost for regular workers. *No LAC* is same as our benchmark specification, but with no labour adjustment cost. *Sym* models wage adjustment using symmetric adjustment costs, and *1-Sec* is the one sector version of the benchmark with just regular workers. The adjustment costs are recalibrated to make the model results comparable.

5.2 Standard Deviations

We compare the standard deviations simulated from different models and summarize the results in Table 7. We find that, both our benchmark models with and without labour adjustment cost do a very good job of accounting for the empirical standard deviations. Both the models generate volatilities close to their empirical counterparts with the model with labour adjustment cost performing slightly better in terms of output and contract employment. Both the models are successful in generating contract labour that is more volatile than the regular. However, the introduction of labour adjustment cost helps capturing the wedge between regular and contract volatilities better. The use of symmetric adjustment costs does a good job of explaining the standard deviations in regular labour market, but predicts a far bigger volatility of contract employment than what we see in the data. It also generates a much smoother output, as the model generated output is just half as volatile as that of the data. Finally, the one-sector model containing only regular workers generates a more volatile labour cycle than what is found in the data.

5.3 Skewness

Table 8 documents the skewness obtained from various models and compares them with the empirical moments. The model with symmetric adjustment costs performs poorly in capturing the skewness in the data. It is unable to generate the contrasting asymmetries found in the empirical cycles of wages and employment. It produces both regular and contract wages to be downward rigid and the direction of employment skewness is opposite of the data skewness. This inability of symmetric cost models to capture the empirical skewness is also documented by Abbritti and Fahr (2013) in their one-sector model.

Considering the asymmetric model with no labour adjustment cost, the model is successful in generating negatively skewed regular employment and a positively skewed contract employment. It also produces price and real wage skewness in line with the data. However, it falters at generating a negatively skewed output as seen in the data. The one-sector model with just regular labour captures the skewness of regular employment quite well. However, its output skewness is about an order of

Table 8
Skewness of annual growth rates

	Data	Asym	No LAC	Sym	1-Sec
Output	−0.037	−0.015	0.082	0.027	−0.195
Price	0.504	0.194	0.178	0.505	0.033
Regular Labour					
Employment	−0.434	−0.067	−0.100	0.196	−0.407
Nominal Wages	0.430	0.461	0.445	−0.499	0.463
Real Wages	0.128	0.392	0.414	−0.318	0.533
Contract Labour					
Employment	0.546	0.081	0.513	−0.199	-
Nominal Wages	−0.610	−0.614	−0.642	−0.631	-
Real Wages	−0.414	−0.540	−0.536	−0.603	-

Note: Skewness of annual growth rates in the ASI data from 1998-99 to 2015-16 along with the model specifications. *Asym* is the benchmark model with asymmetric wage adjustment costs and symmetric labour adjustment cost for regular workers. *No LAC* is same as our benchmark specification, but with no labour adjustment cost. *Sym* models wage adjustment using symmetric adjustment costs, and *1-Sec* is the one sector version of the benchmark with just regular workers. The adjustment costs are recalibrated to make the model results comparable.

magnitude larger (in absolute value) than the data.

By introducing contract labour and explicitly modeling the contrasting wage dynamics, the benchmark model is able to generate output skewness much closer to the data. Specifically, the introduction of contract labour reduces the output skewness from -0.195 in the one-sector model to -0.028 in the two-sector version. Thus, our benchmark model, on top of capturing the contrasting asymmetries of regular and contract employment, also generates output skewness much closer to the data. Incorporating a positively skewed contract employment into our model leads to a reduction in the negative skewness of output.

5.4 Impulse Responses

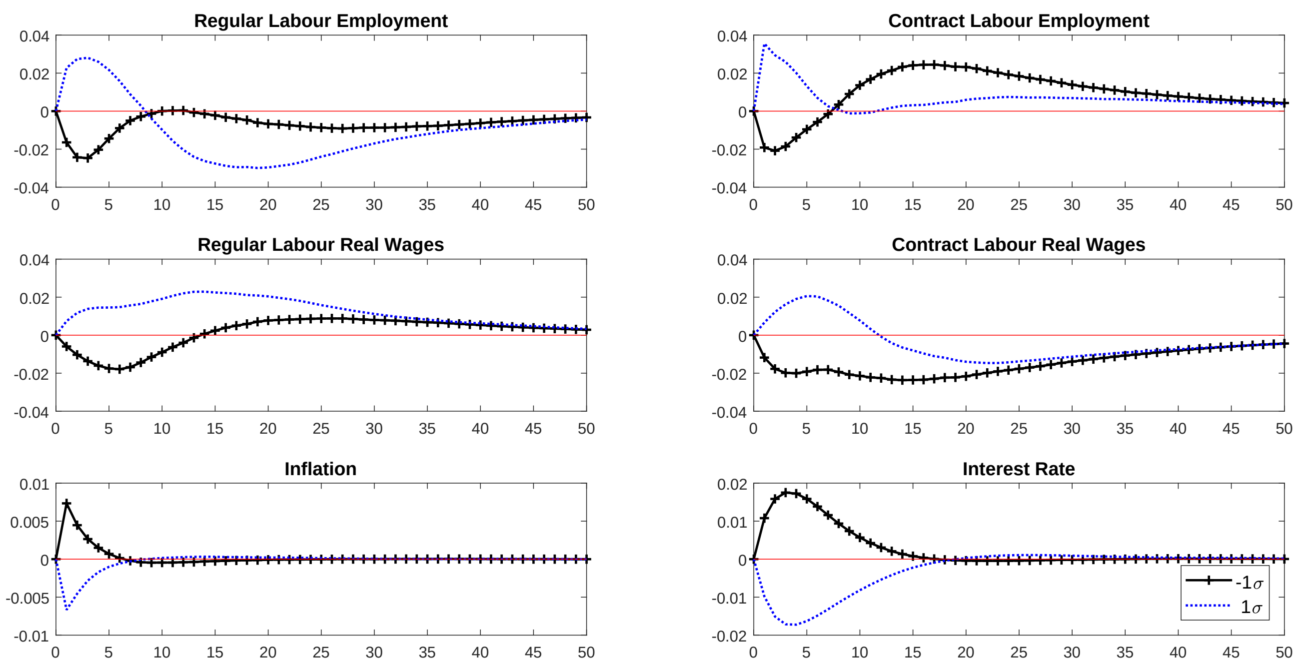

Figure 1: Dynamic response following a positive and negative productivity shocks of 1 standard deviation.

To understand the intuition behind our results, Figure 1 shows the impulse responses of the benchmark model when it is subject to a productivity shock of unit standard deviation. When a model with just sticky prices is perturbed using a negative productive shock, then both nominal and real wages go down to reflect the decline in productivity. However, in our setup, the presence of asymmetric wage adjustment costs makes this reduction in nominal wages costly for regular workers as they face convex costs for any downward adjustment. On the other hand, any decline in nominal wages is comparatively cheaper for contract workers as they face linear costs. Since the regular wages do not adjust as much as the contract wages to reflect the fall in productivity, firms have a reduced incentive to hold on to regular labour compared to contract labour. This leads to a prolonged reduction in regular employment but a quick rebound in the case of contract employment.

Similarly, a positive productivity shock would lead to an increase in nominal and real wages in the absence of any adjustment costs. However, under our setup, this increase in wages is expensive for contract workers but cheaper for regular workers. This leads to a rapid increase in regular wages but a more muted response in contract wages. This reduces the incentive for the firms to hire regular labour and encourages them to hire more contract labour.

This mechanism leads to a sharp decline and a moderate increase, thus resulting in a negatively skewed regular labour. Analogously, it also leads to a rapid increase and a muted decline that result in a positively skewed contract employment over the cycle. These dynamics help the benchmark model to be successful in generating the contrasting asymmetries in both regular and contract labour.

6. Ramsey Policy

Using our benchmark model, we study the optimal monetary policy and the effect of contract labour on the optimal level of grease inflation. A benevolent policymaker follows the Ramsey policy to maximize the representative household's welfare, subject to the equilibrium conditions of the economy. Under Ramsey policy, the policymaker maximizes the household's lifetime utility

$$\mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{c_t(i)^{1-\sigma}}{1-\sigma} - \frac{n_t^r(i)^{1+\rho}}{1+\rho} - \frac{n_t^c(i)^{1+\rho}}{1+\rho} \right], \tag{27}$$

Table 9
Optimal Inflation under Ramsey Policy

Model	Optimal Inflation
Symmetric (Benchmark)	0.99999
One-Sector	1.00066
Asymmetric	1.00002

Note: Symmetric is the two-sector model with symmetric wage adjustment costs. *One-Sector* is an asymmetric model with just regular workers while *Asymmetric* has both regular and contract workers.

subject to the first-order conditions (6), (7), (11)-(14), (24) and (26).

Along the lines of Kim and Ruge-Murcia (2009), we calculate the optimal rate of inflation as the inflation that prevails at the stochastic steady state under Ramsey policy. In the absence of uncertainty, the optimal rate of gross inflation is 1. In other words, absent stochastic shocks, optimal response under Ramsey policy is to keep wages and prices completely stable. This is intuitive, as the policymaker would prefer to avoid incurring any adjustment costs in the absence of any shocks to the economy.

We next compute the optimal level of grease inflation in the economy. Following Kim and Ruge-Murcia (2009), the optimal grease inflation is computed as the additional inflation obtained under asymmetric wage adjustment costs compared to symmetric wage adjustment costs. In order to obtain the grease inflation, we compute optimal inflation under three different scenarios: (1) economy with symmetric adjustment costs for both regular and contract workers, (2) economy with just regular workers facing asymmetric costs and (3) economy with both regular and contract workers facing asymmetric costs. We report the optimal inflation under different cases in table 9.

When both regular and contract workers face symmetric adjustment costs, the average gross inflation is 0.99999. This is very similar to the estimate obtained by Kim and Ruge-Murcia (2009), even though their paper does not feature dual labour markets like ours. Considering the scenario with just regular workers facing asymmetric adjustment costs, the optimal inflation is 1.00066. This is consistent with Tobin (1972), as the policymaker chooses the optimal inflation to be strictly above 1, in order to avoid suffering the costly downward adjustment of the nominal wages.

Introducing contract workers in the previous setup with both regular and contract workers facing asymmetric costs, regular workers find it costly to reduce their wages while contract workers find it costly to increase their wages. Intuitively, the optimal level of inflation in this case should be lower than the one obtained under the previous case. This is because, while the policymaker would prefer to avoid the adjustment costs incurred by regular workers in lowering their wages, this must be balanced with the costs faced by the contract workers while raising their wages. Under our calibration, we do indeed find that the optimal inflation rate for this scenario is 1.00002, which is less than the case with just regular workers. Hence, in a model with contract labour, the policymaker lowers their choice of optimal inflation.

We calculate the level of grease inflation as the difference between the optimal inflation under economies with symmetric and asymmetric adjustment costs. For the case with just regular workers, the optimal inflation rate is 1.00066, and hence, the optimal grease inflation is 0.067%. Under the scenario with both regular and contract workers facing costly wage adjustments in opposite directions, the optimal grease inflation is 0.003%, which is an order of magnitude smaller than the previous case. Therefore, the presence of contract labour eases the restriction imposed by the downward nominal wage rigidity, and hence lowers the inflation needed to grease the wheels of the economy.

7. Conclusion

We analyse the impact of contract labour on business cycle dynamics and the choice of optimal inflation in India. We first document that regular and contract labour markets have contrasting asymmetries over the cycle. Regular employment is negatively skewed while the contract employment is positively skewed. Also, regular wages are positively skewed while the contract wages are negatively skewed. We show that a standard New Keynesian model augmented with asymmetric wage adjustment costs for both regular and contract workers and a symmetric labour adjustment cost for regular workers does a good job in accounting for the business cycle dynamics of both regular and contract labour markets. We observe that the presence of contract labour reduces the asymmetries in the business cycle. We also derive the optimal grease inflation under this setup using Ramsey optimization. We find that an introduction of contract labour relaxes the constraint of downward nominal wage rigidity and hence reduces the level of grease inflation required in the economy.

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Appendices

A. Annual Survey of Industries

Annual Survey of Industries (ASI) is conducted by National Sample Survey Office (NSSO). In India, ASI is the main source of industrial statistics. ASI covers all the states of India. Its scope encompasses all the factories registered under Sections 2m(i) and 2m(ii) of the Factories Act, 1948, i.e. factories employing 10 or more workers and using power; and those employing 20 or more workers without using power. The sample design of ASI divides the factories into two sets: census sector and sample sector. The sampling design adopted in ASI has undergone considerable changes from time to time. Census sector is defined as units having 100 or more employees(200 or more between 1996-97 to 2002-03), whereas sample sector is selected from (1/5)th of smaller establishments ((1/3)rd until 2003-04). For a detailed discussion on ASI sampling and its limitations, refer to Nagaraj (2002).

A.1 Determination of Base Sample

In Table A1, we provide details of the data cleaning procedure for obtaining the sample used for the study. The original ASI dataset spanning from 1998-99 to 2015-16 has 933,342 plant-year observations. This dataset may contain firms that are closed or did not respond to the survey. We drop 205,684 plants reported as closed or non-responsive. An additional 116 observations are dropped which have missing state codes. 42,889 observations are dropped for reporting non-manufacturing NIC codes. Additionally, a small number of observations which are exact duplicates in all fields are also dropped, assuming these are erroneous multiple entries made from the same questionnaire form. The final sample includes 684,653 plant-year observations.

A.2 Variables

The variables of our interest are nominal wage per manday of the workers, mandays of both regular and contract workers and the output. Man-days in ASI database is defined as sum total of the number of workers attending in each shift over all shifts

Table A1
Sample Size

Step	Dropped observation	Resulting sample size
Original dataset		933342
Factory closed	205684	727658
Missing state codes	116	727542
Non-manufacturing ASI codes	42889	684653
Total observations (# of firms)		684653

worked on all working days during the year. ASI provides firm-level details of the above variables. We use the multipliers in order to arrive at the aggregate yearly figure for the above. Following Allcott et al. (2016), we use revenues as a measure of the output. The variable in the ASI schedule used for measuring the revenues is ”gross sales value”. Inflation (price growth) mentioned in the empirical section is computed using Consumer Price Index for industrial workers.

B. Additional Empirical Evidence

For robustness of our empirical results, we calculate the moments by only considering firms which are present for at least 5 years. We use this definition because in Annual Survey of Industries, the classification of the units in census and sample sector frames is done in a 5-year cycle and is not changed during the period. We again use the data cleaning methodology described in the previous section to arrive at the yearly aggregate values of the variables. Column 2 of Table B1 and Table B2 provide the standard deviation and skewness, respectively, for consistent firm panel. We find that for regular workers, the employment growth remains negatively skewed while nominal wage growth is positively skewed. The signs of skewness of employment and nominal wage growth for contract workers are also similar to original dataset. The magnitudes vary as the samples considered are significantly different in column 1 and column 2. However, with similar signs and directions, we can be assured of consistency of our results.

Table B1
Standard Deviation: Original Data and Consistent Panel Data

	Original Data	Consistent Firm Panel
Regular Labour		
Employment	0.043	0.049
Nominal wage	0.035	0.057
Contract Labour		
Employment	0.065	0.085
Nominal wage	0.049	0.075

Note: Standard deviations of annual growth rates obtained from Annual Survey of Industries 1998-99 to 2015-16. *Original data* has all the firms that are a part of sample defined in table A1 while *consistent firm panel* contains only those firms that are present for at least 5 years.

Table B2
Skewness: Original Data and Consistent Panel Data

	Original Data	Consistent firm Panel
Regular Labour		
Employment	-0.434	-0.179
Nominal wage	0.430	0.056
Contract Labour		
Employment	0.546	1.220
Nominal wage	-0.610	-1.140

Note: Skewness of annual growth rates obtained from Annual Survey of Industries 1998-99 to 2015-16. *Original data* has all the firms that are a part of sample defined in table A1 while *consistent firm panel* contains only those firms that are present for at least 5 years.

C. Calibration

Table C1
Calibration: Symmetric Model

Parameter			Performance		
Description		Value	Target to Match	Data	Model
Regular Labour					
Wage rigidity	ϕ_w^r	0.80	Std. dev. of nominal wage growth	0.035	0.032
Labour adjustment	κ^r	0.92	Std. dev. of employment growth	0.043	0.039
Contract Labour					
Wage rigidity	ϕ_w^c	4.90	Std. dev. of nominal wage growth	0.048	0.045

Table C2
Calibration: No LAC Model

Parameter			Performance		
Description		Value	Target to Match	Data	Model
Regular Labour					
Wage rigidity	ϕ_w^r	4770	Std. dev. of nominal wage growth	0.035	0.036
Wage asymmetry	ψ^r	18600	Skewness of nominal wage growth	0.430	0.445
Contract Labour					
Wage rigidity	ϕ_w^c	4100	Std. dev. of nominal wage growth	0.048	0.045
Wage asymmetry	ψ^c	-18000	Skewness of nominal wage growth	-0.610	-0.642

Table C3
Calibration: One-Sector Model

Parameter			Performance		
Description		Value	Target to Match	Data	Model
Regular Labour					
Wage rigidity	ϕ_w^r	3400	Std. Dev. of nominal wage growth	0.035	0.033
Wage asymmetry	ψ^r	12000	Skewness of nominal wage growth	0.430	0.463

D. Segmented Labour Market Model

D.1 First Order Conditions

We consider all firms and households to be identical, hence we drop i and z from the notations. The simplified first order conditions are

1.

$$\left[(1-\epsilon_p)(1-\Gamma_t)y_t - {\Gamma_t}'\pi_t y_t + y_t\epsilon_p mc_t\right] + E_t\left[\beta\frac{c_{t+1}^{-\sigma}}{c_t^{-\sigma}}{\Gamma_{t+1}}'y_{t+1}\pi_{t+1}\right] = 0 \tag{28}$$

2.

$$i_t = \frac{1}{\beta}E_t\left[\pi_{t+1}\frac{c_t^{-\sigma}}{c_{t+1}^{-\sigma}}\right] \tag{29}$$

3.

$$\frac{(n_t^r)^{1+\rho}}{w_t^r}\varepsilon_w + E_t\beta c_{t+1}^{-\sigma}\left[(\Omega_{t+1}^r)^2 n_{t+1}^r (\Phi_{t+1}^r)'\right] + (1-\varepsilon_w)c_t^{-\sigma}(1-\Phi_t^r)n_t^r - \Omega_t^r(\Phi_t^r)' c_t^{-\sigma} n_t^r = 0 \tag{30}$$

4.

$$\frac{(n_t^c)^{1+\rho}}{w_t^c}\varepsilon_w + E_t\beta c_{t+1}^{-\sigma}\left[(\Omega_{t+1}^c)^2 n_{t+1}^c(\Phi_{t+1}^c)'\right] + \\ (1-\varepsilon_w)c_t^{-\sigma}(1-\Phi_t^c)n_t^c - \Omega_t^c(\Phi_t^c)'c_t^{-\sigma}n_t^c = 0 \tag{31}$$

5.

$$c_t = w_t^r s n_t^r(1-\Phi_t^r) + w_t^c(1-s)n_t^c(1-\Phi_t^c) + (1-\Gamma_t)y_t - w_t h_t \tag{32}$$

6.

$$y_t = a_t h_t^{1-\alpha} \tag{33}$$

7.

$$a_t = \rho_a a_{t-1} + \epsilon_t^a \tag{34}$$

8.

$$\tilde{w}_t^r = w_t^r + \kappa^r(n_t^r - n_{t-1}^r) \tag{35}$$

9.

$$s n_t^r = \gamma h_t\left[\frac{w_t}{\tilde{w}_t^r}\right]^\delta \tag{36}$$

10.

$$(1-s)n_t^c = (1-\gamma)h_t\left[\frac{w_t}{w_t^c}\right]^\delta \tag{37}$$

11.

$$w_t = [\gamma(\tilde{w_t^r})^{1-\delta} + (1-\gamma)(w_t^c)^{1-\delta}] \tag{38}$$

12.

$$\frac{\Omega_t^r}{\pi_t} = \frac{w_t^r}{w_{t-1}^r} \tag{39}$$

13.

$$\frac{\Omega_t^c}{\pi_t} = \frac{w_t^c}{w_{t-1}^c} \tag{40}$$

D.2 Steady State

After the model has been specified, the next step involves solving for the steady state of the variables. As mentioned in Table D1, for variables a_t, Ω^r_t, Ω^c_t and π_t, we fix the steady state values.

Also, at steady state, Γ_t, Γ'_t, Φ^r_t, Φ^c_t, $\Phi^{r\prime}_t$, and $\Phi^{c\prime}_t$ are equal to zero. Using the FOCs mentioned in the previous section, we arrive at the following steady state equations.

Equation 28 gives

$$[(1-\epsilon_p)y + y\epsilon_p mc = 0 \tag{41}$$

$$mc = \frac{w}{(1-\alpha)(h)^{-\alpha}}$$

Equation 29 gives

$$i = \frac{1}{\beta} \tag{42}$$

Equation 30 gives

$$\frac{(n^r)^{1+\rho}}{w^r}\epsilon_w + (1-\epsilon_w)c^{-\sigma}n^r_t = 0 \tag{43}$$

Equation 31 gives

$$\frac{(n^c)^{1+\rho}}{w^c}\epsilon_w + (1-\epsilon_w)c^{-\sigma}n^c_t = 0 \tag{44}$$

Equation 32 gives

$$c = w^r s n^r + w^c(1-s)n^c + (h)^{(1-\alpha)} - wh \tag{45}$$

Equation 33 gives

$$y = h^{(1-\alpha)} \tag{46}$$

Table D1
Steady State Values

Variable	Steady State Value
a	1
π	1
Ω^r	1
Ω^c	1

Equation 35 gives

$$\tilde{w^r} = w^r \tag{47}$$

Equation 36 gives

$$sn^r = \gamma \left[\frac{w}{\tilde{w^r}}\right]^{\delta} h \tag{48}$$

Equation 37 gives

$$(1-s)n^c = (1-\gamma)\left[\frac{w}{w^c}\right]^{\delta} h \tag{49}$$

Equation 38 gives

$$w = [\gamma(\tilde{w^r})^{1-\delta} + (1-\gamma)(w^c)^{1-\delta}]^{\frac{1}{1-\delta}} \tag{50}$$

The above equations are solved to obtain the steady state. We obtain steady state values for n_t^r, n_t^c, w_t^r, $\tilde{w_t^r}$, w_t^c, w_t, π_t, c_t, y_t, i_t and h_t.

E. Model with only Regular Labour

E.1 First Order conditions

In case of model with only regular labour, the first order conditions are

1.
$$\left[(1-\epsilon_p)(1-\Gamma_t)y_t - {\Gamma_t}'\pi_t y_t + y_t\epsilon_p mc_t\right] + E_t\left[\beta\frac{c_{t+1}^{-\sigma}}{c_t^{-\sigma}}{\Gamma_{t+1}}' y_{t+1}\pi_{t+1}\right] = 0 \tag{51}$$

2.
$$i_t = \frac{1}{\beta}E_t\left[\pi_{t+1}\frac{c_t^{-\sigma}}{c_{t+1}^{-\sigma}}\right] \tag{52}$$

3.
$$\begin{aligned}\frac{(n_t^r)^{1+\rho}}{w_t^r}\varepsilon_w + E_t\beta c_{t+1}^{-\sigma}\left[(\Omega_{t+1}^r)^2 n_{t+1}^r(\Phi_{t+1}^r)'\right] + \\ (1-\varepsilon_w)c_t^{-\sigma}(1-\Phi_t^r)n_t^r - \Omega_t^r(\Phi_t^r)' c_t^{-\sigma} n_t^r = 0\end{aligned} \tag{53}$$

Table E1
Steady State Values

Variable	Steady State Value
a	1
π	1
Ω^r	1

4.

$$c_t = (1 - \Gamma_t)y_t - \Phi^r_t w^r_t n^r_t \tag{54}$$

5.

$$y_t = a_t (n^r_t)^{(1-\alpha)} \tag{55}$$

6.

$$a_t = \rho_a a_{t-1} + \epsilon^a_t \tag{56}$$

7.

$$\frac{\Omega^r_t}{\pi_t} = \frac{w^r_t}{w^r_{t-1}} \tag{57}$$

E.2 Steady State

For the variables, a_t, Ω^r_t and π_t, we fix the steady state values, as specified in Table E1. Also, at steady state, Γ_t, Γ'_t, Φ^r_t, and $\Phi^{r\prime}_t$ are equal to zero. Using the FOCs mentioned in the previous section, we arrive at the following steady state equations.
Equation 51 gives

$$(1 - \epsilon_p)y + y\epsilon_p mc = 0 \tag{58}$$

$$mc = \frac{w^r}{(1-\alpha)(n^r)^{-\alpha}}$$

Equation 52 gives

$$i = \frac{1}{\beta} \tag{59}$$

Equation 53 gives

$$\frac{(n_t^r)^{1+\rho}}{w^r}\epsilon_w + (1-\epsilon_w)c^{-\sigma}n_t^r = 0 \tag{60}$$

Equation 54 gives

$$c = y \tag{61}$$

Equation 55 gives

$$y = (n^r)^{(1-\alpha)} \tag{62}$$

The above four equations are solved to obtain the steady state. We obtain steady state values for n_t^r, w_t^r, c_t, y_t, i_t.