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Satadru Das
Reserve Bank of India

Chetan Ghate
Indian Statistical Institute–Delhi Centre
Centre for Applied Macroeconomic Analysis, ANU

Subhadeep Halder
Indian Statistical Institute–Delhi Centre
New York University Abu Dhabi

Debojyoti Mazumder
Reserve Bank of India

Sreerupa Sengupta
Reserve Bank of India

Satyarth Singh
Reserve Bank of India

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Keywords

business cycles, informal labor markets, monetary policy, inflation targeting, NK-DSGE models

JEL Classification

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Address for correspondence:

(E) cama.admin@anu.edu.au

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Satadru Das † — RBI

Chetan Ghate ‡ — ISI-Delhi & CAMA

Subhadeep Halder § — ISI- Delhi & NYUAD

Debojyoti Mazumder ¶ — RBI

Sreerupa Sengupta || — RBI

Satyarth Singh ** — RBI

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†Reserve Bank of India. E-mail: satadrudas@rbi.org.in

‡Economics and Planning Unit, Indian Statistical Institute–Delhi Centre. Centre for Applied Macroeconomic Analysis (CAMA), Australian National University (ANU), Australia. E-mail: cghate@isid.ac.in

§Indian Statistical Institute–Delhi Centre and New York University Abu Dhabi. E-mail: sh7991@nyu.edu

¶Reserve Bank of India. E-mail: debojyotim@rbi.org.in

||Reserve Bank of India. E-mail: ssengupta1@rbi.org.in

**Reserve Bank of India. E-mail: satyarthsingh@rbi.org.in

1 Introduction

A large literature on emerging market and developing economies (EMDEs) using Dynamic Stochastic General Equilibrium (DSGE) models highlights the importance of informal labor markets in shaping business cycles. This paper asks: how does the *composition* of employment between formal and informal labor impact inflation stabilization and monetary policy transmission under inflation targeting. To address this question, we build a NK-DSGE model with formal and informal labor markets that are segmented. While our model is calibrated to India, the NK-DSGE setup is general enough to study monetary policy transmission in countries with large informal labor markets.

To highlight the quantitative importance of informal employment, Figure 1, which uses the recently available and updated India-KLEMS dataset, depicts formal and informal employment trends in the Indian economy between 1980-81 and 2019-20. Informal employment consists of self-employed and casual workers, whereas formal employment consists of regular workers.[1] Figure 1 shows that self-employment dominates the total employment structure. However, over time, its share has declined very slowly from 58% in 1980-1981 to 53% in 2019-20.[2] Casual workers constituted about 29% of employment in 1980-1981, which decreased to 23% during 2019-20. The share of informal employment (self-employment and casual) has declined very slowly over the years, and constitutes the bulk of employment even today. Formal employment has increased from 13 per cent in 1980-81 to 24 per cent in 2019-20. This is primarily driven by the formalisation of workers in the manufacturing sector, where the share of regular employment has increased from 27 % in 1980-81 to 50 % in 2019-20.

Figure 2 presents a growth accounting decomposition, where real gross value added (GVA) growth is decomposed between contributions from factor accumulation (labor and capital) and total factor productivity (TFP) growth. The long-term drivers of GVA growth show that during 1980-81 and 2019-20, the capital input is the dominant factor

[1] Based on the PLFS 2022-23, 93.9 per cent of the workers in the formal sector were regular, 6.3 per cent were casual, and 0.01 per cent were self-employed. In each previous year between 2017-2018 and 2021-22, more than 90 per cent of the workers each year are regular-salaried. In the informal sector, in 2022-2023, only 10.4 per cent of the workers were regular, 24 per cent were casual, and 64.7 per cent were self-employed. Hence, the formal sector is characterised predominantly by regular workers, while the informal sector is characterised predominantly by casual and self-employment. While a large proportion of regular employment is without contracts (58.2 per cent in PLFS 2022-2023 based on Usual Principal Subsidiary Status (UPSS)), it is hard to ascertain whether these are high-salaried or low-salaried workers. By regular employment, we therefore include all workers with and without wage contracts (as classified by UPSS). One way to interpret regular workers without contracts is outsourced labor attached to the formal enterprise.

[2] In India, a majority of self-employed are engaged in agriculture, with an average share of 67 per cent.

(64.9% average). The labor input plays a significant role and, on average, accounts for 31.5% of GVA growth. The remaining 3.6% of GVA growth is explained by growth in total factor productivity.[3]

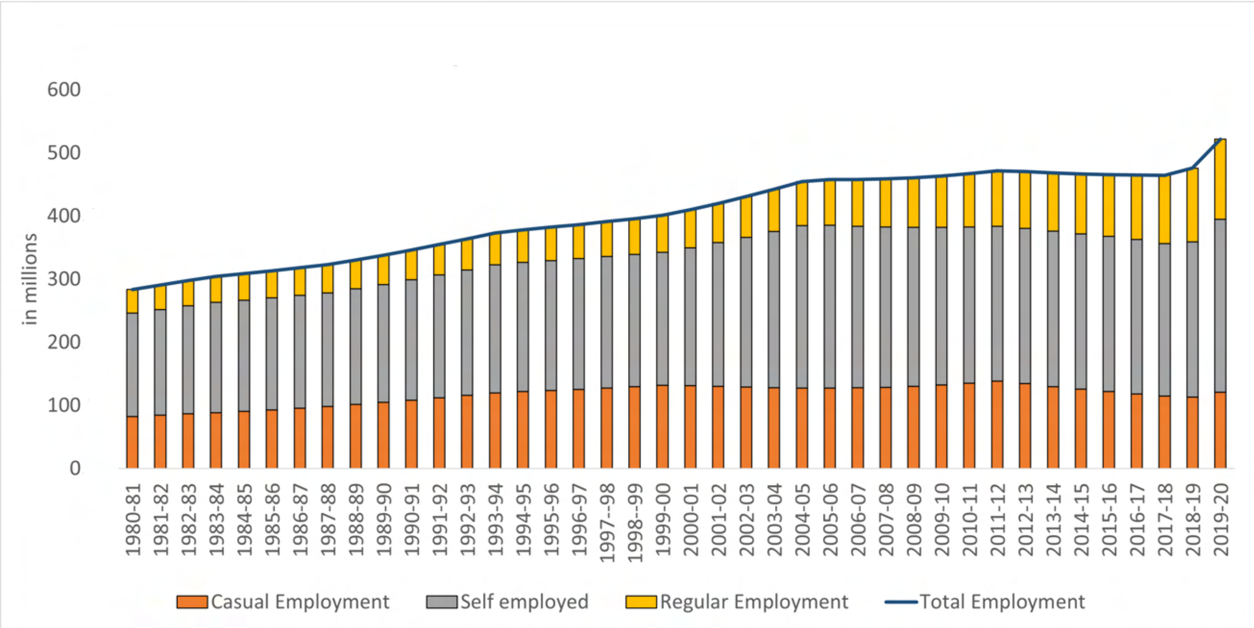


Figure 1: Composition of Total Employment
Sources: India KLEMS, NSS, PLFS dataset; and Authors' calculations.

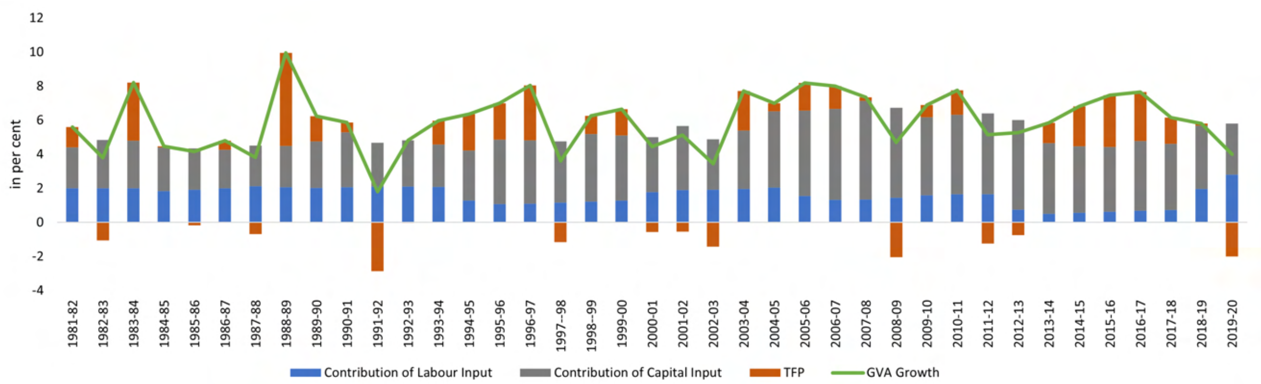


Figure 2: Drivers of GVA growth - 1980-81 to 2019-20
Sources: India KLEMS, NSS, PLFS dataset; and Authors' calculations.

Both figures suggest that within the context of a DSGE setup, ignoring labor mar-

[3]Under the assumption of constant returns to scale (CRS) and competitive factor markets, GVA growth can be decomposed into contributions from factor accumulation and total factor productivity growth. The GVA growth accounting decomposition is represented by:

$$\Delta lnY_t = \bar{\nu}_{K_t}\Delta lnK_t + \bar{\nu}_{L,j}\Delta lnL_t + \nu_t$$

where ΔlnY_t is the growth in real GVA for the total economy. ΔlnK_t and ΔlnL_t are growth in factor inputs - capital (K) and labor (L), respectively. The parameter, $\bar{\nu}$, is the two-period average compensation shares in gross value added. ν_t is the TFP growth rate.

kets generally, and informal labor markets specifically, limits the scope of analysis when studying monetary policy questions.

One limitation of the India KLEMS dataset is that it is available only at an *annual* frequency. It is well recognized that a study of monetary policy requires higher frequency data. To study the impact of monetary policy shocks at a higher frequency (monthly), we assemble a high-frequency *monthly* data using various macroeconomic and financial indicators. The measure of the monetary shock is calculated using a methodology similar to Coibion et al. (2019). These authors use the movement of federal funds futures immediately after the announcement of monetary policy to calculate the unanticipated component of monetary policy. This strategy helps us in filtering out the components of monetary policy that are in response to prevailing macroeconomic conditions and, therefore, already priced into future contracts. The informal employment data comes from the Consumer Pyramids Household Survey (CPHS) dataset compiled by CMIE, which provides monthly data on salaried workers, daily wage labour and self-employment.[4] CPHS reports employing workers in four categories: business, salaried employees, small traders, daily wage laborers, and farmers. While wage employment is classified as casual, self-employment is a sum of different types of business enterprise owners in the informal sector. We sum the daily wage labourers, small traders, and business owners to get total "self and casual employment" which will be a proxy for the informal sector employment while salaried workers are considered as formal employment. However, the CPHS dataset is only available from 2016 onward. This leads to a limited number of observations for the period we are analyzing and makes any robust inferences tricky. In Section 2.2, we use monthly CPHS data to measure total employment in the informal sector and use it along with other macro variables available at a monthly frequency (with longer duration) to measure the impact of monetary policy shocks in a local projections (LP) framework[5]

The impulse response functions (IRFs) from the LP model show that a one standard deviation contractionary shock in monetary policy leads to a delayed but significant impact on the high-frequency indicator of GDP, with a positive impact in the first 18 months and a subsequent negative impact in the following 22 months. The impact on

[4]CMIE stands for Center for Monitoring the Indian Economy. The CPHS, conducted by CMIE, is conducted in three waves every year, with a single wave done every four months. The survey households are given a recall period of four months, which helps to derive the monthly estimates.

[5]The LP framework has increasingly been used to measure the effects of fiscal policy shocks (Auerbach and Gorodnichenko, 2013; Jordà and Taylor, 2016; Ramey and Zubairy, 2018) and monetary policy shocks (Coibion et al., 2019) on macroeconomic variables, as the empirical strategy is free from misspecification issues found in VARs (Jordà, 2005).

total informal employment starts with a lag of about 8 months and remains negative up to 30 months, although not always statistically significant. The formal sector labor market tightness index, constructed by the authors, also sees a broadly negative but mostly statistically insignificant impact. The policy shock has a significant and negative impact on non-food and non-fuel consumer price inflation (Core CPI), which starts with a lag of about 8 months and remains negative up to 40 months. The peak impact of one standard-deviation monetary policy shock on CPI is estimated to be about 40 bps.

Given Figure 1 and Figure 2, and the IRF analysis from the CPHS dataset, we build a medium-scale NK-DSGE model with dual labor markets and search and matching frictions. Our main research question is how does the *composition* of employment between formal and informal labor in a large EMDE (like India) impacts inflation stabilization and monetary policy transmission under inflation targeting. To address this, we assume that the labor market is segmented between formal and informal laborers in line with the literature describing the labor market of emerging economies (Gutierrez et al., 2019; Sugiharti et al., 2022). The formal sector has both public and private sector jobs, which are subject to search and matching frictions. In the informal sector, as in the data, there are self-employment and casual employment jobs. We assume that only casual jobs in the informal sector are subject to search and matching frictions. Like Michaillat (2014), households derive utility over consuming a final private good and a public good. The final private good is produced by two types of intermediate goods firms: formal intermediate good firms and informal intermediate good firms. The public good is produced only by formal labor.

Both formal firms and the government look for workers by posting vacancies, and only a fraction of the vacancies are matched. Firms in the informal sector looking for casual workers also post vacancies. Unemployed workers search for jobs. Wages are determined by Nash wage bargaining, where casual labor has less bargaining power. Labor market segmentation means that households either supply hours in the formal sector or the informal sector. Monetary policy follows a Taylor Rule. To the best of our knowledge, this is the first rigorous analysis using annual employment data (constructed using information from NSS, PLFS, and India KLEMS datasets) to identify a set of stylised facts of India's labor market indicators, which can assist in the calibration exercise. We also augment our empirical analysis with high-frequency monthly data from the CPHS dataset to generate IRFs using local projections that quantify the impact of monetary policy shocks on inflation, the unemployment rate, and output.

Our model framework, calibrated to India, allows us to examine how monetary policy surprises impact different types of labor (formal, informal), and what the differential impact is, as in the IRFs. Like Alberola and Urrutia (2020), we are interested in the implications of informality for inflation stabilization and monetary policy under inflation-targeting regimes. We find that a contractionary monetary policy shock leads to a decline in aggregate consumption, a decline in inflation, a decline in investment, a decline in output, a decline in the capital stock, and a decline in private formal employment. Unemployment rises in both formal and informal labor markets. There is a decline in casual and self-employment, which implies that total informal employment falls. When we exogenously raise the proportion of formal firms contributing to final good production (3 per cent relative to baseline), we find that a contractionary monetary policy shock leads to a small additional reduction in inflation relative to baseline on impact, suggesting that monetary policy is *more* effective when there is more formality in the economy. When we conduct a counterfactual analysis using a higher increase in the formal good elasticity with respect to output, we get a reduction in the impact effect of monetary policy relative to the baseline.

We also use the annual India KLEMS, NSS, PLFS dataset to identify key labor market stylised facts that characterise the business cycle in India, a large emerging market economy, over a 40-year period. In recent years, the India KLEMS dataset has become publicly available and provides an annual time series of persons employed. The KLEMS database with additional information from the National Sample Survey (NSS) and Periodic labor Force Survey (PLFS) datasets allows us to calculate the composition of total employment between regular workers (formal), and casual and self-employed workers (informal), and therefore make our research possible.[6] One of the novel aspects of our paper is that we use the KLEMS data to calibrate several structural parameters, which allows us to understand the mechanism behind the impact of monetary policy shocks on heterogeneous labor market outcomes.

We find regular (formal) employment to be pro-cyclical. Casual employment (informal), in contrast, is counter-cyclical.[7] Self-employment, which constitutes the bulk of informal employment, has an insignificant correlation with output. This suggests that

[6]As detailed in Appendix A, the KLEMS dataset uses various rounds of the National Sample Survey (NSS) and the EUS (Employment-Unemployment Survey) to calculate regular, casual, and self-employment annually between 1980-81 and 2011-12. KLEMS uses the PLFS dataset, started in 2017-18, to provide regular, casual, and self-employment series from 2017-18 onwards. The values between 2011-2012 and 2017-18 are interpolated.

[7]However, when we add construction sector GVA to modern sector GVA, we find that casual employment becomes strongly pro-cyclical. This happens because the share of the construction sector in total casual employment increased from 5 per cent in 1980 to 39 per cent in 2019, and construction employment is strongly pro-cyclical.

upturns in the Indian business cycle have historically been associated with an increase in regular (formal) employment and a decline in casual (informal) employment. These results also hold when we confine output to "modern sector" output by combining manufacturing and service sector GVA to get modern sector GVA.[8]

1.1 Literature Review

DSGE models are increasingly being used to study business cycles in emerging market economies and the Indian economy (Gabriel et al., 2012, 2016; Ghate et al., 2018; Banerjee and Basu, 2019; Banerjee et al., 2020; Kumar, 2023). However, these models are constructed without reference to labor markets due to the lack of a comprehensive data set on formal and informal labor market indicators.[9] We build on this literature by building a medium-scale NK-DSGE model with search and matching frictions across employment types (regular, self, and casual) as in the data. We calibrate the model and provide model validation by matching key moments from the India-KLEMS data. This allows us to trace the impact of monetary policy surprises on job vacancy rates, unemployment rates, and employment levels of different types of labor in both the formal and informal labor markets.

Our model incorporates features of both Michaillat (2014) and Alberola and Urrutia (2020). Like Alberola and Urrutia (2020), we assume that labor markets are dualistic with search and matching frictions. However, we assume three different types of labor (regular, casual, and self-employed), which Alberola and Urrutia (2020) do not. Like these authors, we are interested in the implications of the presence of each of these types of labor for inflation stabilization. Michaillat (2014) builds a NK-DSGE model to estimate the public employment multiplier in the US. He shows that the public employment multiplier doubles when the unemployment rate increases from 5% to 8% in the US. While our model borrows some features from Michaillat (2014), the focus of our study is different. We add informal labor markets to the basic model in Michaillat (2014). However, we are interested in monetary transmission when labor markets are dualistic, and how different labor types in a multi-sector production framework affect

[8] The share of casual workers in agriculture is around 37 per cent, self-employed workers around 61 per cent, and regular workers is 2 per cent. We proxy for output using GVA data, since KLEMS reports sectoral GVA data for twenty-seven sectors in the economy from 1980-81 to 2019-20. In Appendix C we show that these stylised facts are consistent when output (real gross domestic product) is measured from the demand side as well.

[9] Gabriel et al. (2012) and Banerjee et al. (2020) treat consumers as informal workers as a rule of thumb. The lack of labor market indicators means that the output gap is usually used as a measure of slack.

inflation stabilization.

Following the HANK literature, our paper contributes to a growing body of research exploring how monetary policy transmission is mediated through labor markets (Kaplan et al., 2018; Auclert et al., 2020; Morrison, 2025). Unlike these papers, however, our papers focuses on labor markets in EMDEs where a large component is informal and there are heterogenous labor types. More generally, our paper contributes to a growing literature on monetary transmission in EMDEs.[10]We contribute to this literature by identifying the mechanism behind the transmission of monetary policy through heterogeneous labor markets. The novel feature of our analysis is that we study how monetary transmission affects both self-employment and casual employment, the predominant forms of informal labor, which have large shares in total employment in many EMDEs.

2 Some Stylised Facts on Indian Labor Markets

In this Section, we produce some stylized facts governing Indian labor markets. Identifying these stylized facts has only recently become possible with the release of the India-KLEMS dataset.

2.1 GVA and Employment: KLEMS, NSS and PLFS Datasets

Real gross value added (GVA), our preferred proxy for GDP, and regular, casual and self-employment series for India for the period starting 1980-81 to 2019-20 are obtained from India KLEMS data with additional information from NSS and PLFS employment-unemployment survey rounds.[11] We choose real gross value added (GVA), real gross domestic product (RGDP), and regular, casual, and self-employment (in numbers of people). The cyclical components of GVA, RGDP, and the employment series are extracted using a full sample, asymmetric Christiano-Fitzgerald (CF) filter after removing a linear trend.[12] The cyclical components of the variables are then used for correlations, auto-correlations, standard deviations, relative standard deviations, and the covariance. The detailed data source of the variables and the transformations used

[10]See various chapters of Ghate and Kletzer (2016) for a discussion of monetary policy in India. See also Alberola and Urrutia (2020) and the references therein, and Alex (2025).

[11]Details on the dataset are provided in Appendix A.

[12]To extract a business cycle component from a time series model, y_t, two different approaches are used: frequency extraction and signal extraction. Under frequency extraction, one estimates the component of y_t that fluctuates cyclically at a frequency in a range that corresponds to a business cycle between, for example, 1-8 years per cycle. This is done most efficiently by operating in the frequency domain.

are provided in Appendix A. We generate stylised facts for employment and output cycles for three alternate specifications - (i) total GVA, (ii) modern sector GVA, and (iii) modern sector plus construction GVA. This allows us to study how formal and informal employment have varied across the Indian business cycle over the last 40 years, and how these relationships differ across broad sectors in the economy.

	σ_x	$\frac{\sigma_x}{\sigma_{GVA}}$	$\rho_{x,GVA}$	$Cov(x, GVA)$	$\rho_{x_{t,t-1}}$
Real GVA	0.13	1	1	0.02	0.71
Regular Employment	0.03	0.22	0.77	0.002	0.57
Casual Employment	0.02	0.13	-0.79	-0.002	0.57
Self Employment	0.01	0.09	-0.21*	-0.0003	-0.02*

* indicates insignificance

Table 1: Total GVA and Employment Cycles

Sources: India KLEMS, NSS, PLFS dataset, and Authors' calculations.

In Table 1, σ_x represents the standard deviation of a variable x; $\frac{\sigma_x}{\sigma_{GVA}}$ represents the relative volatility of variable x with respect to GVA; $\rho_{x,GVA}$ measures the correlation between the x and and GVA; $Cov(x, GVA)$ denotes the covariance between a variable and total GVA; and $\rho_{x_{t,t-1}}$ denotes the first-order auto-correlation. We see that regular employment is strongly correlated with total GVA (correlation = 0.77) in the Indian economy. The covariance of regular employment and total GVA is 0.02, suggesting that it is pro-cyclical. Casual labor, in contrast, is counter-cyclical, with a covariance of -0.002, suggesting that downturns in the Indian business cycle are associated with an increase in casual employment, and *vice-versa*, historically. We observe that all forms of employment are less volatile than total output. However, the relative volatility of regular employment is higher than the relative volatility of casual and self-employment. Self-employment shows a statistically non-significant a-cyclical relationship with output.

Figure 3 plots the cyclical component of regular employment (formal), casual employment (informal), and self-employment (informal) against total output (measured using GVA). Table 1 and Figure 3 show that during a business cycle upturn, an increase in output increases the demand for regular employment, whereas during an economic downturn, due to fewer employment opportunities and the relatively higher wages of

	σ_x	$\frac{\sigma_x}{\sigma_{GVA}}$	$\rho_{x,GVA}$	$Cov(x, GVA)$	$\rho_{x_{t,t-1}}$
Real GVA	0.49	1	1	0.25	0.79
Regular Employment	0.03	0.06	0.75	0.01	0.64
Casual Employment	0.03	0.06	-0.46	-0.01	0.57
Self Employment	0.01	0.02	0.14*	0.01	0.25*

* indicates insignificance

Sources: India KLEMS, NSS, PLFS dataset; and Authors' calculations.

Table 2: Modern Sector GVA and Employment Cycles.

formal workers, regular employment decreases. Casual employment and GVA cycles, on the other hand, are counter-cyclical. During a business cycle downturn, there is an increase in the employment of casual workers as firms switch demand from workers in regular employment to casual employment. During a business cycle upturn, due to increased demand, firms tend to hire more regular workers with higher skills, and hence the demand for casual workers decreases, and the demand for regular workers increases.

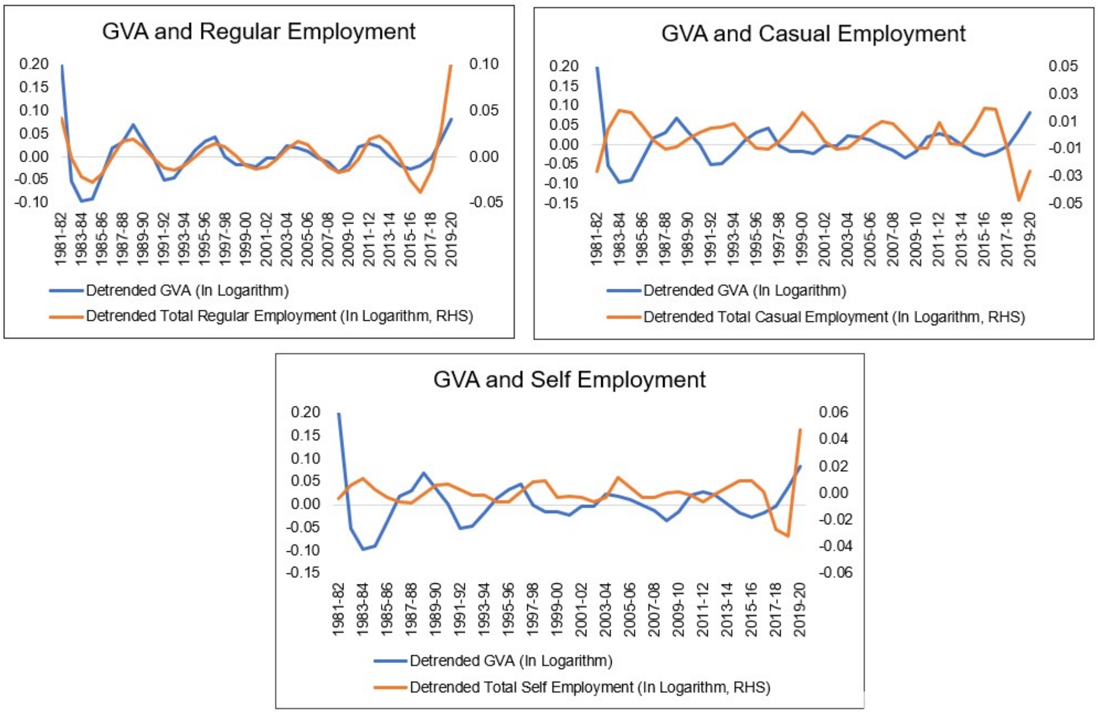


Figure 3: Total GVA and Employment Dynamics: 1980-2020
Sources: India KLEMS, NSS, PLFS dataset; and Authors' calculations.

When we redo the above exercise by adding manufacturing and service sectors to get "modern sector" GVA, the results strengthen. As can be seen from Table 2, the covariance between regular employment and GVA is positive (0.01). Formal employment is pro-cyclical when output is measured by modern sector GVA. In contrast, the covariance between casual employment and GVA is -0.01, or counter-cyclical. The correlation between self-employment and modern sector GVA is statistically insignificant, like before.[13] Modern sector GVA and employment cycles are shown in Figure 4.[14]

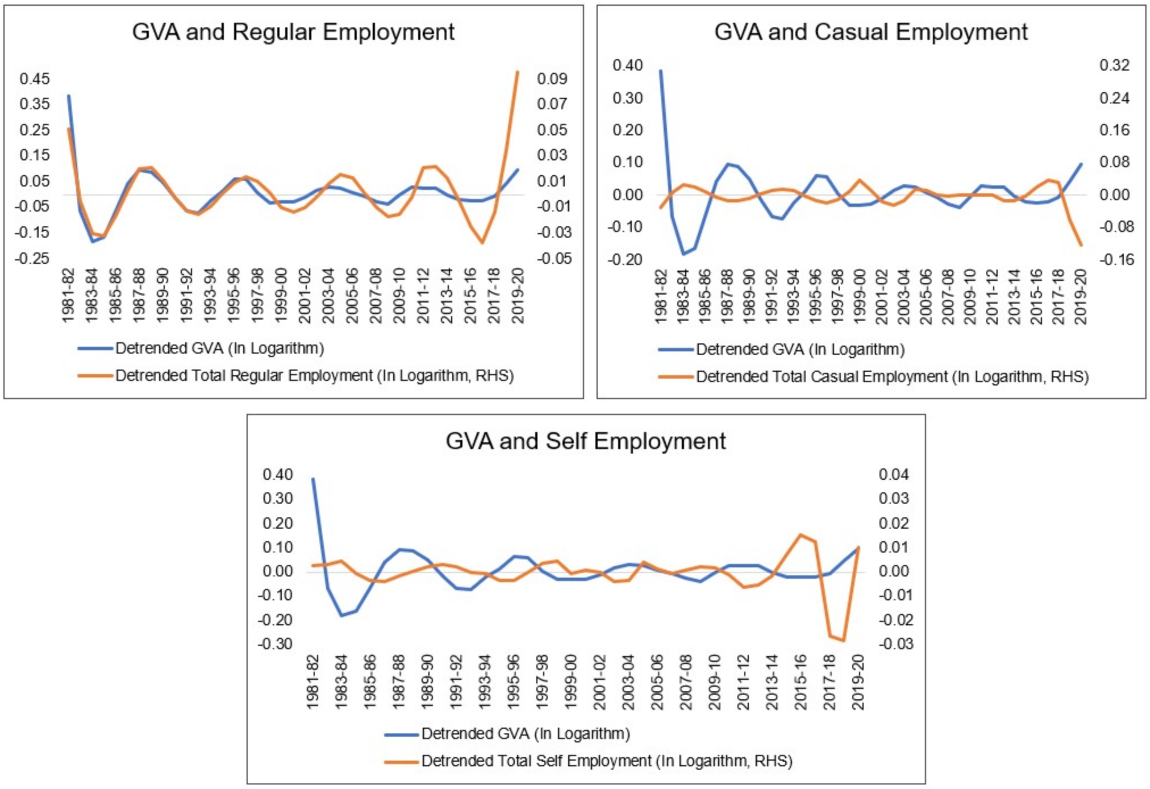


Figure 4: Modern Sector GVA and Employment Dynamics: 1980-2020
Sources: India KLEMS, NSS, PLFS dataset; and Authors' calculations.

Finally, to study employment over changing structural patterns of the economy, we examine the business cycle moments across three sub-periods: 1980-81 to 1999-00, 2000-01 to 2009-10, and 2010-11 to 2019-20. The results show that the volatility of real GVA and regular employment is 0.18 and 0.03, respectively, during 1980-81 to 1999-00, and this declines to 0.02 and 0.01, respectively, between 2000-01 to 2009-10, but further increases to 0.03 and 0.04, respectively, during 2010-11 to 2019-20. Employment relative to output has witnessed an increased volatility over the years.

[13]Self-employment in the modern sector averages 48 per cent between 1980-2019, and 43 per cent during 2017-2019.

[14]In Appendix B, we also study the relation between employment and the modern sector with the "construction" sector (using construction GVA) that represents a fuller presentation of modern sector output.

During 2010-11 to 2019-20, regular employment was 1.2 times more volatile than real GVA, even though across the entire sample, the relative volatility is much more muted.[15]

2.2 Impulse Responses using LLP

The primary focus of our paper is to study the impact of monetary policy transmission in an economy with heterogeneous labor markets. To supplement the stylized facts from Section 2.1 with IRF analysis, we assemble high-frequency *monthly* data on various macroeconomic and macro-financial indicators. These include overnight indexed swap (OIS) rates, short-term and long-term benchmark interest rates, consumer price inflation, a multi-variable monthly economic activity indicator, an indicator of formal sector labor market tightness, and informal sector employment from the CPHS dataset compiled by CMIE. The data for interest rates, OIS, economic activity, and labor market tightness are from the period January 2010 to November 2019. The inflation data for the combined consumer price index is available from January 2012, while the employment data is only available from January 2014.[16] Using this data, we use a local projections (LP) framework to identify the impact of a monetary policy shock on a variety of macroeconomic variables, including labor market indicators. Specifically, we estimate the following set of regressions.

$$\triangle X_{t+h,t-1} = \alpha_h + \beta_h * (ee_{t-1}) + \gamma * (\triangle X_{t-1,t-2}) + \epsilon_t \quad \text{where } h = 1, 2,., 40 \qquad (1)$$

In the model above, X is a macroeconomic or macro-financial outcome variable,

[15]The pro-cyclicality of regular employment with GVA is high and significant across all sub-periods. Casual employment is significantly counter-cyclical during 1980-81 to 1999-00 and from 2010-11 to 2019-20. For self-employment, we find a transition from significant counter-cyclicality during 1980-81 to 1999-00 to non-significant pro-cyclicality for the next two sub-periods.

[16]The indicator of labor market tightness is constructed using two indicators - the Naukri JobSpeak Index, and the formal sector composite purchasing manager's index (PMI) of employment. The Naukri JobSpeak Index is a measure of the number of vacancies advertised on the online employment platform Naukri.com. The index has been log-transformed and de-trended using a CF filter to obtain a cyclical component. The PMI employment measures the dynamics of hiring in formal sector firms. This variable, too, is log transformed and filtered in the same way. Finally, the formal sector tightness index is obtained as the first principal component of the two variables. The index is positively correlated with both JobSpeak Index and PMI employment, and therefore, an increase in the index implies tightening of labor market conditions and vice versa. The CPHS data on total employment is obtained at a monthly frequency from the CMIE website. CMIE reports estimates of total employment in non-farm casual and self-employed categories. This matches our definition of the informal sector. However, the CMIE employment data start from January 2016, which reduces the number of observations to 48. The CMIE also publishes a household-level dataset where they categorize each household as casual or self-employed based on the job status of the primary earner. This dataset is available at a monthly frequency from January 2014. The number of households in each category of employment is highly correlated with the number of individual workers in each category, with a coefficient of 0.9. We use this correlation to extrapolate individual-level employment data from 2014 to 2016. This increases the number of observations substantially and helps make the estimates more robust. The employment data is also log transformed and filtered using a Christiano-Fitzgerald filter to obtain cycles.

and ee_{t-1} is the measure of the monetary policy shock. The coefficients β_h are plotted against time to obtain the impulse response functions (IRF) along with their confidence interval bands. The outcome variables analysed in this model are short-term and long-term sovereign bond yields, inflation rate as measured by consumer price index - core (non-food, non-fuel), a high frequency nine indicator dynamic factor measure of economic activity which has been shown to track year-on-year, quarterly GDP growth rate well (Bhadury et al., 2021), total informal sector employment, and formal sector labor market tightness. The level series of the economic activity indicator is seasonally adjusted, log-transformed, and de-trended using an asymmetric Christiano Fitzgerald filter to obtain the cycles. The local linear projections are carried out on these cycles. The transformations on the other variables have been elaborated in the footnote.

The measure of the monetary shock is calculated using a methodology similar to Coibion et al. (2019). They use the movement of federal funds futures immediately after the announcement of monetary policy to calculate the unanticipated component of monetary policy. This strategy helps in filtering out the components of monetary policy that are in response to prevailing macroeconomic conditions and, therefore, already priced into future contracts. As a result, the movement in the yields of futures contracts immediately after the policy should represent innovations in the policy. However, in the case of India, there are no marketable futures contract on the policy rate. To bypass this issue, the one-day change in the yield of one-month overnight indexed swap (OIS) contracts on the day of the policy is used as the measure of monetary policy surprise or innovation. The one-day change in yields of OIS contracts in India has been found to capture monetary policy or other macroeconomic shocks adequately; it has also been found to be an effective predictor of market reaction to monetary policy shocks (Das et al., 2020). In the present study, the monthly average of the shocks is used as the main explanatory variable.[17]

The sample is restricted between January 2010 and November 2019 for the following reasons: first, the measure of the monetary policy shock, *i.e.*, OIS data, is not available for all days prior to 2010. Second, the RBI undertook several unconventional

[17] Lakdawala and Sengupta (2024) provides a novel method for the construction of shocks of monetary policy in India. These authors use changes in OIS rates of different maturities and principal component analysis to decompose monetary policy surprise measures into two factors: path and target. When we use their measure of monetary policy surprise using our local linear projection setup, the results are weaker than the surprise measure that we use (change in the one-month OIS rates on the day of the policy). We also compare the three measures (path, target, and our measure) using a regression similar to Kuttner (2001) to examine how they differ in their effect on short-term and long-term interest rates. We find that our measure of policy surprise has a larger coefficient than the decomposed factors. These results are available from the authors on request.

monetary policy actions apart from changes in the policy rate from November 2019, which may complicate the relationship between OIS and the policy rate. Third, the study intends to avoid the COVID period.

The results from the empirical exercise are represented in terms of the following IRFs in Figure 5. The black line plots the reaction of the macro variables to one standard deviation shock in monetary policy. The darker shaded region is a one standard deviation confidence interval, and the lighter shaded region is the 90 per cent confidence interval. The reaction of all the dependent variables should be interpreted in terms of percentage, except that of inflation, which is to be interpreted in terms of percentage points. The standard errors are obtained using Newey-West to make them robust to serial autocorrelation.

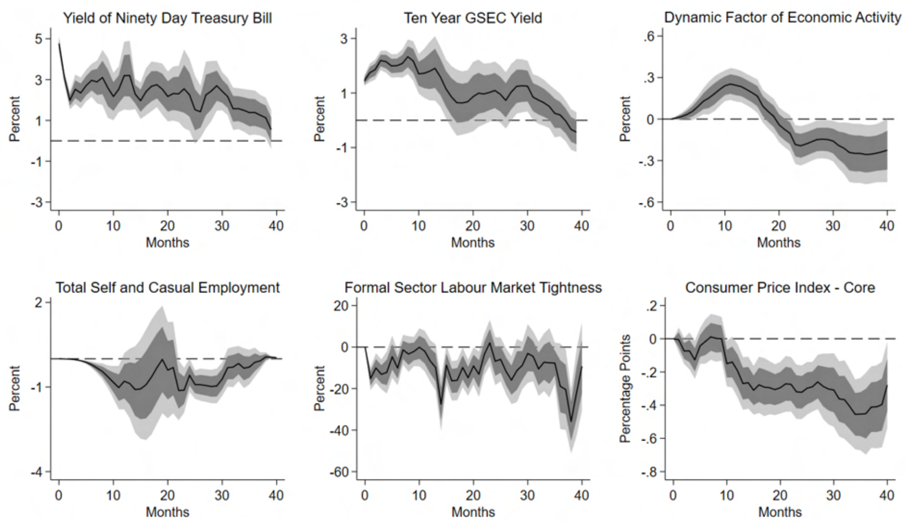


Figure 5: Local Linear Projections IRFs

Note: Each panel plots the impulse response function (IRF) of the concerned variable to one standard deviation shock in the monetary policy surprise variable. The lighter shaded area plots the 90 per cent confidence interval of the impulse responses, while the darker shaded area plots one standard deviation confidence bands. All the panels except panel 6 are to be interpreted in terms of percentage change, panel 6 should be interpreted in terms of percentage points change. The CPHS publishes data on total salaried employment as well, which can be a proxy for the formal sector. However, the IRFs for salaried employment are largely insignificant and volatile and therefore not reported here.

Source: Authors' calculations.

The first and second panels show the effect of a one standard deviation shock in monetary policy on short-term (T-Bill rates) and long-term government securities (10-year GSEC yield). The IRFs show that the effects are positive, immediate, and remain statistically significant for up to 40 months after the shock in the case of T-Bills and up to 18 months for GSECs. The third panel shows the effect of monetary policy shock on output cycles as captured by the de-trended nine indicator dynamic factor. The effect is initially positive for up to 15-16 months and then turns negative and remains negatively significant up to 40 months.[18] The fourth panel shows a negative effect of the policy shock on informal employment. Informal employment falls from the 7^{th} month after the policy shock and remains negative up to 30 months, although it is not always statistically significant. The fifth panel plots the response of the index of labor market tightness to a positive policy shock. The impulse response is very volatile and statistically insignificant for most periods, although the response is largely negative, implying a reduction of tightness in the labor market. The last panel shows the response of core inflation to the policy. The impact is significant after about 10 months and remains negatively significant for the rest of the months.

3 The Model

From Section 2.1, it is apparent that the relation between the GVA cycle and the employment cycle of different types of employment is varied. This suggests segmentation in the labor market. Section 2.2 illustrates how monetary policy surprises lead to inflation outcomes via heterogeneous labor markets. This leads to the question: How does an economy with segmented and heterogeneous labor markets react to a monetary policy shock? In this Section, we address this question by building a medium scale NK-DSGE model with dual labor markets. To establish model validation, we calibrate the model to match moments of the modern sector of the Indian economy as presented in Table 2.[19] We use the calibrated model to understand the effect of a monetary policy shock on different types of employment. We show that the direction of the model generated impulse response for relevant variables are largely in line with the empirically estimated impulses, estimated in Section 2.2. We also study the outcomes from the monetary policy shock under different counterfactuals that capture different structural features of EMDEs.

3.1 Final Good Production

Our model features both formal private and public sector jobs, and casual and self-employment in the informal sector. The labor market is assumed to be segmented

[18] We also checked our results using the monthly Index of Industrial Production (IIP). The results are not intuitive. The dynamic factor-based indicator we use captures a much larger section of economic activity compared to IIP, as the latter is only a measure of industrial activity and does not include the large service sector in India. In addition, IIP is not strongly correlated with GDP growth, while the dynamic factor-based indicator tracks GDP growth with precision. Using IIP as a gauge of economic activity also has several well-known drawbacks.

[19] We do not include the agriculture sector in the model, and in the rest of the analysis.

between formal and informal laborers, as in Srivastava (2019). Labor market segmentation means that households either supply hours in the formal sector, or in the informal sector.[20]

The private final good, p, is produced by two types of monopolistically competitive intermediate good firms: formal intermediate good firms and informal intermediate good firms. The public good, g, is produced by formal labor, employed in the public sector ($L_{g,t}$). For simplicity, we assume that formal and informal intermediate goods are produced by ϕ and $1-\phi$ measures of monopolistically competitive firms, respectively. Formal firms are indexed by i and informal firms are indexed as j. The production function of final good bundles *formal* (Y_F) and *informal* (Y_I) intermediate goods as follows,

$$Y_t = A\left[\left(\int_0^{\phi} Y_{F,t}(i)^{\frac{\epsilon-1}{\epsilon}}di\right)^{\frac{\epsilon}{\epsilon-1}}\right]^{\gamma}\left[\left(\int_{\phi}^{1} Y_{I,t}(j)^{\frac{\epsilon-1}{\epsilon}}dj\right)^{\frac{\epsilon}{\epsilon-1}}\right]^{1-\gamma}. \tag{2}$$

where ϵ is the common elasticity of substitution between formal varieties and informal varieties. The parameter $\gamma \in (0,1)$ depicts the importance of formal inputs in the production process. Hence, one way to interpret $(1-\gamma) \in (0,1)$ is that it constitutes the production "linkage" between the informal intermediate input market and the final goods sector. A high value of γ means that this linkage is small.[21]

We assume that the production of formal intermediate goods uses capital (K_t) and formal labor employed in the private sector (L_p). The production function of the formal i^{th} firm is Cobb-Douglas and homogeneous of degree one. That is,

$$Y_{F,t}(i) = \bar{z}_F z_{F,t} L_{p,t}(i)^{\alpha_F} K_t(i)^{1-\alpha_F}. \tag{3}$$

where $z_{F,t}$ is a time dependent technology parameter of the formal sector, and $\bar{z}_F$ is the time independent productivity parameter of the formal sector. The technology shock, $z_{F,t}$, is assumed to follow an AR(1) stochastic process (in logs).[22]The informal intermediate goods are produced by casual (L_c) and self-employed (L_s) workers. The production function $Y_{I,t}(j)$ is also Cobb-Douglas and is homogeneous of degree one,

$$Y_{I,t}(j) = \bar{z}_I z_{I,t} L_{c,t}(j)^{\alpha_I} L_{s,t}(j)^{1-\alpha_I}, \tag{4}$$

where $z_{I,t}$ is the time dependent technology parameter of the informal sector, and $\bar{z}_I$

[20]See Esteban-Pretel and Kitao (2021) for a structural life cycle model with equilibrium unemployment in a dual economy that models the effects of different labor market and fiscal policies, with workers moving across sectors.

[21]See Castillo et al. (2010).

[22]Specifically, $ln(z_{F,t}) = \rho_F ln(z_{F,t-1}) + \varepsilon_{F,t}$.

represents a time-independent productivity differential between the formal and informal sectors. By assumption, the informal sector uses an inferior time-independent technology compared to the formal sector. This implies $\bar{z}_F > \bar{z}_I$. Following Fernández and Meza (2015), we assume that the technology shock in the informal sector is related to the technology shock in the formal sector, as there is a pass-through of technological development from the formal to the informal sector. The relation is as follows: $z_{I,t} = z_{I,t-1}^{\rho_I} z_{F,t}^{\omega}$, where $0 < \rho_I < 1$ and $0 < \omega < 1$.

Monopolistically competitive firms face a quadratic Rotemberg price adjustment cost, given by $\psi > 0$.

The total cost, TC_t faced by a final good firm is

$$TC_t = \int_0^{\phi} P_{F,t}(i) Y_{F,t}(i) di + \int_{\phi}^{1} P_{I,t}(j) Y_{I,t}(j) dj \tag{5}$$

where $P_{F,t}(i)$ is the price of i^{th} variety of formal intermediate goods and $P_{I,t}(j)$ is the price of the j^{th} variety of the informal intermediate good. The firm minimises TC_t with respect to $Y_{F,t}(i)$ and $Y_{I,t}(j)$ subject to the production function described in equation (2). The first order conditions (FOC) and the zero profit condition result in the demand equations for the formal and informal intermediate goods

$$Y_{F,t}(i) = \frac{P_t}{P_{F,t}} \left(\frac{P_{F,t}(i)}{P_{F,t}} \right)^{-\epsilon} \gamma Y_t \tag{6}$$

and,

$$Y_{I,t}(j) = \frac{P_t}{P_{I,t}} \left(\frac{P_{I,t}(j)}{P_{I,t}} \right)^{-\epsilon} (1-\gamma) Y_t \tag{7}$$

where P_t, $P_{F,t}$, and $P_{I,t}$ are the price index of the final good, formal intermediate good, and informal intermediate good, respectively. The price indices are defined as follows.

$$P_t = \frac{1}{\gamma^{\gamma}(1-\gamma)^{1-\gamma}} P_{F,t}^{\gamma} P_{I,t}^{1-\gamma} \tag{8}$$

$$P_{F,t}^{1-\epsilon} = \int_0^{\phi} P_{F,t}(i)^{1-\epsilon} di \tag{9}$$

$$P_{I,t}^{1-\epsilon} = \int_{\phi}^{1} P_{I,t}(j)^{1-\epsilon} dj. \tag{10}$$

The terms of trade (TT_t) between goods of the informal and formal sector are defined as $\frac{P_{I,t}}{P_{F,t}}$. The per-unit formal good's cost deflated by the final good's price ($\frac{P_{F,t}}{P_t}$) can be expressed as a function of TT_t. Similarly, $\frac{P_{I,t}}{P_t}$, can be written as a function of TT_t in the following way:

$$\frac{P_{F,t}}{P_t} = \gamma^{\gamma}(1-\gamma)^{1-\gamma} TT_t^{-(1-\gamma)} \quad (11)$$

$$\frac{P_{I,t}}{P_t} = \gamma^{\gamma}(1-\gamma)^{1-\gamma} TT_t^{\gamma}. \quad (12)$$

3.2 Labor Markets

Formal (private and public) and informal (casual) labor markets are subject to search and matching frictions. Both firms and the government search for workers by posting costly vacancies, and unemployed workers search for jobs. The term $\chi_F \bar{z}_F z_{F,t}$ is the cost of posting a vacancy faced by private firms in the formal sector. For public sector jobs, the cost of posting a vacancy is given by $\chi_g \bar{z}_g z_{F,t}$. Unemployed formal workers simultaneously search for private and government jobs, and only a fraction of them are matched through a common matching function. We assume that the job break rates of private and public jobs are different: the private sector job break rate (λ_p) is greater than the public sector job break rate (λ_g).

In the informal labor market, only casual jobs face a search and matching friction. Self-employed workers in the informal sector face a competitive labor market. Therefore, in the case of self-employment, the labor market clears from the demand side. Firms in the informal sector looking for casual workers post costly vacancies. The cost of posting a vacancy to hire a casual worker in the informal sector is $\chi_I \bar{z}_I z_{I,t}$. Unemployed informal workers search for jobs. Through a matching function, a fraction of them end up being matched. The job break rate of the casual jobs is λ_c. The matching function is given by

$$M_{j',t} = M_{0j'}(U_{j't}^{\eta_{j'}} V_{j't}^{1-\eta_{j'}}), \quad (13)$$

where $j' \in \{F, I\}$, $M_{0j'}$ is the matching efficiency, and η_j' is the elasticity parameter of the matching function with respect to $U_{j't}$. The probability that unemployed workers face with being matched with a job is

$$f_{j'}(\theta_{j',t}) = \frac{M_{j',t}}{U_{j't}} = M_{0j'} \theta_{j',t}^{1-\eta_{j'}}. \quad (14)$$

Similarly, the probability that vacant firms face of being matched with a worker is

$$q_{j'}(\theta_{j',t}) = \frac{M_{j',t}}{V_{j't}} = M_{0j'} \theta_{j',t}^{-\eta_{j'}}. \quad (15)$$

Labor dynamics of formal sector workers and casual workers can now be defined. Employment dynamics in the frictional labor markets have two parts: workers who retain their jobs and workers who are newly employed from the unemployed pool. For the formal sector, the labor dynamics that a household faces are given by

$$L_{p,t} + L_{g,t} = (1-\lambda_p)L_{p,t-1} + (1-\lambda_g)L_{g,t-1} + (1-(1-\lambda_p)L_{p,t-1} - (1-\lambda_g)L_{g,t-1})\, f_F(\theta_{F,t}). \tag{16}$$

Similarly, for casual labor in the informal sector, the dynamics are given by,

$$L_{c,t} = (1-\lambda_c)L_{c,t-1} + (1-(1-\lambda_c)L_{c,t-1} - L_{s,t})f_I(\theta_{I,t}). \tag{17}$$

The total number of casual laborers at time t is the total of the number of casual workers who retain their jobs from the last period and the number of newly employed casual workers matched from the unemployed pool of informal laborers.

3.3 Households

Following Alberola and Urrutia (2020), an infinitely lived household has both formal and informal types. We assume that the formal (F) and informal (I) sectors have employment that is of two types each. Households derive utility from consuming the final private good and a public good. The household's expected utility function follows Michaillat (2014), and is given by

$$\mathbb{E}_0 \sum_{t=0}^{+\infty} \beta^t \left[ln\, C_t + \chi ln\, g_t\right] \tag{18}$$

where $\chi > 0$ is the exogenous preference parameter for the public good. Since the labor market is segmented, households choose labor hours in private or public employment within the formal sector and between self-employed or casual employment categories within the informal sector. Households supply a fixed proportion, ϕ, and, $1-\phi$, of labor hours to both the formal and informal labor employment, respectively. Households also invest in the capital stock and one-period risk-free bonds. The household owns both the informal and formal firms, and their labor income is taxed at the constant rate, $\tau \in (0,1)$, on formal wage income.

The household budget constraint is

$$\begin{aligned} C_t + I_t + \frac{B_t}{P_t} = \phi(1-\tau)\left(w_{p,t}L_{p,t} + w_{g,t}L_{g,t}\right) + (1-\phi)\left(w_{c,t}L_{c,t} + w_{s,t}L_{s,t}\right) \\ + R_{t-1}\frac{B_{t-1}}{P_t} + r_t K_t + \phi\Pi_{F,t} + (1-\phi)\Pi_{I,t}, \end{aligned} \tag{19}$$

where I_t is investment in the capital stock, B_t is the nominal bond holding of riskless one period bonds, P_t is the price of the final good, $R_t > 1$ is the gross return from holding bonds, r_t is the return from capital, $\Pi_{F,t}$ is the profit from formal firms and $\Pi_{I,t}$ is the profit from informal firms. The aggregate capital stock grows according to

$$K_{t+1} = I_t + (1 - \delta)K_t, \tag{20}$$

where $\delta \in (0, 1)$ is the depreciation rate. Households maximise inter-temporal utility (18) subject to equations (19), (20), (16) and (17) with respect to $\{C_t, b_t, K_{t+1}, L_{p,t}, L_{g,t}, L_{c,t}, L_{s,t}\}$, respectively. As shown in Appendix (D), the first order condition (FOC) with respect to current consumption is,

$$\zeta_{C,t} = \frac{1}{C_t}. \tag{21}$$

Using the FOC with respect to current consumption and the nominal bond holding, we get equation (22):

$$\frac{1}{R_t} = \beta \mathbb{E}_t \left[\frac{C_t}{C_{t+1}} \frac{P_t}{P_{t+1}} \right]. \tag{22}$$

Equation (23) is the FOC with respect to K_{t+1} (using equation (21)):

$$\beta \mathbb{E}_t \left[\frac{\zeta_{C,t+1}}{\zeta_{C,t}} (r_{t+1} + 1 - \delta) \right] = 1. \tag{23}$$

Equations (22) and (23) lead to the standard household's Euler equations for consumption and bond holdings, respectively:

$$1 = \beta \mathbb{E}_t \left[\frac{C_t}{C_{t+1}} (1 - \delta + r_{t+1}) \right] \tag{24}$$

$$\frac{1}{R_t} = \beta \mathbb{E}_t \left[\frac{C_t}{C_{t+1}} \frac{1}{1 + \pi_{t+1}} \right] \tag{25}$$

The FOC with respect to formal labor supply in the private sector is given by equation (26):

$$\zeta_{F,t} = (1 - \tau) w_{p,t} \zeta_{C,t} + \beta \mathbb{E}_t \left[(1 - \lambda_p) \zeta_{F,t+1} (1 - f_F(\theta_{F,t+1})) \right]. \tag{26}$$

Equation (26) says that optimising households equate the flow return from a private formal job, $\zeta_{F,t}$, to the utility value of the after-tax wage, $(1 - \tau) w_{p,t} \zeta_{C,t}$, plus the discounted flow value of a job in the next period, given that the job is retained, net of the loss in flow value from any additional job creation $(f(\theta_{F,t+1})\zeta_{F,t+1})$, which does not happen if the job is retained.

The FOC with respect to the public sector's formal labor supply is given by equation (26):

$$\zeta_{F,t} = (1-\tau)w_{g,t}\zeta_{C,t} + \beta\mathbb{E}_t\left[(1-\lambda_g)\zeta_{F,t+1}(1-f_F(\theta_{F,t+1}))\right]. \quad (27)$$

As in the case of equation (26), equation (27) implies that optimising households equate the flow return from a formal public job, to the utility value from an after-tax public wage, $(1-\tau)w_{g,t}\zeta_{C,t}$, plus, the discounted flow value of the job from the next period adjusting for the loss of flow value from any additional formal sector job creation ($f(\theta_{F,t+1})\zeta_{F,t+1}$) which does not happen if the job is retained in the next period.

Similar to the above FOCs, the FOC with respect to $L_{c,t}$ is given by equation(28), with similar intuition as above:

$$\zeta_{I,t} = w_{c,t}\zeta_{C,t} + \beta\mathbb{E}_t\left[(1-\lambda_c)\zeta_{I,t+1}(1-f_I(\theta_{I,t+1}))\right]. \quad (28)$$

Self-employed labor supply is given by the following FOC:

$$\zeta_{I,t} = \frac{w_{s,t}}{f_I(\theta_{I,t})}\zeta_{C,t}. \quad (29)$$

There are no search and matching frictions in self-employment. On the margin, informal workers equate the flow return from being self-employed, $\zeta_{I,t}$, with the utility value of the self-employed wage, $w_{s,t}$, adjusted for the probability that the unemployed workers face with being matched with a job, $f_I(\theta_{I,t})$.

3.4 Profits and Wages

We now describe the formal and informal firm's profit maximisation and wage determination problems. We provide details of the derivations in Appendix D.2.1 and D.2.2.

3.4.1 Profit Maximisation

The discounted sum of the infinite profit stream for formal firms (indexed by i) is given by

$$\begin{aligned}\Lambda_{F,t}(i) =& \mathbb{E}_0\sum_{t=0}^{\infty}\beta^t\zeta_{C,t}\left[\frac{P_{F,t}(i)}{P_t}Y_{F,t}(i) - w_{p,t}L_{p,t}(i) - r_tK_t(i) - \right.\\ &\left.\chi_F\bar{z}_F z_{F,t}V_{p,t}(i) - \frac{\psi_F}{2}\left(\frac{P_{F,t}(i)}{P_{F,t-1}(i)}-1\right)^2\frac{1}{\zeta_{C,t}}\right].\end{aligned} \quad (30)$$

The formal firm i maximises, profits, $\Lambda_{F,t}(i)$, with respect to $L_{p,t}, K_t(i), V(i)_{p,t}(i), P_{F,t}(i)$ subject to equations (3), (6) and (A2). The FOC for formal labor in the private formal sector firm is given by equation (31):

$$\mu_{F,t}(i)\left[\alpha_F \bar{z}_F z_{F,t}\left(\frac{K_t(i)}{L_{p,t}(i)}\right)^{1-\alpha_F}\right] = w_{p,t} + \mu_{p,t} - \beta(1-\lambda_p)\mathbb{E}_t\left[\frac{C_t}{C_{t+1}}\mu_{p,t+1}\right] \tag{31}$$

The LHS of equation (31) is the marginal product of a formal worker to a formal firm i. The first term on the RHS of equation (31) is the formal wage ($w_{p,t}$); the second term on the RHS is the discounted *net* shadow price of labor. At period t, the labor demand for firm i is $L_{p,t}(i)$ of which $(1-\lambda_p)L_{p,t-1}$ employees are carried forward from the previous period. At period t, the additional labor intake by a firm is $L_{p,t} - (1-\lambda_p)L_{p,t-1}$. Hence, the flow shadow price of labor ($\mu_{p,t}$) for period t is adjusted by the shadow price of labor, which is carried over to the next period.

The FOC with respect to physical capital for the formal intermediate good producing firm equates the marginal product of capital (LHS) to the rental rate (RHS):

$$\mu_{F,t}(i)\left[(1-\alpha_F)\bar{z}_F\left(\frac{L_{p,t}(i)}{K_t(i)}\right)^{\alpha_F}\right] = \frac{r_t}{z_{F,t}} \tag{32}$$

The optimal vacancy posting for a formal intermediate good (the FOC with respect to $V_{p,t}(i)$) producing firm is given by equation (33):

$$\mu_{p,t}(i)q_F(\theta_{F,t}) = \chi_F \bar{z}_F z_{F,t} \tag{33}$$

On the margin, a formal firm equates the marginal benefit of posting an additional vacancy (LHS) to the marginal cost (RHS).

The intermediate good producing firms enjoy price setting power as they face a monopolistically competitive product market. Taking the FOC with respect to $(P_{F,t}(i)$ gives the price setting equation of the firm. This is in equation (34) below:

$$\frac{P_{F,t}(i)}{P_t} = \mu_{F,t}(i)\frac{\epsilon}{\epsilon-1} + \frac{1}{\gamma}\frac{\psi_F}{\epsilon-1}\frac{C_t}{Y_t}\frac{P_{F,t}}{P_t}\left(\frac{P_{F,t}(i)}{P_{F,t}}\right)^{\epsilon} \left[\beta\mathbb{E}_t\left[\left(\frac{P_{F,t+1}(i)}{P_{F,t}(i)}-1\right)\left(\frac{P_{F,t+1}(i)}{P_{F,t}(i)}\right)\right] - \left(\frac{P_{F,t}(i)}{P_{F,t-1}(i)}-1\right)\left(\frac{P_{F,t}(i)}{P_{F,t-1}(i)}\right)\right]. \tag{34}$$

Equation (34) shows that the relative price ($\frac{P_{F,t}(i)}{P_t}$) is a function of the shadow price of the formal good ($\mu_{F,t}(i)$) multiplied by the demand elasticity of the formal good ($\frac{\epsilon}{\epsilon-1}$)

plus the cost associated with the change in price as monopolistically competitive firms face a Rotemberg price adjustment cost. The aggregate price index, P_t, is given by equation (8).

The discounted profit stream for an informal firm (indexed by j) is given by

$$\begin{aligned}\Lambda_{I,t}(j) =& \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \zeta_{C,t} \left[\frac{P_{I,t}(j)}{P_t} Y_{I,t}(j) - w_{c,t} L_{c,t}(j) - w_{s,t} L_{s,t}(j) - \right. \\ & \left. \chi_I \bar{z}_I z_{I,t} V_{c,t}(j) - \frac{\psi_I}{2} \left(\frac{P_{I,t}(j)}{P_{I,t-1}(j)} - 1 \right)^2 \frac{1}{\zeta_{C,t}} \right].\end{aligned} \tag{35}$$

The informal firm j maximises, profits, $\Lambda_{I,t}(j)$, with respect to $\{P_{I,t}(j), L_{c,t}(j), L_{s,t}(j), V_{c,t}(j)\}$ subject to equations (4) and (7). The FOC of the informal firms are given by equations (36) to (39).

The FOC with respect to $L_{c,t}(i)$ is given by equation (36):

$$\mu_{I,t}(j) \left[\alpha_F \bar{z}_I z_{I,t} \left(\frac{L_{s,t}(j)}{L_{c,t}(j)} \right)^{1-\alpha_I} \right] = w_{c,t} + \mu_{c,t} - (1-\lambda_c)\beta \mathbb{E}_t \left[\frac{C_t}{C_{t+1}} \mu_{c,t+1} \right]. \tag{36}$$

The LHS of equation (36) is the marginal product of labor to informal firm j. The RHS of equation (36) is the casual wage rate, $w_{c,t}$, plus the net shadow price of casual labor. At period t, casual labor demand for firm j is $L_{c,t}(j)$, among which $(1-\lambda_c)L_{c,t-1}$ casual employees are carried forward from the previous period. At period t, the additional casual labor intake by a firm is $L_{c,t} - (1-\lambda_c)L_{c,t-1}$. The flow shadow price of casual labor for period t is net of the shadow price carried over from the previous period.

The demand for self-employed labor is determined by the FOC with respect to $L_{s,t}(i)$:

$$\mu_{I,t}(j) \left[(1-\alpha_I) z_{I,t} z_{I,t} \bar{z}_I \left(\frac{L_{c,t}(j)}{L_{s,t}(j)} \right)^{\alpha_I} \right] = w_{s,t}. \tag{37}$$

Equation (37) shows that on the margin, the return from self-employed labor (LHS) is equal to the wage cost (RHS). Since the self-employed labor market does not have a search and matching friction, the net shadow price term does not appear in equation (37).

Taking the FOC with respect to $V_{c,t}$, the vacancy posting decision for casual labor by informal intermediate good producing firms is given by equation (38):

$$\mu_{c,t}(j)q_I(\theta_{I,t}) = \chi_I \bar{z}_I z_{I,t} \tag{38}$$

The FOC with respect to $P_{I,t}(i)$ is given by equation (39). Analagous to the formal intermediary, this is the price setting condition for the informal intermediate good firm.

$$\frac{P_{I,t}(j)}{P_t} = \mu_{I,t}(j)\frac{\epsilon}{\epsilon-1} + \frac{1}{1-\gamma}\frac{\psi_I}{\epsilon-1}\frac{C_t}{Y_t}\frac{P_{I,t}}{P_t}\left(\frac{P_{I,t}(j)}{P_{I,t}}\right)^{\epsilon} \left[\beta\mathbb{E}_t\left[\left(\frac{P_{I,t+1}(j)}{P_{I,t}(j)}-1\right)\left(\frac{P_{I,t+1}(j)}{P_{I,t}(j)}\right)\right] - \left(\frac{P_{I,t}(j)}{P_{I,t-1}(j)}-1\right)\left(\frac{P_{I,t}(j)}{P_{I,t-1}(j)}\right)\right] \tag{39}$$

The relative price set by the informal firms ($\frac{P_{I,t}(j)}{P_t}$) is a function of the shadow price of the informal good ($\mu_{I,t}(j)$) times its demand elasticity ($\frac{\epsilon}{\epsilon-1}$) and the cost associated with the change in price as monopolistically competitive informal firms face Rotemberg price adjustment costs.

3.4.2 Wage Determination

The public sector wage ($w_{g,t}$) is determined exogenously by government policy (Ghate and Mazumder, 2019). Wages of private formal sector jobs ($w_{p,t}$) and casual informal sector jobs ($w_{c,t}$) are determined by Nash bargaining between workers and firms. The bargaining power of the worker is denoted as $\varphi_{j'}$. The private sector wage, $w_{p,t}$, is determined from

$$w_{p,t} = \underset{w_{p,t}}{arg\ max}\left(\frac{\zeta_{F,t}}{\zeta_{C,t}}\right)^{\varphi_F}\mu_{p,t}^{1-\varphi_F} \tag{40}$$

where $\zeta_{F,t}$ is the utility value of working in the formal sector by the household, $\zeta_{C,t}$ is the shadow price of consumption, and $\mu_{p,t}$ is the shadow price of hiring a formal worker faced by a private formal sector firm.[23] Similarly, the casual informal wage is determined from

$$w_{c,t} = \underset{w_{c,t}}{arg\ max}\left(\frac{\zeta_{I,t}}{\zeta_{C,t}}\right)^{\varphi_I}\mu_{c,t}^{1-\varphi_I} \tag{41}$$

where $\zeta_{I,t}$ is the shadow price of working in the informal sector faced by the household, and $\mu_{c,t}$ is the shadow price of hiring a casual informal worker faced by the informal sector firm.

[23] See Appendix D for details.

The standard Nash sharing rules from equation (40) and equation (41) are given by

$$(1-\varphi_F)\left(\frac{\zeta_{F,t}}{\zeta_{C,t}}\right) = \varphi_F \mu_{p,t} \tag{42}$$

and

$$(1-\varphi_I)\left(\frac{\zeta_{I,t}}{\zeta_{C,t}}\right) = \varphi_I \mu_{c,t}. \tag{43}$$

3.5 Government

The government pays the wage of the public sector worker, $w_{g,t}$, while workers produce the public sector good, g_t. The public sector exogenous wage rule is

$$w_{g,t} = \bar{w}_g z_{F,t}^{\alpha_g}. \tag{44}$$

The production function of the public good is

$$g_t = \bar{z}_g z_{F,t}(\phi L_{g,t})^{\alpha_g} \tag{45}$$

The labor dynamics faced by the government are

$$L_{g,t} = (1-\lambda_g)L_{g,t-1} + q_F(\theta_{F,t})V_{g,t}. \tag{46}$$

The government faces the budget constraint

$$\phi L_{g,t} w_{g,t} + \phi \chi_g \bar{z}_g z_{F,t} V_{g,t} + \frac{R_{t-1}}{P_t} B_{t-1} = \tau \phi (w_{p,t} L_{p,t} + w_{g,t} L_{g,t}) + \frac{B_t}{P_t}. \tag{47}$$

3.6 Monetary Policy

The nominal interest rate, R_t, is set by monetary policy, which follows a Taylor Rule

$$R_t = R_0 \Big(\frac{R_{t-1}}{R_0}\Big)^{\rho_r} (1+\pi_t)^{\rho_\pi(1-\rho_r)} \varrho_t. \tag{48}$$

where π_t is the inflation rate at time period t, $\rho_r \in [0,1)$ is the interest-rate smoothing parameter, and $\rho_\pi > 1$ captures how monetary policy reacts to inflation. R_0 is the gross steady state nominal interest rate. ϱ_t is the stochastic shock component of monetary policy, which is independent of the technology shock. $ln(\varrho_t)$ follows an AR(1) process given by

$$ln(\varrho_t) = \rho_m ln(\varrho_{t-1}) + \varepsilon_{m,t} \tag{49}$$

where $0 < \rho_m < 1$ is the persistence parameter and ε_m is white noise.

3.7 Market Clearing

After incorporating the firms' per period profit and the government's budget constraint into the household's budget constraint, the economy-wide resource constraint is obtained. The price of the formal sector intermediate good is assumed to be the numeraire.

$$Y_t = C_t \left(1 + (1-\phi)\frac{\psi_I}{2}\left(\frac{\pi_t}{1-\gamma}\right)^2\right) + I_t + \left(\phi\chi_F \bar{z}_F V_{F,t} + \phi\chi_g \bar{z}_g V_{g,t}\right) z_{F,t} + (1-\phi)\chi_I \bar{z}_I z_{I,t} V_{c,t} \tag{50}$$

Final goods production is used to consume (adjusted for Rotemberg pricing), invest, and to pay the fixed costs of posting vacancies, by both formal and informal firms.

3.8 New Keynesian Phillips Curve

In a symmetric equilibrium, all intermediate firms of a specific sector choose the equilibrium values of the endogenous variables identically. Thus, we can get rid of firm-specific indices $i \in [0,\phi)$and $j \in [\phi, 1]$ for the formal and informal sectors, respectively. Using equations (39), (8), and (10), the NKPC equation of the model is derived as follows.

$$\begin{aligned} \frac{\pi_t}{1-\gamma}\left(1+\frac{\pi_t}{1-\gamma}\right) =& \beta \mathbf{E}_t\left[\frac{\pi_{t+1}}{1-\gamma}\left(1+\frac{\pi_{t+1}}{1-\gamma}\right)\right] \\ &+ \frac{1}{\psi_I}\frac{Y_t}{C_t}(1-\gamma)\left[\frac{\epsilon\,(1-\phi)^{\frac{\epsilon}{\epsilon-1}}}{\gamma^\gamma(1-\gamma)^{1-\gamma}}\frac{1}{TT_t^\gamma}\frac{w_s}{(1-\alpha_I)z_{I,t}\bar{z}_I L_{I,t}^{-\alpha_I}} - \frac{\epsilon-1}{1-\phi}\right] \end{aligned} \tag{51}$$

The NKPC is similar in form to that in Michaillat (2014). The NKPC equates current inflation to future expected inflation and a composite term corresponding to output (which includes the terms of trade). However, the key departure from Michaillat (2014) is the presence of the informal sector. The role of the terms of trade ($TT_t = \frac{P_{It}}{P_{Ft}}$) in overall inflation is salient. Therefore, not only does the size of the informal sector $(1-\gamma)$ but also the terms of trade and interaction with the formal sector through the elasticity channel play an important role in determining inflation.

The model equations are summarized in Appendix E. The model has 29 endogenous variables and 29 equations. The model is solved and calibrated using Dynare Version 4.5.7 and MATLAB R2024a.

4 The Quantitative Model

4.1 Calibration

To establish model validation in the baseline model, we follow the calibration strategy in Alberola and Urrutia (2020). We calibrate six parameters of the model using simulated method of moments $\{\eta_I, \gamma, \nu_F, \nu_I, \alpha_g, M_{I0}\}$ to match the following six key moments in the data: the wage premium of the formal sector (w^{prem}) which is defined as the ratio of the formal to informal wage using PLFS data; the standard deviation (S.D.) of core inflation (σ_π); the relative standard deviation of self employment to GVA (σ_{l_s}/σ_y); the correlation of salaried employment and GVA ($\rho_{l_f,y}$); the correlation of casual employment and GVA ($\rho_{l_c,y}$); and the correlation with self-employed and GVA ($\rho_{l_s,y}$). These moments are reported in Table 3. As can be seen from Table 3, our model matches the targeted moments from the data exactly.

Sl. No.	Targeted Variables	Data	Model
1	Wage premium of formal sector (w^{prem})	2.34	2.34
2	Standard Deviation of core inflation (σ_π)	0.30	0.30
3	Relative S.D. of self-employed to GVA $\left(\frac{\sigma_{l_s}}{\sigma_y}\right)$	0.02	0.02
4	Correlation with salaried employed and GVA ($\rho_{l_f,y}$)	0.75	0.75
5	Correlation with casual employment and GVA ($\rho_{l_c,y}$)	-0.46	-0.46
6	Correlation with self-employed and GVA ($\rho_{l_s,y}$)	0.14	0.14
	Non-Targeted Variables		
7	Relative S.D. of casual employment to GVA $\left(\frac{\sigma_{l_c}}{\sigma_y}\right)$	0.06	0.0091
8	Relative S.D. of regular employment to GVA $\left(\frac{\sigma_{l_f}}{\sigma_y}\right)$	0.06	0.0269

Table 3: Matching Moments for Targeted and Non-Targeted Variables

In addition, we are able to match two more non-targeted moments, the relative standard deviation of casual employment to GVA, and the relative standard deviation of regular employment to GVA, reasonably well. These outcomes provide a strong ground to make inferences using our model in subsequent sections.

The full list of remaining parameters is in Table 4, divided into five blocks. In the first block, the discount rate, β is set to 0.9932 which is standard in the real business cycle (RBC) literature for monthly representation. The rate of capital depreciation is taken from Banerjee and Basu (2019) and assumes a monthly rate of 0.83 per cent (annual 10 % / 12 months). The size of the formal sector, ϕ, is estimated from the

PLFS dataset for 2017-2018 and 2018-2019, and takes on the value of $\phi = 0.35$.[24] The value of the common elasticity of substitution between formal varieties and informal varieties, ϵ is taken to be 11 following Michaillat (2014). The parameter $A > 0$, a technology constant, in equation (2), is assumed to take on the value 100.99. The four technological parameters, $\bar{z}_F$, $\bar{z}_g$, $\bar{z}_I$ and ω, are assumed to take on the arbitrary values of 2.1, 0.5, 0.2013 and 0.8, respectively.[25] These values help us pin-down the steady state values of the other deep parameters.

In the second block, the parameters correspond to the labor market block of the model. The wage income tax, τ, proxies for the share of direct (labor) income taxes as a percentage of GDP, which is approximately 2.5 per cent as of 2022. Both the job loss rate of the formal private sector and the public sector are obtained from Das et al. (2023).[26] As can be seen, the rate of job loss in the private sector is greater than the job loss rate in the public sector. The matching elasticity of the formal sector η_F is taken from Alberola and Urrutia (2020) and set to 0.4, while the value of the matching efficiency M_{F0} is taken to be 1 following Alberola and Urrutia (2020). We borrow the value of $\chi_F = 0.71$ and $\chi_g = 0.21$ from Alberola and Urrutia (2020) and Michaillat (2014) to proxy for the cost of posting vacancies in the private and public formal sectors. The labor income share of private formal income, $\alpha_F = 0.64$, is estimated from the national accounts data, where the labor income share is estimated as a ratio of compensation of employees to GVA of private corporations. The job loss rate of the casual sector is estimated from the PLFS 2017-2018, 2018-2019, to be 0.05.[27] We borrow the Rotemberg price adjustment parameter from Saxegaard et al. (2010) and assume it to be 118.0. The cost of posting a vacancy for casual labor, χ_I, is borrowed from Michaillat (2014), and estimated to be 0.21.

The casual labor income share, α_I is estimated from the CPHS data published from CMIE in the following way: first, the aggregate quarterly earnings of all workers identified as "casual worker" in the dataset is averaged over quarters; next, the average aggregate quarterly earnings of all workers in the informal sector is similarly calcu-

[24]Since the PLFS provides information which is consistent with the official definition of the informal sector, it is possible to obtain the percentage of the workforce which works in the informal sector. Here, the average informal sector employment proportion for the pre-COVID period for the urban area is estimated using a quarterly representation of the data.

[25]The technology pass through from formal to informal sector is incomplete, and it is assumed that only 80 per cent of formal technological change translates to the informal sector, contemporaneously.

[26]Exploiting the rolling panel data of PLFS, Das et al. (2023) obtains the transition probability of being unemployed from salaried employment in urban India. Here, we consider the pre-COVID average of the transition probabilities.

[27]Using the rolling panel data of PLFS, we calculate the transition probability of being unemployed from casual employment for urban India. We consider the pre-COVID average of transition probabilities.

lated; and lastly, α_I is obtained as the ratio of the two. It is assumed that since the informal sector utilises very little or no capital, all the factor income in the sector is distributed as labor earnings, thereby making aggregate labor income of the informal sector as a measure of the sector's GVA. The value obtained for α_I is 0.19.

In the third block, the parameters correspond to the Taylor Rule in equation (48), which are borrowed from the recent macro literature on India.

The fourth block reports the persistence parameters that govern the exogenous stochastic processes in the model. The formal-sector productivity persistence, ρ_F, is in line with the values estimated by Saxegaard et al. (2010), whereas the informal-sector counterpart, ρ_I, is approximately close to the point estimate in Horvath (2018). The monetary-policy shock persistence, ρ_m, is set to 0.6603, a value that lies within the range estimated by Castillo et al. (2010) and is broadly consistent with the estimate reported by Smets and Wouters (2007).[28]

The remaining parameters from the first four blocks are borrowed from the DSGE literature on India and EMDEs. The technological constants (serial no. 6,7, and 8) and the public sector wage (serial no. 16) are specified arbitrarily, as these are not available or estimated in the literature.

The results of the calibrated parameters are summarized in the fifth block of Table 4, drawing from Table 3.

[28]The value 0.6603 is chosen to evaluate impulse-response functions at a monthly frequency while remaining within the empirical range documented by Castillo et al. (2010). Smets and Wouters (2007) report a similar degree of monetary-policy shock persistence.

Sl. No.	Parameters	Descriptions	Values	Sources
Block 1		General Parameters		
1	β	Time discount rate	0.9932	Standard
2	δ	Rate of capital depreciation	0.0083	Banerjee and Basu (2019)
3	ϕ	Size of formal sector	0.35	Estimated from PLFS for urban area (2017-18, 2018-19)
4	ϵ	Intermediate-good elasticity	11	Michaillat (2014)
5	A	Scaling parameter for the production function of final good	100.99	Arbitrary
6	$\bar{z}_F$	Technology parameter for the private sector	2.1	Arbitrary
7	$\bar{z}_g$	Technology parameter for the public sector	0.5	Arbitrary
8	$\bar{z}_I$	Technology parameter for the informal sector	0.2013	Arbitrary
9	ω	Formal to informal technology pass-through elasticity	0.8	Arbitrary
Block 2		Labour Market Parameters		
10	τ	Wage income tax	0.025	Income tax rate in India
11	λ_p	Job-loss rate of private sector	0.03	Das et al. (2023)
12	λ_g	Job-loss rate of public sector	0.01	Estimated from PLFS
13	η_F	Matching elasticity parameter of formal sector	0.4	Alberola and Urrutia (2020)
14	M_{F0}	Matching efficiency of formal sector	1	Alberola and Urrutia (2020)
15	χ_F	Cost of posting vacancy in private sector	0.71	Alberola and Urrutia (2020)
16	χ_g	Cost of posting vacancy in public sector	0.21	Michaillat (2014)
17	w_g	Public sector wage parameter	0.5	Arbitrary
18	α_F	Labour income share in private formal sector	0.64	Estimated from NAS
19	λ_c	Job-loss rate of casual labour	0.05	Estimated from PLFS, (2017-18, 2018-19)
20	ψ_I	Rotemberg price adjustment parameter	118.0	Saxegaard et al. (2010)
21	χ_I	Cost of posting vacancy for casual labour	0.21	Michaillat (2014)
22	α_I	Casual labour income share in informal sector	0.19	Estimated from CPHS, CMIE
Block 3		Monetary Policy Parameters		
23	R_0	Taylor rule parameter	$\frac{1}{\beta}$	From Steady State Derivation
24	ρ_π	Taylor rule inflation parameter	1.47	Ghate et al. (2018)
25	ρ_r	Taylor rule interest rate parameter	0.7624	Bhadury et al. (2022)
Block 4		Stochastic Process Parameters		
26	ρ_F	Formal productivity persistence parameter	0.8479	Saxegaard et al. (2010)
27	ρ_I	Informal productivity persistence parameter	0.9394	Horvath (2018)
28	ρ_m	Monetary policy persistence parameter	0.6603	Castillo et al. (2010)
Block 5		Calibrated Parameters from Matching Moments		
29	η_I	Matching elasticity of casual labour	0.2501	Calibrated
30	γ	Elasticity of formal sector in final good	0.1198	Calibrated
31	α_g	Labour elasticity of public sector good production	0.6670	Calibrated
32	ν_I	Bargaining power of casual worker in informal sector	0.9936	Calibrated
33	ν_F	Bargaining power of worker in private sector	0.9664	Calibrated
34	M_{I0}	Matching efficiency of casual labour	2.6533	Calibrated

Table 4: List of Parameters

5 The Impact of Monetary Policy Shocks

As mentioned in Section 2.2, we estimate the shock in monetary policy using monthly data. Hence, we interpret the time frequency of the IRFs as monthly. We outline the mechanism of adjustment back to the steady state after a monetary policy shock. To understand the monetary policy mechanism and inflation outcomes via heterogeneous labor markets, we consider the impact of a one standard deviation contractionary monetary policy shock on the economy in a variety of environments, which may be relevant to EMDEs generally, and India specifically (varying degrees of formality, presence of public sector in the labor market). We first highlight the general equilibrium mechanism behind how monetary policy transmission occurs in the baseline model. These impulse response functions are given in Figures 6a, 6b and 6c.

By the Taylor rule in equation (48), a contractionary shock leads to an increase in the real interest rate, R_t. From the Euler equation (22), this leads to a decline in consumption on impact, as can be seen in the impulse response functions in Figure 6a. The decrease in C_t on impact also implies that the term, $\frac{C_t}{C_{t+1}}$ falls. A decline in aggregate consumption, given goods market clearing, means output, Y_t, falls from equation (50). This is seen in the impulse response functions in Figure 6a as well. A rise in the real interest rate implies that the marginal product of capital rises because of no-arbitrage. A decline in output disinflates the economy with inflation falling on impact. There is a decline in the terms of trade, after an initial increase on impact.

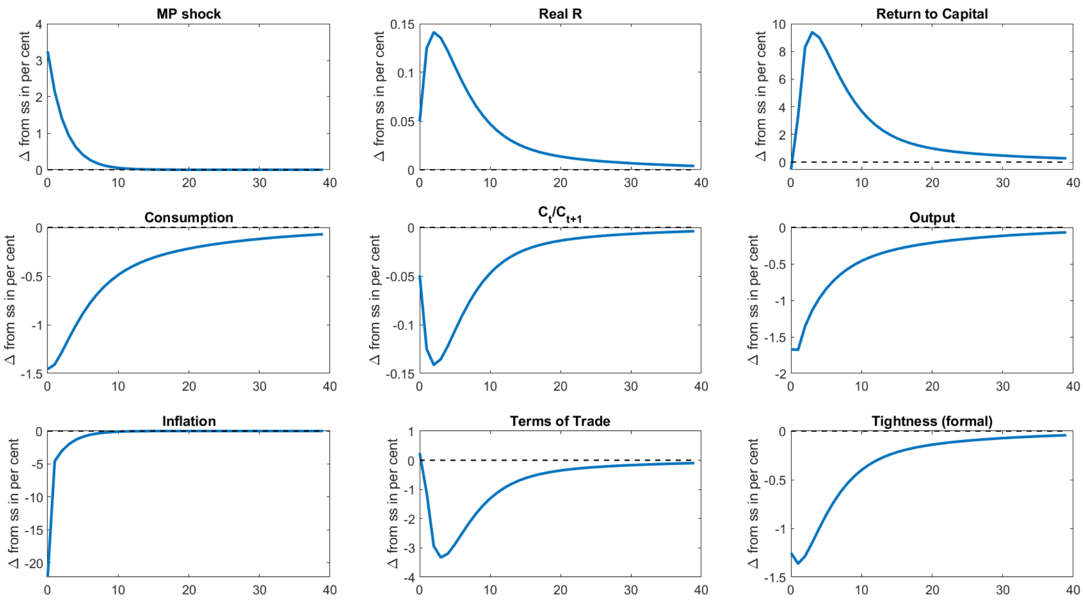
Since formal firms face a higher rental rate of capital, a higher r_{t+1} leads to higher borrowing costs, and a fall in desired investment and the capital stock firms (Figure 6b). In the formal labor market, the private sector formal wage is given by equation (A11). Since the stochastic discount factor, $\beta\frac{C_t}{C_{t+1}}$, falls, it has two effects: both w_p (the private sector wage) and θ_F (formal labor market tightness) fall. This is because the future value of an outside option falls when the stochastic discount factor reduces.[29] In the Nash wage bargaining framework (equation A11), the equilibrium private formal wage falls when the value of the outside option shrinks. For the formal firm, the value of a future vacancy falls as the stochastic discount factor falls (equation A12). This discourages the formal firm from posting additional vacancies. Hence, θ_F falls.

[29]The utility value from being unemployed is the return from the outside option in Nash wage bargaining. The outside option for the formal sector in the Nash bargaining framework presented here is encapsulated within $\frac{\zeta_{F,t}}{\zeta_{C,t}}$ because in the household budget constraint, the unemployed mass of time period t is replaced by $(1-(1-\lambda_p)L_{p,t-1}-(1-\lambda_g)L_{g,t-1})$. Thus, in the dynamic optimisation exercise, $\frac{\zeta_{F,t}}{\zeta_{C,t}}$, which is the return from labor supply in the formal sector, includes the utility return of the household when the worker may become unemployed in the subsequent period. The same intuition holds true from the wage determination of the casual workers in the informal sector as well.

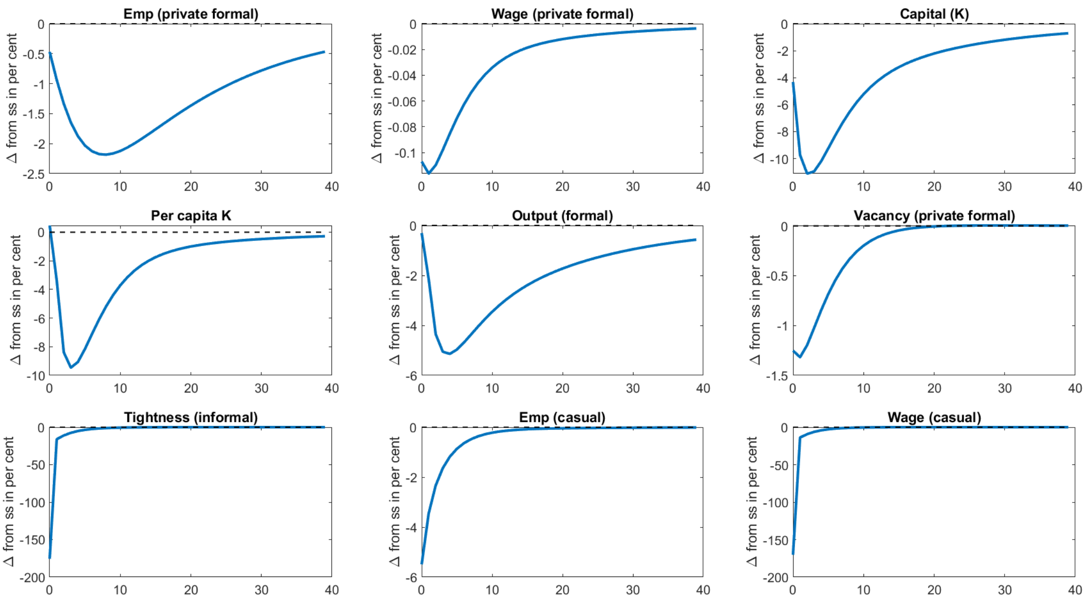
Lower capital and lower employment lead to formal sector output, $Y_{F,t}$, to fall as in equation (A16) and as seen in Figure 6b. A lower level of employment in the formal sector, $L_{p,t}$, implies that formal unemployment, $u_{F,t}$, rises (Figure 6c). Following a monetary policy tightening, the informal counter-part of the economy also experiences a contraction in output, employment, and wages (Figures 6b and 6c). However, since the labor market of self-employed workers is competitive, the speed of adjustment in the informal sector is faster than in the formal sector. A reduction in aggregate demand reduces the demand for informal output. That leads to a fall in self-employment. The labor market tightness for the casual workers reduces due to a reduction in the stochastic discount factor after the monetary policy shock. As a result, casual employment falls. A fall in employment demand leads to a reduction in earnings of casual and self-employment. However, given the parameters of the model, the IRFs suggest fluctuations in self-employment and casual employment wages are high, although consistent with the data.[30]

To summarize: A contractionary monetary policy shock leads to a decline in aggregate consumption, a decline in inflation after an initial increase, a decline in output, a decline in investment, a decline in the capital stock, and a decline in private formal employment. Unemployment rises in both formal and informal labor markets, while both casual and self-employment fall. The model generated impulse response functions are broadly consistent with the impulse response functions in Figure 5, where a monetary policy shock leads to lower inflation and lower output, *via* lower employment in the informal labor market (with both self and casual employment declining) and lower tightness in the formal labor market.

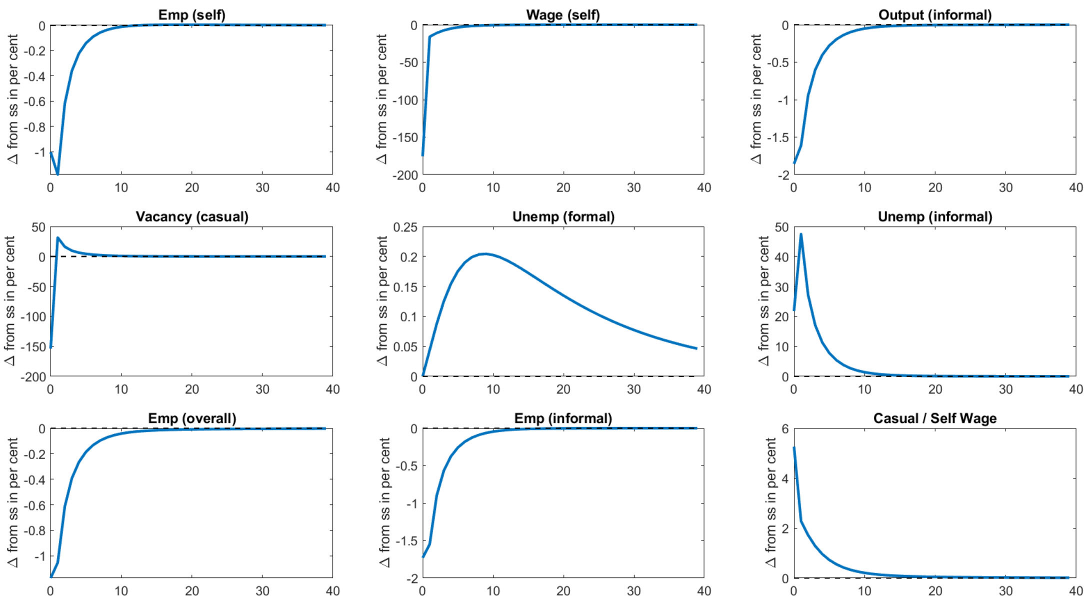
[30]This is consistent with the data on the earnings cycle (using an HP filter) of self-employment. Extracted from quarterly PLFS micro-data from September 2017 to December 2024, this exhibited higher volatility compared to the salaried earnings cycle. To wit, the self-employment earnings cycle witnessed a standard deviation of 124.9; it was 72.8 for the rest of the workers' earnings cycle.


MP shock
Real R
Return to Capital
Consumption
C_t/C_{t+1}
Output
Inflation
Terms of Trade
Tightness (formal)
Δ from ss in per cent

(a)


Emp (private formal)
Wage (private formal)
Capital (K)
Per capita K
Output (formal)
Vacancy (private formal)
Tightness (informal)
Emp (casual)
Wage (casual)
Δ from ss in per cent

(b)



(c)

Figure 6: Impulse Response of a Monetary Policy Shock

6 Some Experiments

Many EMDEs are characterized by structural features such as varying degrees of formality/informality, routine revisions in the public sector wage, and varying degrees (or linkages) of informal product market participation in the production process. We study the impact of a contractionary monetary policy shock on inflation outcomes in three such environments. We compare the impact with the baseline for changes in formality, ϕ, a change in the public sector, w_g, and a change in the formal input elasticity with respect to output, γ. The first experiment proxies for higher formality in the economy. The second experiment assesses the general equilibrium effects of periodic revisions in public sector wages enacted by many developing countries, including India. The third experiment is also a proxy for more formality in the economy.

6.1 Increase in the size of the formal sector

The impact of a contractionary monetary policy with higher ϕ is given in Figures 7a, 7b, and 7c. The solid line corresponds to the baseline, while the dashed line corresponds to the model with the changed value of ϕ. We assume that the size of the formal sector (proxied by ϕ) increases by 1.5 per cent from its baseline level specified in Table 4.[31]

[31]The change in the size of the formal sector is a slow-moving variable in a country like India. That is why for comparative analysis we consider a small increase in formality as a plausible example. The following stylised facts may provide some context. Between 2004-05 and 2009-10 the reduction in

Relative to baseline, inflation witnesses a small additional reduction of 10 basis point on impact, given the small increase in the size of the formal sector (from the NKPC in equation 51). Monetary policy, therefore, transmits better and is more impactful.

The contractions in consumption and aggregate output due to monetary policy tightening moderate given an increase in formality. This is because the rise in R_t with a higher ϕ is less.[32] Formal sector employment experiences a lesser fall in employment compared to the baseline in response to a contractionary monetary policy shock. However, there are differentiated sectoral effects compared to the baseline in terms of employment. On impact, the reduction in casual employment in reaction to monetary policy tightening is larger compared to the baseline. The opposite is the case for self-employment. On impact, the drop in self-employment is less compared to the baseline case.

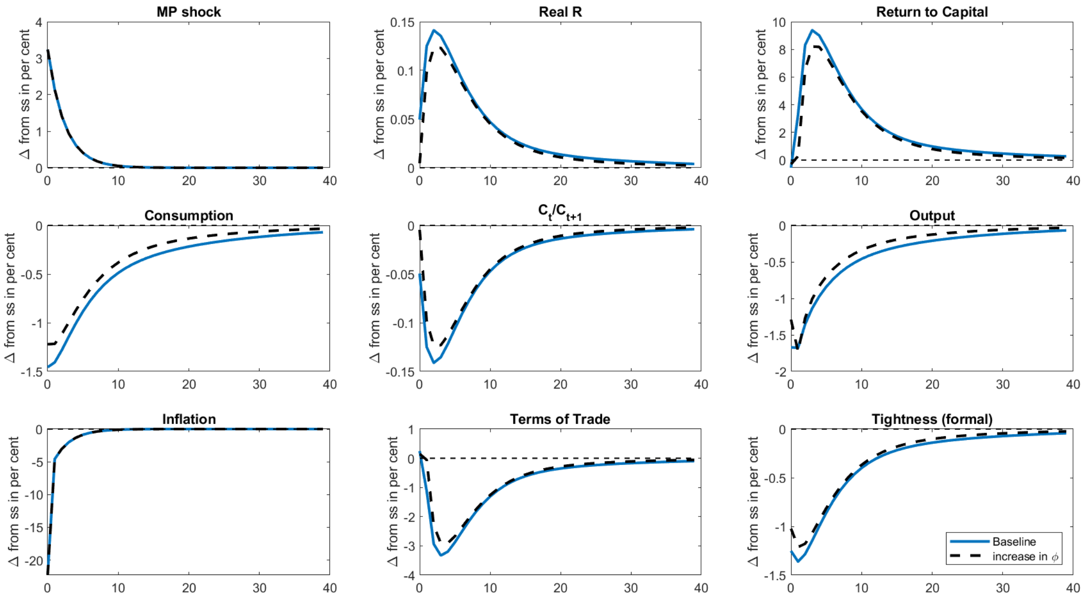
The fall in formal labor market tightness and casual labor market tightness due to monetary tightening moderate under higher ϕ. Reflecting that to private-formal and casual workers' wages, the effect of monetary policy tightening is less contractionary compared to the baseline case. The reduction in the self-employed wage is greater compared to the casual wage under monetary policy contraction (Figure 6c, casual to self-employed wage ratio). This gap widens further when the size of the formal sector employment increases (Figure 7c, casual to self-employed wage ratio).

Interestingly, while an increase in ϕ (size of formal sector) makes the output and employment reduction effect of a contractionary monetary shock more benign, inflation reduces by more compared to the baseline. Why? The model NKPC (Equation 51) includes four endogenous variables $\{Y/C, TT, w_s, L_I\}$. A lesser increase in the real interest rate causes a lesser reduction in Y/C. As the demand for output falls by less, $w_s L_I$ also falls less. The relative price of the informal sector good vis-a-vis the formal sector, TT_t, increases by less on impact. All these endogenous variables point towards a lesser fall (compared to baseline) in inflation from the NKPC (equation 51). However,

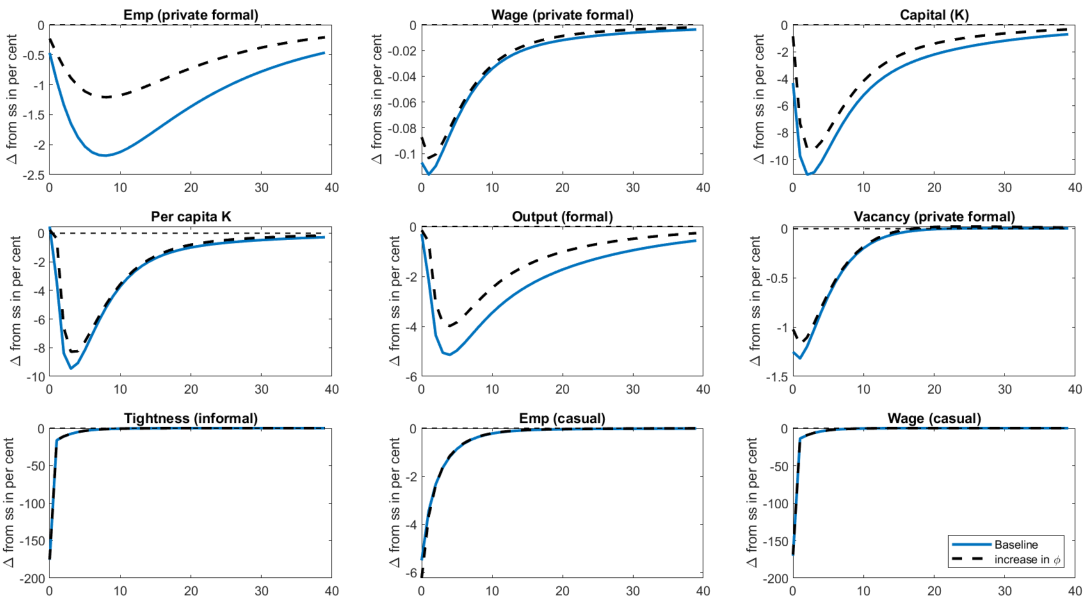
the proportion of informal sector workers was 6.4% (Source: PLFS annual report 2017-18). Broadly, we understand that period as the period of significant structural changes in Indian economy. That is, India witnessed 1.25% per year change in formality when India was undergoing structural changes. So, our example of 1.5% increase in formality is not out of context. Although the recent history of this dynamics is mixed. According to the NSS report of the 2011-12 round, the informal sector used to accommodate 72.4% of the non-agricultural workforce in India. The PLFS report of 2023-24 stated that this became 73.2%. It reduced during the pre-COVID period and reached 68% in 2018-19 according to the PLFS report. However, during COVID and related lockdown, the proportion of informal sector workers increased.

[32] This happens from the Fisher equation, $i_t = R_t - E_t \pi_{t+1}$, and the fast adjustment back to steady state in period 1.

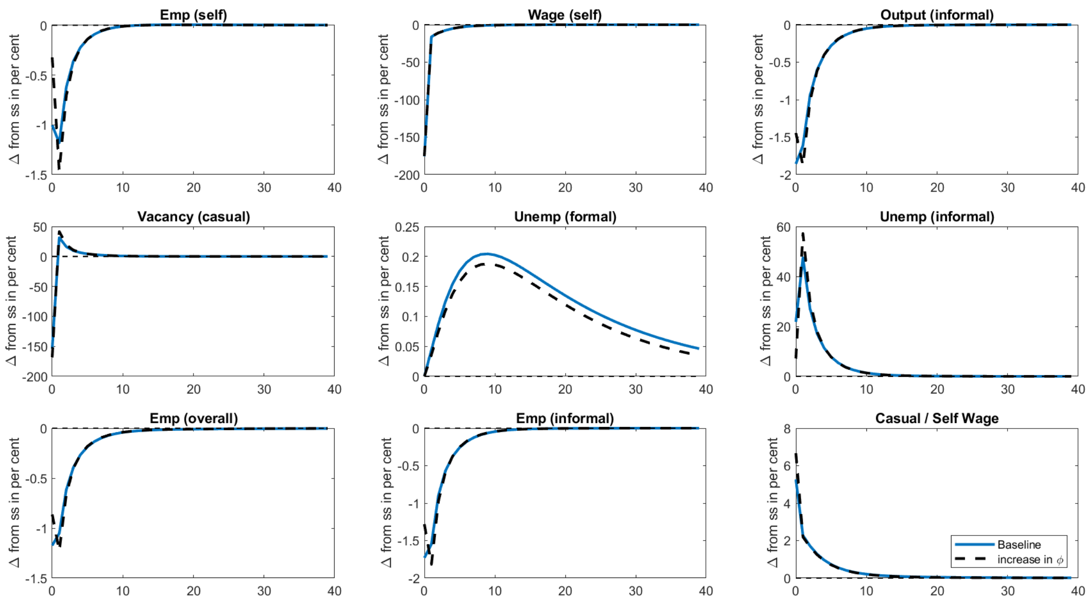
ϕ has a *direct* effect on inflation via the NKPC (equation 51). Since overall inflation reduces more for an increase in ϕ, the direct dis-inflationary effect of ϕ in the NKPC dominates over the effect from other endogenous variables above. As a result, inflation falls further compared to the baseline.


MP shock
Real R
Return to Capital
Consumption
C_t/C_{t+1}
Output
Inflation
Terms of Trade
Tightness (formal)
Δ from ss in per cent
Baseline
increase in ϕ

(a)


Emp (private formal)
Wage (private formal)
Capital (K)
Per capita K
Output (formal)
Vacancy (private formal)
Tightness (informal)
Emp (casual)
Wage (casual)
Δ from ss in per cent
Baseline
increase in ϕ

(b)



(c)

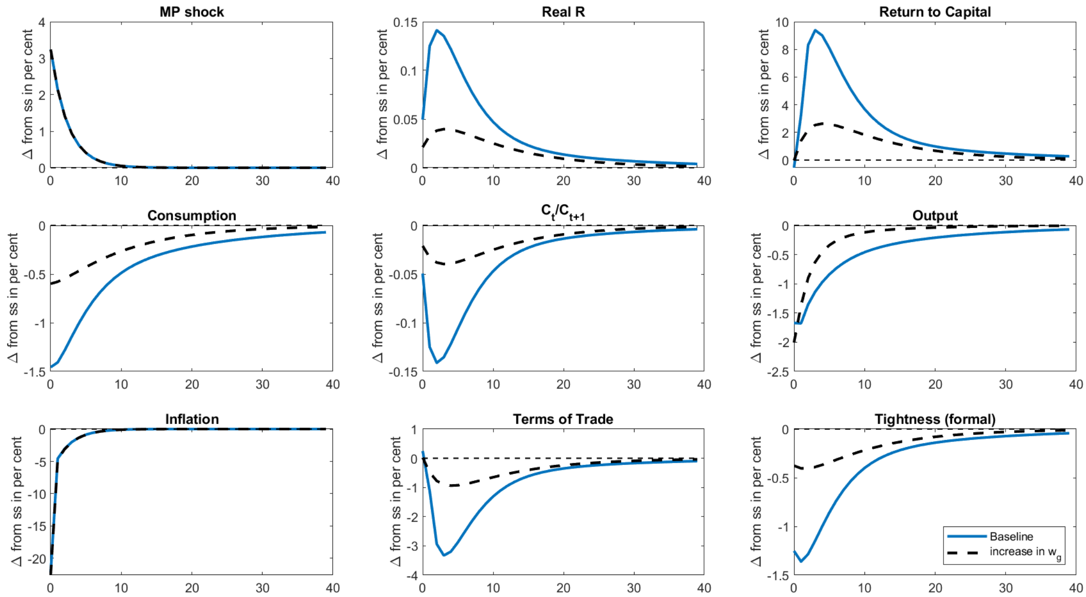
Figure 7: Monetary Policy Shock with Higher ϕ

6.2 Increase in the public sector wage

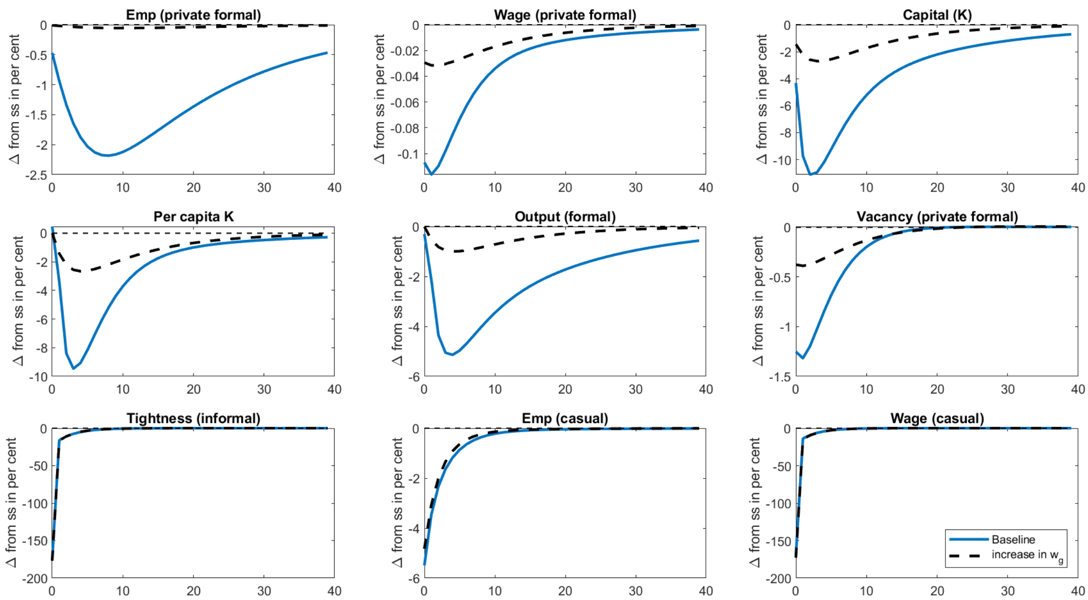
Emerging market and developing economy formal labor markets have a high public sector presence (Ghate and Mazumder, 2019). We now examine how a contractionary monetary policy shock interacts with an increase in the public sector wage by 23 per cent, the most recent public sector pay increases instituted in 2015 in India, as part of the Seventh Pay Commission (Figures 8a-8c).[33]

The exercise reveals an interesting takeaway. The key endogenous variables do not react to a monetary policy shock in the same manner under the high-paying public sector regime compared to the baseline. The equivalence between the return from private and public sector labor market returns in utility terms (Equation A10) induces this differential impact. A contractionary monetary policy shock creates a downward pull in formal private sector wages via a reduced stochastic discount factor. The higher public sector wage, which works as an outside option for formal private sector additively, cushions that fall. Given the positive relation between market tightness and wages under the Nash bargaining rule (Equations A6 and A7), a fall in formal labor market tightness due to a monetary contraction also moderates under high $\bar{w}_g$. As market tightness falls moderately, formal sector employment contraction after a monetary policy shock remains muted.

[33]See chapter 16 of *Report on 7th CPC*.



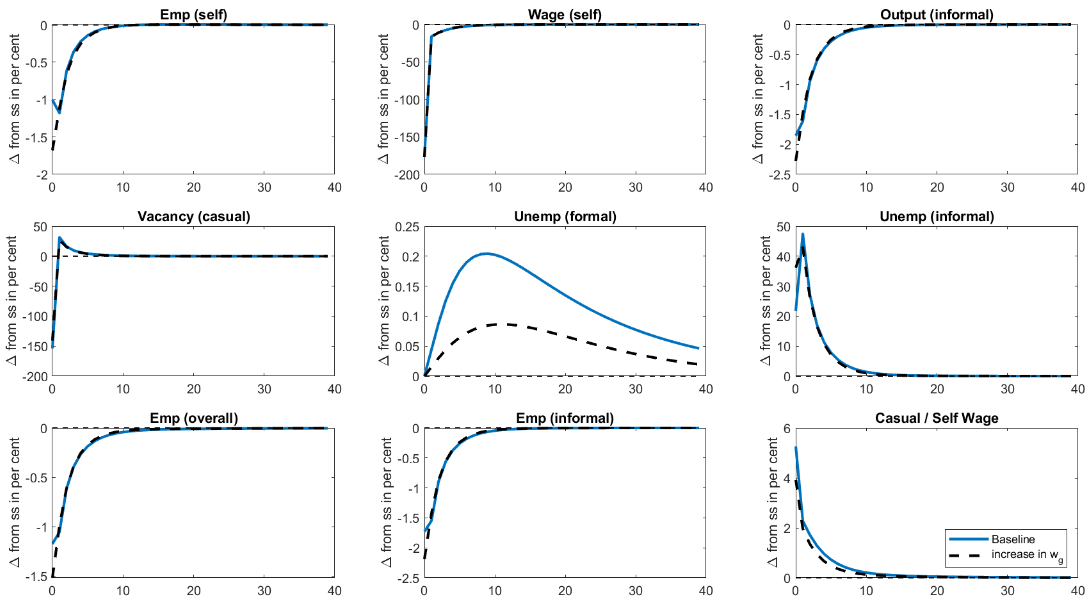
(a)



(b)

6.3 Increase in the formal good elasticity of output

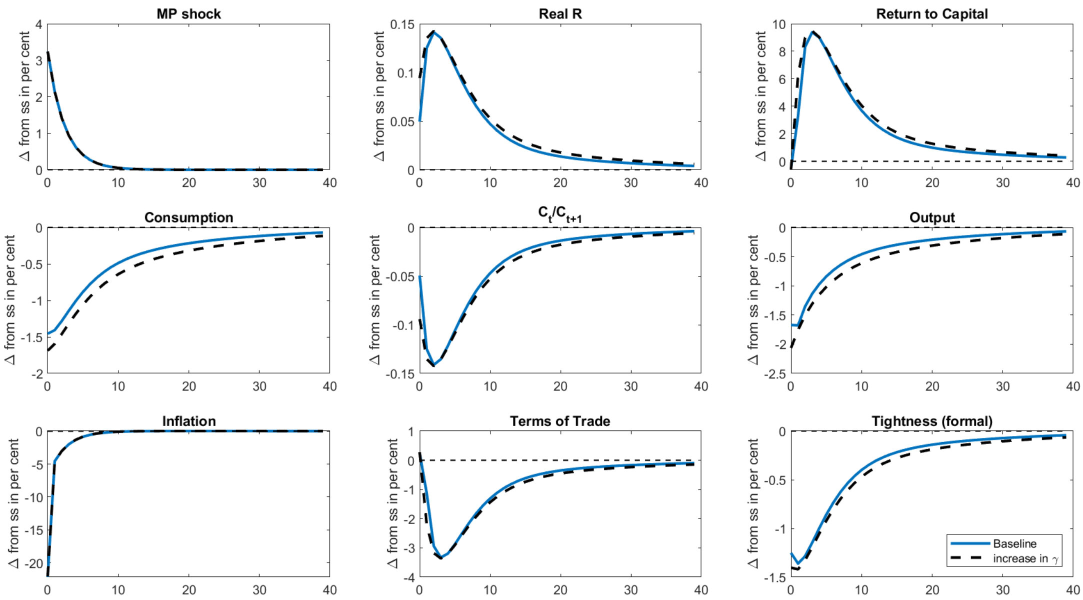
Finally, to proxy for an increase in formality in production, in our model, a one per cent increase in the use of the formal good as an input translates to a γ percentage increase in final output - the formal good elasticity with respect to output. The parameter γ is estimated in Table 4 of Section 4 to match the target variables from the data. Figures 9a, 9b, and 9c show the effect of contractionary monetary policy shock on the economy when γ is (arbitrarily) 25 per cent greater than its baseline value in Table 4.



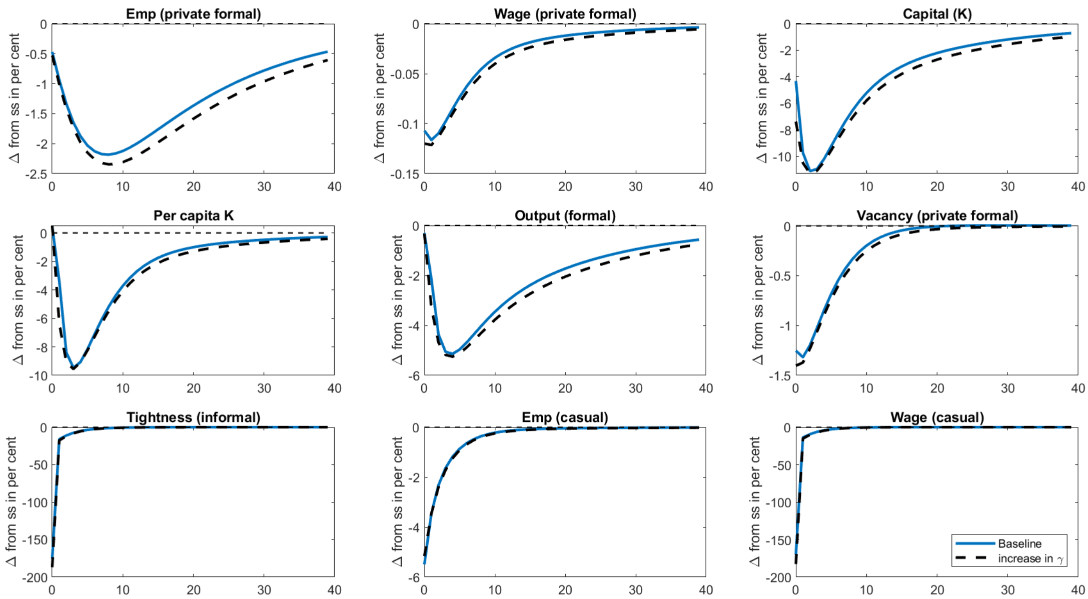
(c)

Figure 8: Monetary Policy Shock with Higher Public Sector Wage

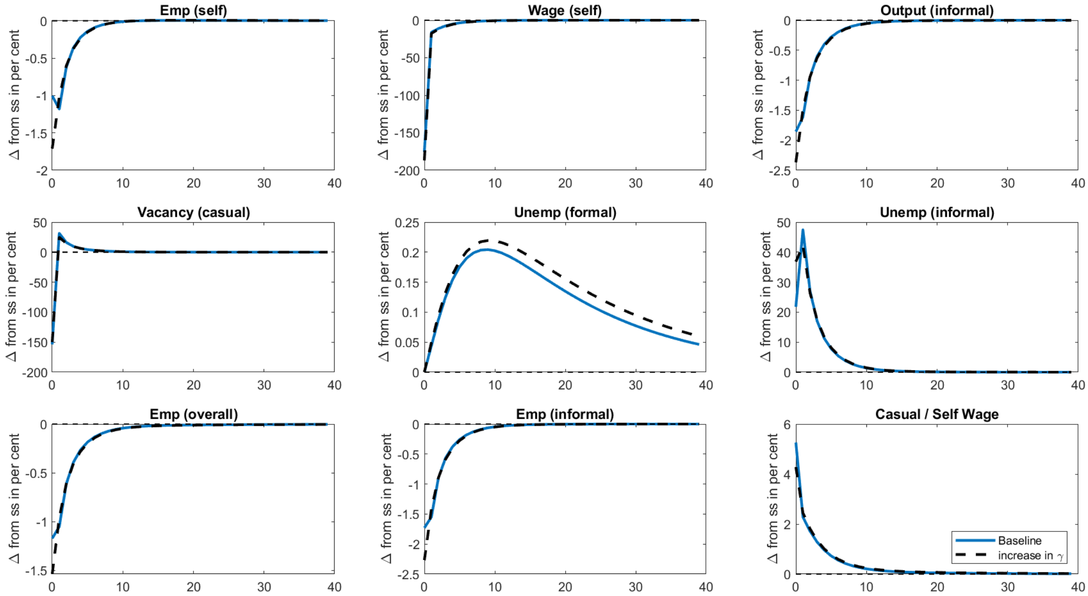
As in the case of a higher ϕ, a higher value of γ does not have much of an impact by the monetary policy shock on final good and consumption. The impact of a contractionary monetary policy shock is, however, seen more at the sectoral level. In the informal sector, a higher γ moderates the fall in market tightness (equation 39) and that results in a moderated fall in the wage of casual and self-employed workers (equations A22 and A23). A higher γ makes a monetary policy shock more contractionary for private formal employment, wages, and the capital stock. However, differentiated relative wage changes in the informal sector impact the demand for casual workers in a way where casual employment decreases to a lesser extent and self-employment falls to a greater extent compared to the baseline. Unlike a higher ϕ, a contractionary monetary policy shock *reduces* the impact of monetary policy on inflation relative to the baseline. That leads to a further increase in the real interest rate. As a result, the stochastic discount factor falls more than the baseline level. That leads to an additional reduction in the formal sector wage and market tightness. Thus, we see a further reduction in formal employment compared to the baseline.


MP shock
Real R
Return to Capital
Consumption
C_t/C_{t+1}
Output
Inflation
Terms of Trade
Tightness (formal)
Δ from ss in per cent
Baseline
increase in γ

(a)


Emp (private formal)
Wage (private formal)
Capital (K)
Per capita K
Output (formal)
Vacancy (private formal)
Tightness (informal)
Emp (casual)
Wage (casual)
Δ from ss in per cent
Baseline
increase in γ

(b)



(c)

Figure 9: Monetary Policy Shock with Higher γ

7 Conclusion

A central concern of macro-stabilisation policy is to devise fiscal and monetary policies that influence the prospects for growth and mitigate the distress due to business cycle fluctuations. A proper evaluation of the benefits of stabilisation policy, however, requires knowledge of the determinants of growth and business cycles, and how monetary transmission occurs through labor markets. EMDE labor markets are characterized by a lot of heterogeneity, and in the Indian case, the generation of stylized facts has been made possible with the India-KLEMS data. Our study provides new insights into the transmission of monetary policy in emerging markets and developing economies with heterogeneous labor markets.

We make several contributions. First, we identify a set of stylised facts on how different types of employment (formal, informal) vary across the Indian business cycle using the annual data based on employment and unemployment survey rounds by NSS, PLFS, and the India KLEMS dataset from 1980-81 to 2019-20. We find that while regular employment is pro-cyclical, casual employment is counter-cyclical historically. To the best of our knowledge, this is the first rigorous analysis using annual employment data (constructed using information from NSS, PLFS, and India KLEMS datasets) to identify a set of stylised facts of India's labor market indicators. We also augment our empirical analysis with high-frequency monthly data from the CPHS dataset to generate IRFs using local projections that quantify the impact of monetary policy shocks on inflation, the unemployment rate, and output.

Building on some of the features in Michaillat (2014) and Alberola and Urrutia (2020), we construct a medium-scale NK-DSGE model with dual labor markets and search and matching frictions to replicate the IRFs. We assume that the labor market is segmented between formal and informal laborers. While our model is calibrated to India, our NK-DSGE setup is general enough to study monetary policy transmission in countries where there are large informal labor markets. We show that the model IRFs match the empirically generated IRFs reasonably well, suggesting that our model is a useful laboratory to think about monetary policy shocks and their inflationary consequences via heterogeneous labor markets.

We find that a contractionary monetary policy shock impacts both inflation and output negatively, as in the data. We find that a contractionary monetary policy shock leads to both a decline in formal and informal employment, and therefore total employment, and leads to lower market tightness in both the formal and informal sectors. This finding is directionally supported by the IRF for employment and formal market tightness using local projections. In the calibrated model, monetary policy impacts unemployment in both informal and formal labor markets negatively. In a counter-factual experiment, when we exogenously raise the proportion of formal firms contributing to final good production (1.5 per cent relative to baseline), we find that a contractionary monetary policy shock leads to a small additional reduction in inflation relative to baseline on impact, suggesting that monetary policy is *more* effective when there is *more* formality in the economy.

Our study uncovers new insights governing the transmission of monetary policy *via* labor markets in a large emerging market economy like India.

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Monetary Policy in Informal Labor Markets

Online Appendix

A Appendix

Gross Domestic Product: This study uses annual GDP data at constant prices for the total economy. The data is obtained from various rounds of NAS, which are then spliced to convert the series to 2011-12 base prices. For tracking economic output (GDP) for the total economy on a monthly basis, a coincident economic indicator (CEII-9) representing all major sectors of the economy is used in the study.[34]

Gross Value Added: This study also uses annual GVA data for the total economy and the modern sector. The National Accounts Statistics (NAS) published by NSO is the basic source of data for the annual GVA series. The total economy GVA includes value added for all sectors of the economy, namely agriculture, mining, manufacturing, construction, and services. The modern sector GVA data corresponds to the gross value added of manufacturing and the service sector. The constant GVA series with base 2011-12 is used in the analysis.

Employment Data: We use PLFS and NSS Employment Unemployment survey rounds. For the annual employment series, the study uses data from the Employment Unemployment Survey rounds of the NSS 38th round (1983) to the 68th round (2011-12)) and the Periodic labor Force Survey rounds (2017-18, 2018-19, 2019-20). The annual series of employment is constructed for the period 1980-81 to 2019-20 using the following steps:

Step 1: Worker participation rates (WPR) based on usual principal and subsidiary status are obtained from seven benchmark NSS rounds- 38th (1983-84), 43rd (1987-88), 50th (1993-94), 55th (1999-2000), 61st (2007-08), 66th (2009-10), and 68th (2011-12) rounds and three PLFS rounds (2017-18, 2018-19, 2019-20).

Step 2: The WPRs are applied to the census population to derive the total number of persons employed for benchmark years. The data for the non-benchmark years are interpolated to create the time series of employment for 1980-81 to 2019-20.

Step 3: The total number of persons employed is further distributed to formal and

[34] CEII 9 provides an estimate of monthly GDP growth and is based on 9 high-frequency indicators. The high-frequency indicators incorporate domestic economic activity, trade, and services indicators. These indicators display high correlation with GDP and track GDP turning points well. The high-frequency indicators used to construct the monthly coincident economic indicator include IIP core, IIP consumer goods, auto sales, exports, non-oil and non-goods imports, foreign tourist arrivals, rail freight, air cargo, and government revenue receipts. The method for constructing CEII-9 is adopted from Bhadury et al. (2021), and the high-frequency indicators are obtained from the CEIC database.

informal workers. Formal workers include regular salaried workers, and informal workers include casual and self-employed workers. Following PLFS classifications, regular workers are defined as workers who are working in other farm or non-farm enterprises as regular wage employees and correspond to PLFS activity status code 31. Casual workers are defined as workers who are engaged as casual wage laborer in public work and in other types of work and get a wage payment according to terms of daily or periodic work contracts (activity status code 41 and 51). The self-employed workers are defined as workers who are engaged in household enterprise as own account workers, employers, and helpers (activity status code 11,12, and 21).

CMIE and Naukri Job Index database For quarterly and monthly employment series, data is obtained from the Consumer Pyramid Household Survey (CPHS) of the CMIE database. Additional information on employment is also collected from Naukri JobSpeak Index.

The data sources of CMIE data and Naukri JobSpeak Index are given as follows:

The CMIE employment series captures the estimated value of the total number of workers employed under various categories of employment, such as salaried employees, small traders, wage laborers, farmers, and business. The frequency of the data used in the study is March 2016 to December 2022 (Quarterly) and January 2016 to February 2023 (Monthly).

The Naukri JobSpeak, published by Info Edge (India) Ltd., is a monthly Index representing the state of the Indian job market and hiring activity based on new job listings and job-related searches by recruiters on the resume database on Naukri.com. The JobSpeak Index captures hiring activity across multiple dimensions, including industries, cities, functional areas, and experience bands. The index is a reliable indicator of white-collar hiring in India. It is aggregated based on the hiring activity of over 100,000 clients with over 70 Lakh new job mandates yearly. The report does not cover gig employment, hyperlocal hiring, or campus placement. The frequency of the data used is from July 2008 to December 2022.

Price Indicator: As an indicator of price, the Consumer Price Index (CPI) data for 2012-2019 is obtained from the Ministry of Statistics and Program Implementation (MoSPI), Government of India. We use CPI core as a measure of price which is obtained by taking out the food and fuel component from the CPI basket .

Monetary policy Indicator : The policy Repo rate is used as the primary monetary policy indicator and the data is obtained from the Reserve Bank of India (RBI). To construct monetary policy surprises, we take the one-day change in one month overnight indexed swap (OIS) rates on the day of the policy announcement from the day before. The OIS tracks the daily Mumbai Interbank Overnight Rate (MIBOR) which is the rate at which banks borrow from each other at the overnight loan market. The data for the OIS is obtained from Bloomberg.

B Appendix

When we add construction GVA to modern sector GVA, we find that regular employment continues to be pro-cyclical (covariance = 0.01). Self-employment continues to be a-cyclical with respect to the real GVA cycle.[35] However, with the inclusion of construction, casual employment is now pro-cyclical (covariance = 0.01). The construction sector has emerged as the largest non-farm employment generator rising from 6.6 per cent of total employment in 1980-81 to 20.5 per cent of total employment in 2019-20. Further, casual workers, on average, account for 76 per cent of employment in construction. When there is an upturn in the business cycle, which typically leads to a boom in the construction sector, this leads to a greater demand for construction workers. As construction workers dominate the total pool of casual workers, this leads to the pro-cyclicality of casual employment and GVA. Table A1 summarises these results. Figure A1 plots the modern sector and construction GVA cycles against employment cycles.[36]

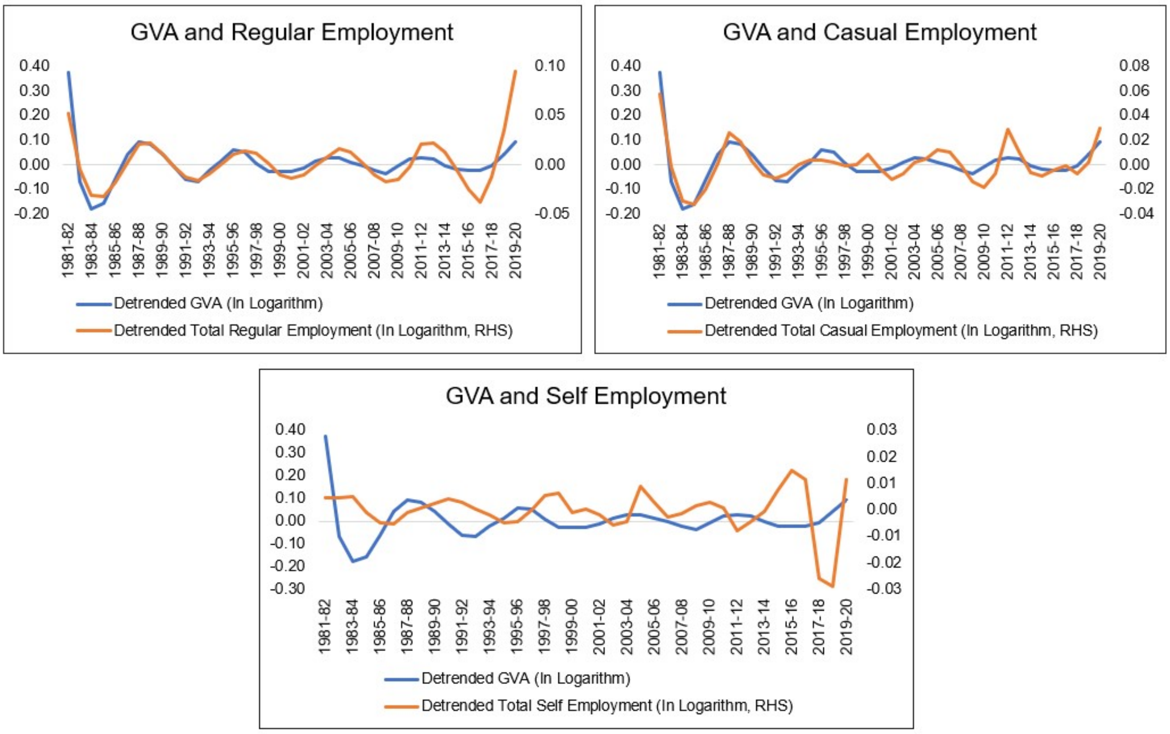


Figure A1: Modern Sector and Construction GVA; and Employment Dynamics: 1980 - 2020

Sources: India KLEMS, NSS, PLFS dataset; and Authors' calculations.

[35]Self-employment in the modern sector with construction averages 44 per cent between 1980-2019, and 36 per cent during 2017-2019.

[36]In this study, we focus on modern sector GVA with construction because it is a more complete representation of the Indian economy.

	σ_x	$\frac{\sigma_x}{\sigma_{GVA}}$	$\rho_{x,GVA}$	$Cov(x, GVA)$
Real GVA	0.40	1	1	0.16
Regular Employment	0.03	0.08	0.8	0.01
Casual employment	0.02	0.073	0.91	0.01
Self employment	0.008	0.020	0.17*	0.000
* indicates insignificance				

Table A1: Modern Sector GVA with Construction and Employment Cycles

Sources: India KLEMS, NSS, PLFS dataset; and Authors' calculations.

C Appendix

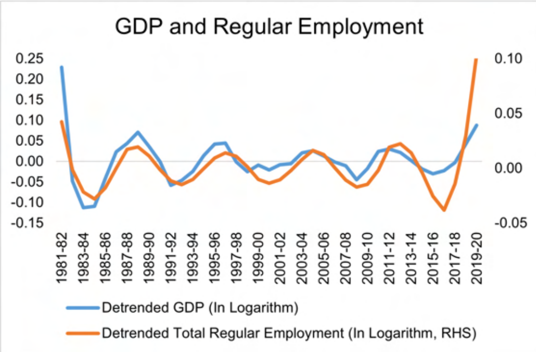
As can be seen in Table A2, regular employment is significantly correlated with real GDP, and casual employment is significantly counter-cyclical. Self-employment is statistically a-cyclical with respect to GDP. All three types of employment are less volatile than output.

	σ_x	$\frac{\sigma_x}{\sigma_{GDP}}$	$\rho_{x,GDP}$	$Cov(x, GDP)$
Real GDP	0.15	1	1	0.02
Regular Employment	0.03	0.20	0.77	0.003
Casual Employment	0.02	0.12	-0.78	-0.002
Self Employment	0.01	0.08	-0.22	0.004

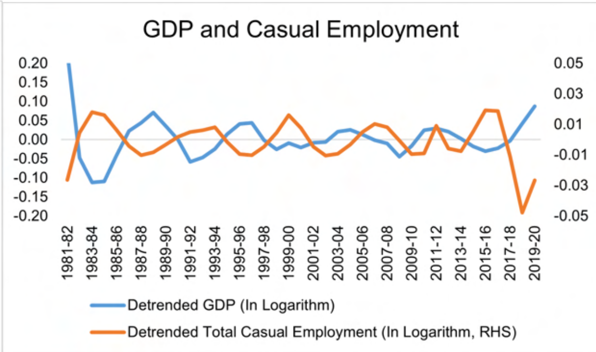
Table A2: Total GDP and Cyclical Employment: 1980-81 to 2019-20

Sources: India KLEMS, NSS, PLFS dataset, and Authors' calculations.

Figure A2 plots the cyclical component of regular, casual, and self-employment with respect to output (measured using RGDP). During business cycle upturns, the demand for regular workers increases, whereas casual workers decline and self-employment remains acyclical. Similarly, during a business cycle downturn, the employment of casual workers increases, and regular employment decreases as firms switch their demand for workers from regular to casual employment. This pattern is consistent when output is measured in terms of GVA.



(a)



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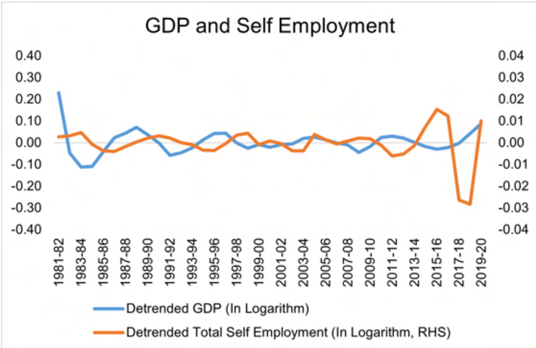

(c)

Figure A2: Total GDP and Employment Dynamics: 1980-2020
Sources: NAS, India KLEMS, NSS, PLFS dataset; and Authors' calculations.

D Appendix

D.1 Household Optimisation

Households maximise inter-temporal utility (18) subject to equations (19), (20), (16) and (17) with respect to $\{C_t, b_t, K_{t+1}, L_{p,t}, L_{g,t}, L_{c,t}, L_{s,t}\}$. I_t is replaced using equation (20) into equation (19). For the household budget constraint equation (19), the relevant Lagrange multiplier is $\zeta_{C,t}$. The Lagrange multipliers for labor dynamics constraints, that is, equation (16) and equation (17), are $\zeta_{F,t}$ and $\zeta_{I,t}$, respectively.
The relevant Lagrange function is,

$$
\begin{aligned}
\mathcal{L}_C = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t & [ln\, C_t + \chi ln\, g_t + \zeta_{C,t} [\phi(1-\tau)\left(w_{p,t}L_{p,t} + w_{g,t}L_{g,t}\right) + \\
& (1-\phi)\left(w_{c,t}L_{c,t} + w_{s,t}L_{s,t}\right) \\
& + R_{t-1}\frac{b_{t-1}}{P_t} + r_t K_t + \phi \Pi_{F,t} + (1-\phi)\Pi_{I,t} - C_t - (K_{t+1} - (1-\delta)K_t) - \frac{B_t}{P_t}\Big] + \\
& \zeta_{F,t}\left[(1-\lambda_p)L_{p,t-1} + (1-\lambda_g)L_{g,t-1} + \right. \\
& \left(1 - (1-\lambda_p)L_{p,t-1} - (1-\lambda_g)L_{g,t-1}\right) f_F(\theta_{F,t}) - L_{p,t} - L_{g,t}\big]\,\phi + \\
& \zeta_{I,t}\left[(1-\lambda_c)L_{c,t-1} + (1-(1-\lambda_c)L_{c,t-1} - L_{s,t}) f_I(\theta_{I,t}) - L_{c,t}\right](1-\phi)]
\end{aligned}
\tag{A1}
$$

The first order conditions are given by:

For $\{C_t\}$: $\zeta_{C,t} = \frac{1}{C_t}$.

For $\{b_t\}$ using the FOC for $\{C_t\}$: $R_t = \frac{1}{\beta}\mathbb{E}_t\left[\frac{C_{t+1}}{C_t}\frac{P_{t+1}}{P_t}\right]$. (Euler equation)

For $\{K_{t+1}\}$: $\beta\mathbb{E}_t\left[\frac{\zeta_{C,t+1}}{\zeta_{C,t}}(r_{t+1} + 1 - \delta)\right] = 1$

For $\{L_{p,t}\}$: $\zeta_{F,t} = (1-\tau)w_{p,t}\zeta_{C,t} + \beta\mathbb{E}_t\left[(1-\lambda_p)\zeta_{F,t+1}(1 - f_F(\theta_{F,t+1}))\right]$

For $\{L_{g,t}\}$: $\zeta_{F,t} = (1-\tau)w_{g,t}\zeta_{C,t} + \beta\mathbb{E}_t\left[(1-\lambda_g)\zeta_{F,t+1}(1 - f_F(\theta_{F,t+1}))\right]$

For $\{L_{c,t}\}$: $\zeta_{I,t} = w_{c,t}\zeta_{C,t} + \beta\mathbb{E}_t\left[(1-\lambda_c)\zeta_{I,t+1}(1 - f_I(\theta_{I,t+1}))\right]$

For $\{L_{s,t}\}$: $\zeta_{I,t} = \frac{w_{s,t}}{f_I(\theta_{I,t})}\zeta_{C,t}$

D.2 Intermediate Goods

The intermediate goods sector is monopolistically competitive. Therefore, these firms have price-setting power. However, firms are subject to quadratic Rotemberg price adjustment costs ($\psi_{j'}$). Additionally, firms face vacancy posting costs ($\chi_{j'} z_{j'} \bar{z}_{j'}$) for hiring a worker from a frictional labor market. After posting vacancies, firms obey the labor dynamics. The labor dynamics that the formal sector firms face is given by

$$L_{p,t}(i) = (1 - \lambda_p) L_{p,t-1}(i) + q_F(\theta_{F,t}) V_{p,t}(i). \tag{A2}$$

The informal sector firms face the following labor dynamics to hire a casual worker:

$$L_{c,t}(j) = (1 - \lambda_c) L_{c,t-1}(j) + q_I(\theta_{I,t}) V_{c,t}(j). \tag{A3}$$

The formal firm i maximises $\Lambda_{F,t}(i)$ with respect to $\{P_{F,t}(i), L_{p,t}(i), K_t(i), V_{p,t}(i)\}$ subject to equations (3), (6) and (A2). One can equate equations (3) and (6) by $Y_{F,t}$. So, the firm optimises subject to two constraints: demand equals supply and labor dynamics. The Lagrange multiplier is denoted as $\mu_{F,t}(i)$ and $\mu_{p,t}(i)$ for the demand-equals-supply constraint and for labor dynamics, respectively.

The Lagrange equation for the formal sector is

$$\begin{aligned} \mathcal{L}_F(i) = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \Big[\Lambda_{F,t}(i) + \mu_{F,t}(i) \left[\bar{z}_F z_{F,t} K_t(i)^{\alpha}_F L_{p,t}(i)^{1-\alpha_F} - Y_{F,t}(i) \right] \\ + \mu_{p,t}(i) \left[(1 - \lambda_p) L_{p,t-1}(i) + q_F(\theta_{F,t}) V_{p,t}(i) - L_{p,t}(i) \right] \Big]. \end{aligned} \tag{A4}$$

$Y_{F,t}(i)$ can be replaced using equation (6). The informal firm j maximises $\Lambda_{I,t}(j)$ with respect to $\{P_{I,t}(j), L_{c,t}(j), L_{s,t}(j), V_{c,t}(j)\}$ subject to equations (4) and (7). The Lagrange multipliers for demand-equals-supply and labor dynamics are denoted as $\mu_{I,t}$ and $\mu_{c,t}$, respectively.

The Lagrange equation for the informal sector is

$$\begin{aligned} \mathcal{L}_I(i) = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \Big[\Lambda_{I,t}(j) + \mu_{I,t}(j) \left[\bar{z}_I z_{I,t} L_{c,t}(j)^{\alpha}_I L_{s,t}(j)^{1-\alpha_I} - Y_{I,t}(j) \right] \\ + \mu_{c,t}(j) \left[(1 - \lambda_p) L_{c,t-1}(j) + q_I(\theta_{I,t}) V_{c,t}(j) - L_{c,t}(i) \right] \Big]. \end{aligned} \tag{A5}$$

$Y_{I,t}(j)$ can be replaced using equation (7).

D.2.1 FOCs from the formal firms' optimisation

$\{L_{F,t}(i)\}$: $\mu_{F,t}(i)\left[\alpha_F \bar{z}_F z_{F,t}\left(\frac{K_t(i)}{L_{F,t}(i)}\right)^{1-\alpha_F}\right] = w_{p,t} + \mu_{p,t} - \beta(1-\lambda_p)\mathbb{E}_t\left[\frac{C_t}{C_{t+1}}\mu_{p,t+1}\right]$

$\{K_t(i)\}$: $\mu_{F,t}(i)\left[(1-\alpha_F)\bar{z}_F\left(\frac{L_{F,t}(i)}{K_t(i)}\right)^{\alpha_F}\right] = \frac{r_t}{z_{F,t}}$

$\{V_{p,t}(i)\}$: $\mu_{p,t}(i)q_F(\theta_{F,t}) = \chi_F \bar{z}_F z_{F,t}$

$\{P_{F,t}(i)\}$:

$$\frac{P_{F,t}(i)}{P_t} = \mu_{F,t}(i)\frac{\epsilon}{\epsilon-1} + \frac{1}{\gamma}\frac{\psi_F}{\epsilon-1}\frac{C_t}{Y_t}\frac{P_{F,t}}{P_t}\left(\frac{P_{F,t}(i)}{P_{F,t}}\right)^{\epsilon} \left[\beta\mathbb{E}_t\left[\left(\frac{P_{F,t+1}(i)}{P_{F,t}(i)}-1\right)\left(\frac{P_{F,t+1}(i)}{P_{F,t}(i)}\right)\right] - \left(\frac{P_{F,t}(i)}{P_{F,t-1}(i)}-1\right)\left(\frac{P_{F,t}(i)}{P_{F,t-1}(i)}\right)\right].$$

As the price of formal sector intermediate goods is set as numeraire, the FOC for $\{P_{F,t}(i)\}$ is used to determine the terms of trade between formal and informal intermediate goods.

D.2.2 FOCs from the informal firms' optimisation

$\{L_{c,t}(j)\}$: $\mu_{I,t}(j)\left[\alpha_F \bar{z}_I z_{I,t}\left(\frac{L_{s,t}(j)}{L_{c,t}(j)}\right)^{1-\alpha_I}\right] = w_{c,t} + \mu_{c,t} - (1-\lambda_c)\beta\mathbb{E}_t\left[\frac{C_t}{C_{t+1}}\mu_{c,t+1}\right]$

$\{L_{s,t}(j)\}$: $\mu_{I,t}(j)\left[(1-\alpha_I)\bar{z}_I\left(\frac{L_{c,t}(j)}{L_{s,t}(j)}\right)^{\alpha_I}\right] = \frac{w_{s,t}}{z_{I,t}}$

$\{V_{c,t}(j)\}$: $\mu_{c,t}(j)q_I(\theta_{I,t}) = \chi_I \bar{z}_I z_{I,t}$

$\{P_{I,t}(i)\}$:

$$\frac{P_{I,t}(j)}{P_t} = \mu_{I,t}(j)\frac{\epsilon}{\epsilon-1} + \frac{1}{1-\gamma}\frac{\psi_I}{\epsilon-1}\frac{C_t}{Y_t}\frac{P_{I,t}}{P_t}\left(\frac{P_{I,t}(j)}{P_{I,t}}\right)^{\epsilon} \left[\beta\mathbb{E}_t\left[\left(\frac{P_{I,t+1}}{P_{I,t}}-1\right)\left(\frac{P_{I,t+1}}{P_{I,t}}\right)\right] - \left(\frac{P_{I,t}}{P_{I,t-1}}-1\right)\left(\frac{P_{I,t}}{P_{I,t-1}}\right)\right].$$

D.3 Wages

The formal private sector firms and workers negotiate wages using the Nash bargaining rule. The rule is described in equation (40). Using equation (40) and the FOCs for $\{L_{F,t}\}$ in the household optimisation and in the formal firms' optimisation, equation

(40) can be reworked as follows

$$
\begin{aligned}
(1-\tau)w_{p,t} = \varphi_F(1-\tau)\mu_{F,t}(i)\left[\alpha_F \bar{z}_F z_{F,t}\left(\frac{K_t(i)}{L_{F,t}(i)}\right)^{1-\alpha_F}\right] \\
+ (1-\lambda_p)(1-\varphi_F)\beta\mathbb{E}_t\left[\frac{\zeta_{C,t+1}}{\zeta_{C,t}}\frac{\zeta_{F,t+1}}{\zeta_{C,t+1}} f_F(\theta_{F,t+1})\right].
\end{aligned}
\tag{A6}
$$

Similarly, the wage of the casual worker is determined using equation (41) and the FOC for $\{L_{c,t}\}$ in the household's and in informal firms' optimisation problem. That is,

$$
\begin{aligned}
w_{c,t} = \varphi_I \mu_{I,t}(j)\left[\alpha_I \bar{z}_I z_{I,t}\left(\frac{L_{s,t}(j)}{L_{c,t}(j)}\right)^{1-\alpha_I}\right] \\
+ (1-\lambda_c)(1-\varphi_I)\beta\mathbb{E}_t\left[\frac{\zeta_{C,t+1}}{\zeta_{C,t}}\frac{\zeta_{I,t+1}}{\zeta_{C,t+1}} f_I(\theta_{I,t+1})\right].
\end{aligned}
\tag{A7}
$$

E Appendix

The model block has 29 equations and 29 variables. The complete set of equations that we have used in our calibration are as follows:

1. Euler equation for bonds

$$\frac{1}{R_t} = \beta \mathbf{E}_t \left[\frac{C_t}{C_{t+1}} \frac{1}{1+\pi_{t+1}} \right] \tag{A8}$$

   Variables: R_t, C_t, π_t

2. Consumption Euler equation

$$1 = \beta \mathbf{E}_t \left[\frac{C_t}{C_{t+1}} (1 - \delta + r_{t+1}) \right] \tag{A9}$$

   Variables: r_t, C_t

3. Private and public formal job equivalence

$$\begin{aligned} w_{p,t} = w_g z_{F,t}^{\alpha_g} + (1-\lambda_g)\beta \mathbf{E}_t \Bigg[\frac{C_t}{C_{t+1}} \left(w_{p,t+1} - w_g z_{F,t+1}^{\alpha_g} \frac{(1-\lambda_p)}{1-\lambda_g} \right) \\ (1 - M_{F0} \theta_{F,t+1}^{1-\eta_F}) \Bigg] \end{aligned} \tag{A10}$$

   Variables: $w_{p,t}, C_t, \theta_{f,t}$

4. Formal sector private job wage determination

$$\begin{aligned} w_{p,t} = & \varphi_F \frac{\alpha_F}{1-\alpha_F} r_t k_{F,t} + (1-\varphi_F) \frac{(1-\lambda_p)(1-\lambda_g)}{\lambda_p - \lambda_g} \\ & \beta \mathbf{E}_t \left[\left(\frac{C_t}{C_{t+1}} \right) \left(w_{p,t+1} - \frac{1-\lambda_p}{1-\lambda_g} w_g z_{F,t+1}^{\alpha_g} \right) M_{F0} \theta_{F,t+1}^{1-\eta_F} \right] \end{aligned} \tag{A11}$$

   Variables: $w_{p,t}, r_t, k_{F,t}, C_t, \theta_{F,t}$

5. labor demand equation (formal sector private firms')

$$\frac{w_{p,t}}{z_{F,t}} = \frac{r_t k_{F,t}}{z_{F,t}} \frac{\alpha_F}{1-\alpha_F} - \frac{\chi_F \bar{z}_F}{M_{F0} \theta_{F,t}^{-\eta_F}} + (1-\lambda_p)\beta \mathbf{E}_t \left[\frac{C_t}{C_{t+1}} \frac{\chi_F \bar{z}_F}{M_{F0} \theta_{F,t+1}^{-\eta_F}} \frac{z_{F,t+1}}{z_{F,t}} \right] \tag{A12}$$

   Variables: $w_{p,t}, r_t, k_{F,t}, C_t, \theta_{F,t}$

6. Public sector labor demand equation

$$L_{g,t}\phi = \left(\frac{w_g}{\bar{z}_g z_{F,t}\alpha_g}\right)^{\dfrac{1}{\alpha_g - 1}} \tag{A13}$$

Variable: $L_{g,t}$

7. Dynamic labor supply constraint in the formal sector

$$\begin{aligned} L_{p,t} + L_{g,t} = (1-\lambda_p)L_{p,t-1} + &(1-\lambda_g)L_{g,t-1} + M_{F0}\theta_{F,t}^{1-\eta_F} \\ &[1-(1-\lambda_p)L_{p,t-1} - (1-\lambda_g)L_{g,t-1}] \end{aligned} \tag{A14}$$

Variables: $L_{p,t}, L_{g,t}, \theta_{F,t}$

8. Per capita capital to total capital demand

$$K_t = L_{p,t}k_{f,t} \tag{A15}$$

Variables: $L_{p,t}, k_{f,t}, K_t$

9. Production function for formal sector

$$Y_{F,t} = \bar{z}_F z_{F,t} L_{p,t}^{\alpha_F} K_t^{1-\alpha_F} \tag{A16}$$

Variables: $Y_{F,t}, L_{p,t}, K_t$

10. Vacancy posting for private job in the formal sector

$$V_{p,t} = \frac{L_{p,t} - (1-\lambda_p)L_{p,t-1}}{M_{F0}\theta_{F,t}^{-\eta_F}} \tag{A17}$$

Variables: $V_{p,t}, L_{p,t}, \theta_{F,t}$

11. Vacancy posting for public job in the formal sector

$$V_{g,t} = \frac{L_{g,t} - (1-\lambda_g)L_{g,t-1}}{M_{F0}\theta_{F,t}^{-\eta_F}} \tag{A18}$$

Variables: $V_{g,t}, L_{g,t}, \theta_{F,t}$

12. Total formal vacancy

$$V_{F,t} = V_{p,t} + V_{g,t} \tag{A19}$$

Variables: $V_{F,t}, V_{p,t}, V_{g,t}$

13. Terms of trade equation (from formal sector)

$$TT_t = \left(\frac{(1-\alpha_F) z_{F,t} \bar{z}_F k_{f,t}^{-\alpha_F}}{r_t} \frac{\epsilon - 1}{\epsilon} \gamma^{\gamma} (1-\gamma)^{1-\gamma} \phi^{\frac{1}{\epsilon - 1}} \right)^{\frac{1}{1-\gamma}} \tag{A20}$$

Variables: $TT_t, k_{f,t}, z_{F,t}$

14. Informal sector, casual and self-employed job equivalence

$$w_{c,t} = \frac{w_{s,t}}{M_{I0} \theta_{I,t}^{1-\eta_I}} - (1-\lambda_c)\beta \mathbf{E}_t \left[\frac{C_t}{C_{t+1}} \frac{w_{s,t+1}}{M_{I0} \theta_{I,t+1}^{1-\eta_I}} \left(1 - M_{I0} \theta_{I,t+1}^{1-\eta_I}\right) \right] \tag{A21}$$

Variables: $w_{c,t}, w_{s,t}, c_t, \theta_{I,t}$

15. Casual wage determination

$$w_{c,t} = \varphi_I \frac{\alpha_I}{1-\alpha_I} w_{s,t} L_{I,t} + (1-\varphi_I)(1-\lambda_c)\beta \mathbf{E}_t \left[\frac{C_t}{C_{t+1}} w_{s,t+1} \right] \tag{A22}$$

Variables: $w_{c,t}, w_{s,t}, C_t, L_{I,t}$

16. Casual labor demand

$$\frac{w_{c,t}}{z_{I,t}} = \frac{\alpha_I}{1-\alpha_I} \frac{w_{s,t}}{z_{I,t}} L_{I,t} - \frac{\chi_I \bar{z}_I}{M_{I0} \theta_{I,t}^{-\eta_I}} + (1-\lambda_c)\beta \mathbf{E}_t \left[\frac{C_t}{C_{t+1}} \frac{z_{I,t+1}}{z_{I,t}} \frac{\chi_I \bar{z}_I}{M_{I0} \theta_{I,t+1}^{-\eta_I}} \right] \tag{A23}$$

Variables: $w_{c,t}, w_{s,t}, L_{I,t}, \theta_{I,t}, C_t$

17. Dynamic labor supply constraint in informal sector

$$L_{c,t} = (1-\lambda_c) L_{c,t-1} + (1 - (1-\lambda_c) l_{c,t-1} - L_{c,t} L_{I,t}) M_{I0} \theta_{I,t}^{1-\eta_I} \tag{A24}$$

Variables: $L_{c,t}, L_{I,t}, \theta_{I,t}$

18. Total self-employed labor demand

$$L_{s,t} = L_{c,t} L_{I,t} \tag{A25}$$

Variables: $L_{c,t}, L_{I,t}, L_{s,t}$

19. Casual vacancy posting

$$V_{c,t} = \frac{l_{c,t} - (1-\lambda_c) L_{c,t-1}}{M_{I0} \theta_{I,t}^{-\eta_I}} \tag{A26}$$

Variables: $V_{c,t}, L_{c,t}, \theta_{I,t}$

20. Informal sector production function

$$Y_{I,t} = \bar{z}_I z_{I,t} L_{c,t}^{\alpha_I} L_{s,t}^{1-\alpha_I} \tag{A27}$$

Variables: $Y_{I,t}, L_{s,t}, L_{c,t}$

21. NKPC

$$\begin{aligned} &\frac{\pi_t}{1-\gamma}\left(1+\frac{\pi_t}{1-\gamma}\right) = \\ &\frac{1}{\psi_I}\frac{Y_t}{C_t}(1-\gamma)\left[\frac{\epsilon\,(1-\phi)^{\frac{\epsilon}{\epsilon-1}}}{\gamma^\gamma(1-\gamma)^{1-\gamma}}\frac{1}{TT_t^\gamma}\frac{w_s}{(1-\alpha_I)z_{I,t}\bar{z}_I L_{I,t}^{-\alpha_I}} - \frac{\epsilon-1}{1-\phi}\right] \\ &+\beta\mathbf{E}_t\left[\frac{\pi_{t+1}}{1-\gamma}\left(1+\frac{\pi_{t+1}}{1-\gamma}\right)\right] \end{aligned} \tag{A28}$$

Variables: $\pi_t, Y_t, TT_t, C_t, L_{I,t}, w_{s,t}$

22. Law of Motion of Capital

$$K_{t+1} = I_t + (1-\delta)K_t \tag{A29}$$

Variables: K_t, I_t. K_t is the *predetermined* variable

23. Economy-wide production function

$$Y_t = A\left(\phi^{\frac{\epsilon}{\epsilon-1}} Y_{F,t}\right)^\gamma \left((1-\phi)^{\frac{\epsilon}{\epsilon-1}} Y_{I,t}\right)^{1-\gamma} \tag{A30}$$

Variables: $Y_t, Y_{F,t}, Y_{I,t}$

24. Consumption demand

$$C_t = Y_t - \phi\left(\chi_F \bar{z}_F V_{F,t} + \chi_g \bar{z}_g V_{g,t}\right) z_{F,t} - (1-\phi)\chi_I \bar{z}_I z_{I,t} V_{c,t} - I_t - (1-\phi)\frac{\psi_I}{2} C_t \left(\frac{\pi_t}{1-\gamma}\right)^2 \tag{A31}$$

Variables: $Y_t, V_{F,t}, V_{g,t}, C_t, i_t, \pi_t$

25. Taylor Rule

$$R_t = R_0\left(\frac{R_{t-1}}{R_0}\right)^{\rho_r}(1+\pi_t)^{\rho_\pi(1-\rho_r)}\varrho_t \tag{A32}$$

Variables: R_t, π_t

26. Real interest rate

$$RR_t = \frac{R_t}{1+\pi_{t+1}} \tag{A33}$$

Variables: RR_t, R_t, π_t

27. Total informal sector employment

$$Inf_{emp,t} = L_{c,t} + L_{s,t} \tag{A34}$$

Variables: $Inf_{emp,t}, L_{c,t}, L_{s,t}$

28. Total formal sector employment

$$For_{emp,t} = L_{p,t} + L_{g,t} \tag{A35}$$

Variables: $For_{emp,t}, L_{p,t}, L_{g,t}$

29. Stochatic discount factor

$$SDF_t = \beta \mathbf{E}_t \Big(\frac{C_t}{C_{t+1}} \Big) \tag{A36}$$

Variables: SDF_t, C_t

- Total number of variables: 29
- Total equations: 29
- Variable list

  $SDF_t, C_t, For_{emp,t}, L_{p,t}, L_{g,t}, Inf_{emp,t}, L_{c,t}, L_{s,t}, RR_t, R_t, \pi_t, Y_t,$
  $TT_t, L_{I,t}, w_{s,t}, V_{F,t}, V_{g,t}, I_t, Y_{F,t}, Y_{I,t}, K_t, \theta_{I,t}, V_{c,t}, w_{c,t}, k_{f,t}, V_{p,t}, \theta_{F,t}, r_t, w_{p,t}$

Description of Variables

1. SDF_t: The stochastic discount factor
2. C_t: Consumption
3. $For_{emp,t}$: Total formal employment
4. $L_{p,t}$: Labor in private enterprises(formal)
5. $L_{g,t}$: Labor in public sector (public)
6. $Inf_{emp,t}$: Total informal employment
7. $L_{c,t}$: Casual labor
8. $L_{s,t}$: Self-Employed labor
9. RR_t: Real Interest rate
10. R_t: Gross nominal interest rate on bonds
11. π_t: Inflation rate
12. Y_t: Total Output
13. TT_t: Terms of Trade
14. $L_{I,t}$: Ratio of casual to self labor (auxiliary variable)
15. $w_{s,t}$: Wage in self sector
16. $V_{F,t}$: Formal vacancy rate
17. $V_{g,t}$: Vacancy in public sector
18. I_t: Investment rate
19. $Y_{F,t}$: Total formal output
20. $Y_{I,t}$: Total informal output
21. K_t: Capital Stock
22. $\theta_{I,t}$: Labor market tightness in informal sector
23. $\theta_{F,t}$: Labor market tightness in formal sector
24. $V_{c,t}$: Vacancy in casual sector

25. $w_{c,t}$: Wages in casual sector

26. $k_{f,t}$: Ratio of capital stock to formal labor (auxiliary variable)

27. $V_{p,t}$: Vacancy in private sector

28. r_t: Gross interest rate on capital (rental rate)

29. $w_{p,t}$: Wages in private sector