General equilibrium welfare analysis of monetary policy using Indian household survey data

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Abstract

A change in the conventional monetary policy transmits to consumer prices and returns on financial assets, leading to a series of general equilibrium effects on household income and consumption. A simplistic dynamic general equilibrium model with household heterogeneity is developed to illustrate its transmission mechanism. The channels are then estimated by combining numerous household surveys and aggregate time series data. Compensating variation arising from the policy change quantifies the welfare outcomes which vary significantly over different sources of heterogeneity and different channels of transmission. The findings suggest weak and asymmetric monetary policy transmission into consumer prices, leading to weak first- and second-order price effects on household consumption. Household asset positions predominantly determine welfare consequences. The distributional analysis highlights a pro-rich bias of policy tightening.

Keywords: Welfare; Redistribution; Heterogeneity; Monetary policy; Indian household surveys.

JEL *classification:* C31; C32; D31; D60; E21; E52.

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1 Introduction

The uneven incidence of monetary policy interventions has been one of the central questions in the modern macroeconomic literature. As monetary policy propagates through various channels, quantifying the overall impact and assessing its distributional consequences is a challenging endeavor.

One traditional approach is to numerically solve a general equilibrium model to obtain the optimal policy functions of household consumption, income, and assets, and analyze their response to a monetary policy shock. The introduction of heterogeneity in such models (e.g., Gornemann et al. (2016); Kaplan et al. (2018); Auclert (2019); Bhandari et al. (2021); Bilbiie and Ragot (2021); Acharya et al. (2023))[1] provides a better understanding of the transmission channels and redistribution. However, only a limited source of heterogeneity can be incorporated into such models due to computational difficulties.

The empirical approach circumvents this issue; nevertheless, sticks to an aggregate level analysis (e.g., seminal work by Romer and Romer (1998) and later Galbraith et al. (2007); Villarreal (2014); Davtyan (2017) among others). Coibion et al. (2017) is one of the early studies that exploit the wide range of heterogeneity present in survey data to quantify inequality outcomes at the household level. However, they do not measure the welfare impact.

This paper introduces a direct measure of welfare, the compensating variation arising from a change in monetary policy. The novelty lies in estimating the compensating variation using survey data. This is achieved in two steps. First, derive the general equilibrium relationships between the policy variable and the household decisions using a simplistic dynamic general equilibrium model featuring heterogeneous households. Second, use regression estimations to obtain these correlations from survey data. As the compensating variation is derived from the household inter-temporal budget constraint, I am able to measure welfare explicitly through each of these estimated components for each household in the entire income distribution.

This framework exploits the notion of 'money metric welfare' (i.e., welfare measured in monetary units, e.g., Indian rupees). There is a long-standing strand of literature starting with Deaton (1987, 1988, 1990, 1997) and Friedman and Levinsohn (2002), who

[1]See McKay and Wolf (2023) for a summary of this literature.

argue that the welfare effect of a policy intervention on households can be estimated by the price elasticities and consumption shares of different consumer items in the household budget. Deaton (1987) explains that the tools for the welfare analysis of any policy measure are essentially the same; a theoretical model is developed linking the policy variable with prices and prices with the expenditure shares. Then, econometric techniques are used to estimate these links from survey data.

According to this analytical understanding, welfare, defined as compensating variation, is characterized by the change in the exogenous income in the household budget. Some of the applications include Petrin (2002) who evaluates the introduction of minivans in the US car market, Goolsbee and Petrin (2004) who examines the availability of satellite TV in addition to cable TV in US, Porto (2006) who assesses the Mercosur trade reforms in Argentina, Paul (2011) who evaluates welfare effect of tariff reform in India, De Nardi et al. (2016) who evaluate access to Medicaid insurance for retirees in US, and so forth. Nonetheless, this method is yet to be explored in evaluating the welfare outcomes of a monetary policy shock.

Another recent development using a similar method is the application of the envelope theorem to evaluate the 'money metric welfare' impact of macroeconomic shocks[2]. Some of the applications are notably by Fagereng et al. (2022), who analyze the impact of capital gains on welfare; Canto et al. (2023), who quantify the distributional effects of monetary policy shocks and oil shocks in the USA; Pallotti et al. (2023) who measure the effects of the recent inflation outburst in the euro area. Due to the envelop theorem, their welfare metric is defined from the Lagrangian in household optimization.

However, my welfare estimate is characterized by the compensating variation measured as the change in household exogenous income (therefore, in the line of Porto (2006) and others). The payoff of this approach is twofold. First, it reconfirms some of the crucial findings of the existing literature[3], that explores how monetary policy in-

[2]A detailed survey of the empirical methods, both parametric and non-parametric, that uses microdata for quantifying welfare-effects and dead-weight loss resulting from realized or hypothetical policy change can be found in Bhattacharya (2024)

[3]e.g., Ahmed and Dua (2001); Bhattacharyya and Ray (2007); Aleem (2010); Singh (2011); Khundrakpam and Jain (2012); Mishra and Mishra (2012); Mohanty (2012); Sengupta (2014); Das (2015); Mishra et al. (2016); Jawadi et al. (2016); Ghosh (2019); Bhattacharya and Jain (2020); Goyal and Parab (2021); Sengupta et al. (2023) use time series econometrics to analyze monetary policy transmission into real economic variables in India.

fluences real economic variables in India. Consistent with their findings, I obtain weak and asymmetric monetary policy transmission into consumer prices and observe wide variation in the magnitude and direction of co-movements among prices of different consumer goods. Second, this study reduces the disconnect between the two mainstream approaches that evaluate the welfare implication of monetary policy. While the general equilibrium model provides a micro-foundation to the channels that are estimated, the extensive use of survey data allows me to exploit numerous sources of heterogeneity present in the data, like heterogeneity in skills, sources of income, budget allocation in consumption, and sectoral location (rural, urban).

One obvious obstacle is the availability of comparable data sets for different socio-economic indicators. Household surveys in India are predominantly sample surveys that are irregular and outdated. I approach this problem by considering the surveys with the least time difference and using econometric techniques to approximate their original distribution. Then, the comparability of the original and the approximated distribution are examined using different statistical tests.

While there are certain drawbacks in such approximations, being able to tie these variables together contributes significantly to quantifying the effect. my findings suggest that, on average, a monetary policy tightening from 4% to 5% leads to a welfare reduction by Rs.165.61 in $2011-12$ prices, in rural households, which is around 17% of the rural poverty line as recommended by the Rangrajan Committee 2014. It leads to a welfare reduction by Rs.405.00 in urban households, in $2011-12$ prices, which is around 29% of the urban poverty line. As the welfare estimates are obtained for each household, it is feasible to employ local polynomial regressions to observe the differential impact on different parts of the income distribution over different sources of heterogeneity. Richer households almost uniformly appear to be immune to the policy change.

The non-availability of reliable recent data on household consumption, income, and debt investments is an inevitable constraint. This study offers a flexible method that can be reproduced and updated on the availability of recent data. It can also be replicated with suitable data from countries that use interest rate as a conventional monetary policy instrument.

The rest of this paper is organized as follows. Section 2 discusses the general equilibrium model featuring household heterogeneity, from which the detailed derivation of compensating variation is explained in section 3. Section 4 contains the data sources, the estimation strategies, and the analysis of results. Section 5 provides the concluding remarks.

2 A general equilibrium model with household heterogeneity

In this section, I derive the general equilibrium relationships between monetary policy (repo rate) and household consumption, wage earnings, and return on financial assets using a simplified version of the two-agent model by Debortoli and Gali (2017) along with the two-sector model by Aoki (2001). The purpose of this model is to identify the channels of monetary policy pass-through and derive the estimable form of the compensating variation.

2.1 Households

Consider an economy populated with households j, each having household members i who possess skill level n. Household members supply labor l_{nt}^{ij} to firms and earn wages w_{nt}, where n can be high H, medium M, and low L. Households consume two types of homogeneous goods: traditional goods, a, and modern goods, m. And they save in financial assets b. The expected lifetime utility of an infinitely lived household j is,

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[u_t^j - v_t^j \right] \tag{1}$$

where β is the discount rate. The household utility takes CRRA form,

$$u_t^j = \frac{{c_{at}^j}^{1-\sigma_a}}{1-\sigma_a} + \frac{{c_{mt}^j}^{1-\sigma_m}}{1-\sigma_m} \tag{2}$$

$$v_t^j = \frac{{l_{Ht}^j}^{1+\psi_H}}{1+\psi_H} + \frac{{l_{Mt}^j}^{1+\psi_M}}{1+\psi_M} + \frac{{l_{Lt}^j}^{1+\psi_L}}{1+\psi_L} \tag{3}$$

where, c_{at}^j and c_{mt}^j are real consumption expenditure on goods a and m. Labor markets are perfectly competitive for each type of skill. Household choice variables are real consumption expenditures on two goods and the labor supply of each skill type (note: there may be multiple members of one skill type within a household; the household chooses the total labor supply of each skill type given a competitive wage rate for each skill type). Households receive return r_{bt} on asset. Besides wage earning $\sum_i w_{nt}\, l_{nt}^{ij}$ and return on asset $r_{bt}\, b_t^j$, households receive some exogenous income x_t^j. The evolution of household assets, therefore, follows,

$$b_{t+1}^j = \sum_i w_{nt}\, l_{nt}^{ij} + r_{bt}\, b_t^j + x_t^j - C_{at}^j - C_{mt}^j \tag{4}$$

where $C_{at}^j = p_{at}\, c_{at}^j$ and $C_{mt}^j = p_{mt}\, c_{mt}^j$ are nominal consumption expenditures. A change in x_t^j is the amount of money that a household should receive or give up to remain at the same level of utility; therefore, it provides the measure of compensating variation as in Hicks (1939) and Mas-Collel et al. (1995). Households maximize expected lifetime utility in equation 1 subject to the budget constraint in equation 4 (see Appendix 5.1).

2.2 Firms

2.2.1 Traditional firm

The traditional firm produces homogeneous traditional goods, using labor of all skill types and capital, and sells them in a perfectly competitive market.

$$Y_t^a = F(L_{Ht}^a, L_{Mt}^a, L_{Lt}^a, K_t^a) \tag{5}$$

Where Y_t^a is the total output of traditional goods, L_{nt}^a is the total labor demand for skill type n, and K_t^a is the total demand for capital in the traditional sector. Household invests their assets b into productive capital k at a given return r_{bt}, and firm hire capital for production at the competitive rate r_{kt}, which depreciates at rate δ. At equilibrium, $r_{bt} = r_{kt} - \delta$. The profit of traditional representative firm at time t is,

$$\Pi_t^a = p_{at} Y_t^a - w_{Ht}\, L_{Ht}^a - w_{Mt}\, L_{Mt}^a - w_{Lt}\, L_{Lt}^a - r_{kt} K_t^a \tag{6}$$

where, p_{at} is the competitive price of traditional goods. The representative firm chooses demand for factors of production given the competitive price of inputs to maximize profit (detailed derivation in Appendix 5.2); therefore,

$$p_{at} = f(w_{Lt}, w_{Mt}, w_{Ht}, r_{kt}). \tag{7}$$

2.2.2 Modern firm

The modern firm produces homogeneous modern goods, using labor of all skill types and capital, and sells them in a perfectly competitive market.

$$Y_t^m = G(L_{Ht}^m, L_{Mt}^m, L_{Lt}^m, K_t^m) \tag{8}$$

where Y_t^m is the total output of modern goods, L_{nt}^m is the total labor demand for skill type n, and K_t^m is the total demand for capital in the modern sector. The profit of modern representative firm at time t is,

$$\Pi_t^m = p_{mt} Y_t^m - w_{Ht}\, L_{Ht}^m - w_{Mt}\, L_{Mt}^m - w_{Lt}\, L_{Lt}^m - r_{kt} K_t^m \tag{9}$$

where, p_{mt} is the competitive price of modern goods. The representative modern firm maximizes profit at each period (detailed derivation in Appendix 5.3); therefore,

$$p_{mt} = g(w_{Lt}, w_{Mt}, w_{Ht}, r_{kt}). \tag{10}$$

2.3 Monetary policy authority

Monetary policy authority sets the nominal interest rate (repo rate) r_t following a Taylor-type rule,

$$r_t = \bar{r}_{b,t} + \beta \Pi_t + \zeta_t \tag{11}$$

where $\bar{r}_{b,t}$ is steady state real interest rate on asset b, $\beta > 0$ and $\zeta_t = 0$ at steady state. In a general equilibrium model, the real interest rate is determined by Fisher equation $r_{b,t} = i_{b,t} - \Pi_t$ at given $i_{b,t}$ and Π_t, and that rate must be consistent with the equilibrium condition of asset market. This paper studies the welfare effect of a one-time shock ζ_t. Note that the households choose the path of b_t at a given real rate $r_{b,t}$ and firms hire capital at the given rate r_{kt}; therefore, at equilibrium $r_{bt} = r_{kt} - \delta$ must hold, where δ is the rate depreciation of capital.

A conventional exercise of analytically and numerically solving the model to obtain the steady state real interest rate can be ignored here as this paper utilizes an empirically estimated value of the pass-through from the repo rate to the return on household financial assets. Therefore, the simplest form of that relationship becomes,

$$r_{bt} = \alpha\, r_t \tag{12}$$

where α is the pass-through of the repo rate into the return on asset. Hence, the effect of a monetary policy intervention through ζ that changes r_t, leads to a change in $r_{b,t}$ to the magnitude of $\alpha\, r_t$.

2.4 Equilibrium

The equilibrium of the economy is defined as the set of prices $\{p_{at}, p_{mt}, w_{Lt}, w_{Mt}, w_{Ht}, r_{bt}, r_{kt}\}$ and allocations $\{Y_t^a, Y_t^m, c_{at}^j, c_{mt}^j, L_{nt}^a, L_{nt}^m, b_t^j, K_t^a, K_t^m\}$ such that the households maximize expected lifetime utility, firms maximize profits, and all markets clear. The goods markets clear when,

$$\sum_j c_{at}^j = Y_t^a\,, \quad \sum_j c_{mt}^j = Y_t^m \tag{13}$$

the labor markets clear for each skill type when,

$$L_{nt}^a + L_{nt}^m = \sum_j \sum_i l_{nt}^{ij}\,, \quad n \in \{H, M, L\} \tag{14}$$

capital market clear when,

$$\sum_j b_t^j = K_t^a + K_t^m \tag{15}$$

Combining equation 7 and 10 with equilibrium condition in equation 14I obtain (derivation in the Appendix 5.4),

$$p_{at} = f_1(p_{mt}, w_{Lt}, w_{Mt}, w_{Ht}, r_{kt}) \tag{16}$$

and

$$p_{mt} = g_1(p_{at}, w_{Lt}, w_{Mt}, w_{Ht}, r_{kt}) \tag{17}$$

A change in the repo rate leads to a change in the return on asset through equation 12, which influences prices following equation 16 and 17. This leads to three sets of adjustments in household consumption and income. (1) The first-order price effects: the effect on consumer expenditure due to changes in the prices. (2) The second-order price effects: the effect on consumer expenditure due to the interdependence of prices, i.e., prices influencing each other after the first-order price effect. (3) The wage-earning effect: the general equilibrium reaction of wage earnings to a change in r_{bt}. These can also be categorized broadly into indirect and direct effects. Change in the repo rate changes prices of consumer goods, which gives rise to the first- and second-order price effects and wage-earning effects; therefore, they are indirect effects. On the other hand, a change in the repo rate inducing a change in r_{bt} directly effects the income of the households; therefore, it is a direct effect. The first- and second-order price effects are traditionally known as the *consumption effect*, and the effect on wage earning through prices of consumer goods is known as the *labor income effect*.

3 Derivation of compensating variation

Compensating variation is measured as the changes in the exogenous income x_t^j for each household j. Taking total derivative of equation 4,

$$\begin{aligned} dx_t^j = & \frac{\partial C_{at}^j}{\partial p_{at}} dp_{at} + \frac{\partial C_{at}^j}{\partial p_{mt}} \frac{\partial(p_{mt})}{\partial(p_{at})} dp_{at} - \frac{\partial(\sum_i w_{nt} l_{nt}^{ij})}{\partial p_{at}} dp_{at} \\ & + \frac{\partial C_{mt}^j}{\partial p_{mt}} dp_{mt} + \frac{\partial C_{mt}^j}{\partial p_{at}} \frac{\partial(p_{at})}{\partial(p_{mt})} dp_{mt} - \frac{\partial(\sum_i w_{nt} l_{nt}^{ij})}{\partial p_{mt}} dp_{mt} + \frac{\partial b_{t+1}^j}{\partial r_{bt}} dr_{bt} - \frac{\partial(r_{bt} b_t^j)}{\partial r_{bt}} dr_{bt} \end{aligned} \tag{18}$$

changes in the prices are induced by changes in interest rate, therefore,

$$dp_{at} = \frac{\partial p_{at}}{\partial r_{bt}} dr_{bt}, \;\; dp_{mt} = \frac{\partial p_{mt}}{\partial r_{bt}} dr_{bt} \tag{19}$$

with some rearrangements, the compensating variation is obtained as,

$$\begin{aligned} \frac{dx_t^j}{e_t^j} = & s_{at}^j \epsilon_{a,r} \frac{dr_{bt}}{r_{bt}} + s_{mt}^j \epsilon_{m,a} \epsilon_{a,r} \frac{dr_{bt}}{r_{bt}} - \theta_t^j \gamma_a \epsilon_{a,r} \frac{dr_{bt}}{r_{bt}} \\ & + s_{mt}^j \epsilon_{m,r} \frac{dr_{bt}}{r_{bt}} + s_{at}^j \epsilon_{a,m} \epsilon_{m,r} \frac{dr_{bt}}{r_{bt}} - \theta_t^j \gamma_m \epsilon_{m,r} \frac{dr_{bt}}{r_{bt}} \\ & + s_{bt+1}^j \epsilon_{bt+1,r} \frac{dr_{bt}}{r_{bt}} - s_{bt}^j (\epsilon_{bt,r} + 1) dr_{bt} \end{aligned} \tag{20}$$

where e_t^j is the household consumption expenditure at time t, $s_{at}^j = \frac{C_{at}^j}{e_t^j}$ and $s_{mt}^j = \frac{C_{mt}^j}{e_t^j}$ are the shares of household consumption expenditure on a and m, $s_{bt+1}^j = \frac{b_{t+1}^j}{e_t^j}$ and $s_{bt}^j = \frac{b_t^j}{e_t^j}$ are the ratio of household assets to household consumption expenditure for the period $t+1$ and t. $\theta_t^j = \frac{\sum_i w_{nt} l_{nt}^{ij}}{e_t^j}$ are the ratio of household wage-earning to household consumption expenditure. $\epsilon_{a,r} = \frac{\partial p_{at}}{\partial r_{bt}} \frac{r_{bt}}{p_{at}}$ and $\epsilon_{m,r} = \frac{\partial p_{mt}}{\partial r_{bt}} \frac{r_{bt}}{p_{mt}}$ are elasticities of prices with respect to r_{bt}, $\epsilon_{m,a} = \frac{\partial p_{mt}}{\partial p_{at}} \frac{p_{at}}{p_{mt}}$ and $\epsilon_{a,m} = \frac{\partial p_{at}}{\partial p_{mt}} \frac{p_{mt}}{p_{at}}$ are elasticities between prices, note that these elasticities can not be interpreted as own or cross-price elaticities. $\gamma_a = \frac{\partial(\sum_i w_{nt} l_{nt}^{ij})}{\partial p_{at}} \frac{p_{at}}{\sum_i w_{nt} l_{nt}^{ij}}$ and $\gamma_m = \frac{\partial(\sum_i w_{nt} l_{nt}^{ij})}{\partial p_{mt}} \frac{p_{mt}}{\sum_i w_{nt} l_{nt}^{ij}}$ are the elasticities of wage earnings with respect to prices, and $\epsilon_{bt+1,r} = \frac{\partial b_{t+1}^j}{\partial r_{bt}} \frac{r_{bt}}{b_{t+1}^j}$, $\epsilon_{bt,r} = \frac{\partial b_t^j}{\partial r_{bt}} \frac{r_{bt}}{b_t^j}$ are the elasticities of household savings with respect to r_{bt} at period $t+1$ and t.I estimate the elasticity of wage earnings with respect to prices for each type of skill, i.e., $\gamma_{H,a}$, $\gamma_{M,a}$, $\gamma_{L,a}$, $\gamma_{H,m}$, $\gamma_{M,m}$, and $\gamma_{L,m}$.

4 Estimation using survey data

Having established the estimable form of the compensating variation, this section discusses the estimation process using data and presents the results for each component in the equation 20. It consists of three types of components: the shares s's and θ's, the elasticities ϵ's and γ's, and the change in r_{bt}.

Among the shares, $s_{a,t}$ and $s_{m,t}$ are directly obtained from the survey date; therefore, no estimation is required. The shares $s_{b,t}$ and θ_t are calculated from the data that involves some prediction analysis.

The pass-through of the repo rate r_t into r_{bt} is obtained from the existing literature. I consider the weighted average call money rate (WACR) as r_{bt} throughout the empirical estimation because it is the operating target of the monetary policy in India, which means the central bank controls liquidity to anchor this rate close to the policy rate. Das (2015)[4] finds that the long-run elasticity between the repo rate and WACR is 1.43[5]. I also obtain the elasticity of household savings with respect to the interest rate $\epsilon_{b,r}$ from Athukorala and Sen (2004)[6]. They report the long-run response of the saving rate with respect to the real interest rate is 0.20.

The elasticities ϵ's and γ's are estimated using numerous econometric techniques that are discussed in the following subsections.

4.1 Consumption effect

$s^j_{at}\epsilon_{a,r}\frac{dr_{bt}}{r_{bt}}$, $s^j_{mt}\epsilon_{m,a}\epsilon_{a,r}\frac{dr_{bt}}{r_{bt}}$, $s^j_{mt}\epsilon_{m,r}\frac{dr_{bt}}{r_{bt}}$ and $s^j_{at}\epsilon_{a,m}\epsilon_{m,r}\frac{dr_{bt}}{r_{bt}}$ measures effect consumption expenditure. To calculate the expenditure shares, I need data on the household budget

[4]Das (2015) uses a vector error correction model on bi-monthly data from end-March 2002 to end-October 2014 to estimate pass-through from the repo and reverse repo rate to bank lending and deposit rates in India.

[5]I test the sensitivity of my results to a change in this pass-through. I drastically reduce the value from 1.43 to 0.5 indicating that a one percentage point repo rate tightening now leads to only a half percentage point increase in WACR. Figures 8 and 9 in the appendix depict the total indirect effect in rural and urban areas, side by side, for the original and newly implemented value of the pass-through. Only a minor effect of this change is noticed at the two ends of the distribution, making the overall effect negligible.

[6]Athukorala and Sen (2004) undertake a comprehensive investigation on the various determinants of the savings rate in India. This is one of the few studies that provide a reliable estimate of the correlation between savings and the real interest rate. The recent findings by Ghosh and Nath (2023) suggest a fairly close value of this correlation to be 0.13; however, I choose to carry on my exercise with the value 0.20

shares on different consumer goods.

The National Sample Survey Organisation (NSSO) conducts primary surveys in India to collect household and individual data on different socio-economic variables. I use NSSO 68^{th} round Household Consumer Expenditure Survey Type 1[7], conducted between July 2011 and June 2012 to obtain household consumer expenditure on different items. This is the latest available survey of this kind. The consumer items are classified into categories a and m. Category a consists of all food and energy items[8] and category m consists of all other consumer items. The reason behind this categorization is that the literature suggests, in India, food and energy prices are mostly influenced by supply-side factors (Nair and Eapen, 2012; Anand et al., 2016; Bhoi et al., 2019); therefore, they are less sensitive to a change in the domestic monetary policy, compared to other consumer items.

To estimate the elasticities, I obtain data on the consumer price indices (CPIs) for different consumer items from the Economic and Political Weekly Research Foundation from January 1996 to December 2019, in monthly frequency. They published CPIs separately for agricultural laborers (AL) and industrial workers (IW) till 2011. Therefore, CPI for rural and urban households is only available from 2012 onwards. CPI AL and CPI IW, being the longer series, are the obvious choice for the estimation. However, NSSO surveys do not ask questions about whether the households belong to AL or IW categories. Therefore, rural households are associated with CPI AL, and urban households are associated with CPI IW.

I use monthly data on the Weighted Average Call Rate (WACR), the exchange rate of the Indian rupee with respect to the dollar (ER), and the Index of Industrial Production (IIP) from January 1996 to December 2019 along with the monthly CPIs to estimate $\epsilon_{a,r}$, $\epsilon_{m,r}$, $\epsilon_{a,m}$, and $\epsilon_{m,a}$. Data on WACR, ER, and IIP are obtained from the *Real Time Handbook of Statistics on the Indian Economy* published by the Reserve Bank of India.

I check the stationarity of the log deseasonalized variables, determine the optimal lag, and apply a suitable regression model depending on the order of integration, in this case, a vector auto-regression and auto-regressive distributed lag model[9] on the

[7]Because Type 1 collects data on durable as well as non-durable consumer expenditure.

[8]Block 5.1, 5.2 and 6 in Consumer Expenditure Survey Schedule 68 Type 1.

[9]There are a number of studies that explore the elasticities between prices and interest rates in India

variables.

The rationale behind using WACR in this estimation is that it is the operating target[10] of monetary policy in India that influences consumer price movements. The prices of consumer goods are majorly influenced by short-term interest rates like WACR, and household savings decisions are primarily motivated by the return on savings offered by banks. Therefore, WACR is used to estimate $\epsilon_{a,r}$, $\epsilon_{m,r}$, whereas the deposit rate in commercial banks is used to obtain $\epsilon_{b,r}$.

4.2 Labor income effect

$\theta_t^j \gamma_a \epsilon_{a,r}$ and $\theta_t^j \gamma_m \epsilon_{m,r}$ in equation 20 measures the effect on wage earnings. To estimate the elasticity of wage earnings with respect to prices, data on the individual wage earnings for different types of skilled labor are obtained from NSSO 68^{th}, 66^{th}, 64^{th}, 62^{nd} and 61^{st} rounds of Employment and Unemployment Survey conducted in $2004-05$, $2005-06$, $2007-08$, $2009-10$ and $2011-12$. These are the latest five employment-unemployment surveys by NSSO that collect data on labor income and various other labor-force indicators. Using five consecutive surveys provides the time variation that is crucial for the estimation.

Porto (2006) explains the problem of using consumer prices in a regression is the lack of price variability across households, and to overcome this issue, one can exploit the time variability of prices and the time variability of surveys[11]. The estimations for rural and urban households are carried out separately.

$$\begin{aligned} ln(w_n^j) = \delta_0 + \sum_i \big(\eta_{Hi}^j\, edu_H^j * ln(p_i) + \eta_{Mi}^j\, edu_M^j * ln(p_i) + \eta_{Li}^j\, edu_L^j * ln(p_i)\big) \\ + \delta_{1H}^j edu_H^j + \delta_{2M}^j edu_M^j + \delta_{\mathbf{3n}}^{\mathbf{j}} \mathbf{X_n^j} + \delta_{4n}^j State_n^j + \delta_{5n}^j Time_n^j + e_n^j \end{aligned} \tag{21}$$

where $i \in \{a, m\}$, and $n \in \{L, M, H\}$. edu's are skill dummies. Skill is captured by education level; edu_L^j takes value one if the individual's education level is below

using this method, e.g., Hutchison et al. (2010); Ghosh (2019).

[10] An operating target is the interest rate variable that is directly controlled by monetary policy actions of the central bank of India. Rapid transmission from the policy rate (repo rate) into WACR is considered to be an efficient operating procedure. WACR represents the rate at the unsecured overnight money market.

[11] This approach has also been explored by Goldberg and Tracy (2003) to estimate wage responses from a change in exchange rate by exploiting the time variability of the Current Population Surveys in the United States.

primary and zeros otherwise. Similarly, edu_M^j and edu_H^j represent education levels below secondary and secondary or above, respectively. The wage earnings across skills are assumed to respond to price changes differently. And the interaction of prices with education dummies resolves the issue that prices have no variation over households. $\mathbf{X}_n^j$ is the vector of individual characteristics such as age, sex, religion, social group, etc. The sum of coefficients η_{ni}^j over n is the elasticity of wage earnings with respect to prices of item category i. δ_0 is the constant and e_n^j is the random error.

The wage earnings of households in the Household Consumer Expenditure Survey are predicted using the information available from the Employment and Unemployment Survey. I apply a two-part method to obtain the prediction for each household member and then sum them up within each household. First, a binary variable P_n^j is created that takes the value one if member n in the household (j) from the employment-unemployment survey earns wage, zero otherwise. Then P_n^j is regressed on individual and household level characteristics $(\mathbf{Y_n^j})$. The individual-level controls include age, gender, and education, while the household-level controls include consumption expenditure, household size, main occupation (agricultural, self-employed, etc.), religion, social group, and sector (rural, urban).

$$P_n^j = \varphi_0 + \varphi_{\mathbf{1}} \mathbf{Y_n^j} + \omega_n^j \tag{22}$$

where φ_0 is the constant, ω_n^j is the random error. The estimated coefficients from this equation are inserted in equation 23 to obtain the predicted probabilities. The sample is restricted to include individuals only in the working age group, i.e., aged 15 to 65.

$$\widehat{P_n^j} = \hat{\varphi}_0 + \hat{\varphi}_{\mathbf{1}} \mathbf{Y}_n^j \tag{23}$$

where $\widehat{P_n^j}$ is the predicted probability of wage earning for member n in household j in the Household Consumer Expenditure Survey and $\hat{\varphi}$'s are the estimated coefficients from the Employment and Unemployment Surveys, and $\mathbf{Y_n^j}$ consists of the same variables as in equation 22.

In the second part, a Mincer (1974) specification is applied to regress log wage earning for member n in household j in the Employment and Unemployment Survey on their education, age, and age^2 with a bunch of individual and household level controls.

$$ln(w_n^j) = \varphi_{01} + \varphi_{02}\, Education_n^j + \varphi_{03}\, Age_n^j + \varphi_{04}\, {Age_n^j}^2 + \varphi_{\mathbf{05}}\, \mathbf{Z_n^j} + \omega_n^j. \tag{24}$$

Then, I take the estimated coefficients and apply the exact same specification on members n of households j from the Household Consumer Expenditure Survey,

$$\widehat{ln(w_n^j)} = \hat{\varphi_{01}} + \hat{\varphi_{02}}\, Education_n^j + \hat{\varphi_{03}}\, Age_n^j + \hat{\varphi_{04}}\, {Age_n^j}^2 + \hat{\varphi_{\mathbf{05}}}\, \mathbf{Z_n^j} \tag{25}$$

where $\hat{\varphi}$'s are the estimated coefficients from the Employment and Unemployment Surveys. Z_n^j is the vector of the exact same variables as in 24. I transform $\widehat{ln(w_n^j)}$ into $\widehat{w_n^j}$ following Wooldridge (2013) p.212, using, $\widehat{w_n^j} = (\exp \frac{Error\,Variance}{2})\,(\exp \widehat{ln(w_n^j)})$, where $Error\,Variance$ is approximated using the mean squared error from the regression 24. Finally, the predicted wage earning $\widehat{w_n^j}$ are multiplied with $\widehat{P_n^j}$ and summed up over all members n in household j to obtain the expected sum of predicted wage earning for each household in the Household Consumer Expenditure Survey that is used in the calculation of θ_n^j.

4.3 Direct effect

The components that measure the direct effect are; s_{bt+1}^j, $\epsilon_{bt+1,r}$, s_{bt}^j, and $\epsilon_{bt,r}$. NSSO 70^{th} round Debt & Investment Survey conducted between January-December 2013 provides data on the household financial assets. This is not the most recent survey of this kind; however, this is the closest in date to the latest available Household Consumer Expenditure Survey that was conducted between July 2011 and June 2012. The sample households in these two surveys being different, I need to predict the financial asset holding of the households in the Consumer Expenditure Survey from the information available in the Debt & Investment Survey. Using surveys conducted around the same reduces the time variability in the household characteristics used in the prediction.

The same prediction method is applied as in equation 24 to obtain the value of household financial assets (b_t^j) in the Household Consumer Expenditure Survey from the information available in the Debt & Investment Survey. I estimate,

$$ln(b_t^j) = \varphi_2 + \varphi_{\mathbf{3}}\mathbf{Z_1^j} + \omega^j \tag{26}$$

where b_t^j is the total financial assets holding of household j in the Debt & Investment Survey, φ_2 is constant, $\mathbf{Z_1^j}$ is the vector of household characteristics like household size, number of households members with different (below primary, primary, secondary and above) education level, number of senior citizens, household type (agricultural, self-employed, etc.), religion, social group, sector (rural, urban) and age, sex, education level of the household head, etc., ω^j is random error. I take the estimated coefficients $\hat{\varphi}$s from 26 and obtain b_t^j for the households in the Household Consumer Expenditure Survey using,

$$\widehat{ln(b_t^j)} = \hat{\varphi}_2 + \hat{\varphi}_\mathbf{3}\mathbf{Z_1^j} \tag{27}$$

and $\widehat{ln(b_t^j)}$ is transformed into $ln(b_t^j)$ using the same method as specified before in section 4.2.

It is assumed that $s_{bt+1}^j = s_{bt}^j$. The predicted value of household financial assets to household consumer expenditure ratio at $t+1$ and t can not be distinguished due to the limitation of available data sets on these variables. However, if one has access to more frequent and comparable datasets on this, the aforementioned prediction method can be employed to obtain both s_{bt+1}^j and s_{bt}^j. Nonetheless, this assumption leads to an upward bias in my estimation, i.e., a bigger value of the direct effect that dominates all indirect effects.

As discussed earlier, I obtain the value of $\epsilon_{b,r}$ from the literature. Athukorala and Sen (2004)[12] suggest that the elasticity of private savings with respect to the real interest rate in India is 0.20. Private savings include household as well as corporate savings. This is the closest estimate found in the literature that is relevant to my calculations. It is also assumed that the elasticity of household savings with respect to interest rate does not change drastically for consecutive periods; therefore, $\epsilon_{bt+1,r} = \epsilon_{bt,r}$.

4.4 Elasticities and compensating variation estimates

In this section, I analyze the results obtained from each of the aforementioned estimation methods and tie them together to obtain the overall estimates of the compensating variation for each household over different sources of heterogeneity.

4.4.1 Elasticities of prices

The elasticities of prices with respect to interest rate ($\epsilon_{a,r}$, $\epsilon_{m,r}$) and the elasticities among prices ($\epsilon_{a,m}$, $\epsilon_{m,a}$) are estimated using data on log of CPIs, WACR, ER, and IIP.

[12] Athukorala and Sen (2004) look at the determinants of private savings in India. They found that the real interest rate on bank deposits has a positive and significant impact on the private savings rate. They primarily investigate how inflation affects private savings in India. Their findings suggest that inflation positively affects the private saving rate over and above its effect operating through the real return to saving.

All the variables exhibit strong seasonality; however, the seasonal variation in WACR has reduced in recent years. Therefore, all the variables are de-seasonalized and then tested for stationarity using the Dickey-Fuller (DF), Augmented Dickey-Fuller (ADF), and Philips-Perron (PP) tests. CPIs, ER, and IIP exhibit non-stationarity at the level; they become stationarity at the first difference. However, WACR is stationary at the level. Due to the difference in the order of integration among variables, the appropriate model to choose is an Auto Regressive Distributed Lag (ARDL) model. The parameters for rural and urban are estimated separately; the results are depicted in table 3 in the Appendix. Some of the coefficients are statistically insignificant at some of the lags. They are tested for the joint significance of all lag coefficients for each variable using the F test, which is statistically significant. Elasticities (ϵ) are the sum of the coefficients of the respective variables over all the lags. I also estimate the coefficients using a Vector Auto Regression (VAR) model at differences to check the robustness of the ARDL results. Table 4 in the Appendix depicts that the elasticities obtained from the ARDL and the VAR model are fairly close. Table 1 illustrates weak and asymmetric monetary

Table 1: Estimated Elasticities of CPIs with Respect to WACR and Elasticities Between CPIs for Rural and Urban Households

Elasticity	Description	Rural	Urban
$\epsilon_{a,r}$	p_a w.r.t. $WACR$	0.0014	0.0017
$\epsilon_{m,r}$	p_m w.r.t. $WACR$	0.0012	-0.0020
$\epsilon_{a,m}$	p_a w.r.t. p_m	0.0053	-0.0140
$\epsilon_{m,a}$	p_m w.r.t. p_a	0.0167	0.1355

policy transmission and weak co-movements among consumer prices. Food and energy prices are positively correlated with the short-term interest rate (WACR). The varying signs of elasticities among prices indicate asymmetric relationships among prices. The varying magnitudes indicate different levels of price stickiness in different consumer item categories. These signs and magnitudes in elasticities can not be interpreted with the theoretical understanding of the underlying relationships. As Porto (2006) obtains similar asymmetries and explains that while estimating these complex, general equilibrium relationships, there are no theoretical predictions. The author also refers to Dixit and Norman (1980), suggesting that the complex general equilibrium relationships are not transitive. This relates to the larger strand of literature that estimates the own and cross-price elasticities of different commodity items in the household budget. Pioneering works like Deaton (1989) provide evidence of varying signs and magnitudes of own and cross-price elasticities for meat, fish, starches, cereals, etc. in rural and urban areas.

4.4.2 First and second order price effects

The shares of household consumption expenditure on items a and m are obtained from the NSSO 68^{th} round Household Consumer Expenditure Survey conducted between $2011-12$. This survey comprises of $1,01,662$ households. Around 60% of them live in rural areas, and around 40% of them live in urban areas. Figure 1 depicts that

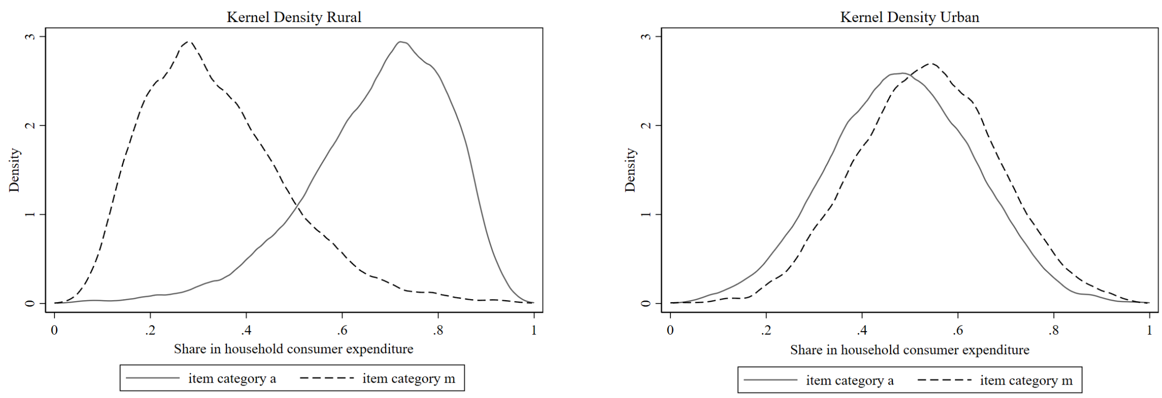

Figure 1: Kernel Density of Consumption Shares

rural households allocate almost 80% of their total expenditure only on food and energy (category a), while urban households spend almost equally on categories a and m. This stark difference in the allocation of the household budget itself is an indication that monetary policy transmission will differ substantially between rural and urban areas.

The expenditure shares are multiplied with the respective elasticities and rate of change in WACR following equation 20 to derive CV for each household arising from the first- and second-order price effects. I observe the distributional effects using locally weighted Fan (1992) regressions along the log per capita expenditure. Conceptually, this runs linear or polynomial (wherever applicable) regressions of the compensating variation on the log of per capita expenditure using only local data points. This non-parametric approach is suitable in scenarios where the nature of the underlying relationships is unknown and can vary at different per-capita expenditure levels. A non-parametric approach allows the data to choose the best local shapes of the regression function. Figure 2 plots CV as % of household expenditure along log per capita expen-

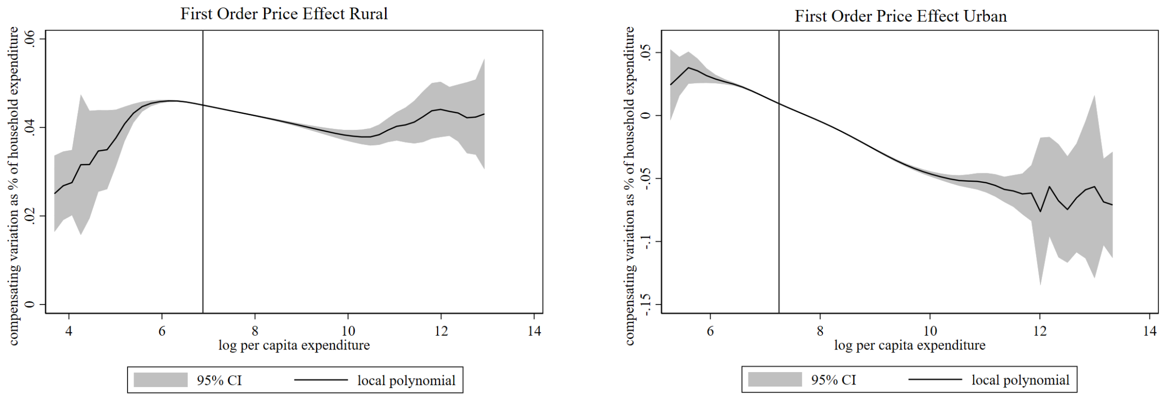

Figure 2: First Order Price Effects

diture due to a monetary policy (repo rate) tightening from 4% to 5%. The vertical lines correspond to poverty lines at monthly per capita consumer expenditure of Rs. 972 in rural areas and Rs. 1407 in urban areas at $2011-12$ consumer prices (recommendation from the Rangrajan Committee 2014). The polynomial fit lying above zero indicates households are worse off due to the policy change because they have to be compensated with a positive amount of money to achieve the initial utility level. And the polynomial fit lying below zero indicates that they are better off.

Figure 2 displays that rural households are worse off due to the policy tightening. And most urban households above the poverty line are better off due to the policy tightening. The slope of the polynomial fit indicates a pro-rich bias in urban areas. The two tails of the distribution show a wider confidence band than the middle. This can be attributed to the presence of only a few households with extreme values (therefore, higher variance) and a concentration of households in the middle of the distribution. The average welfare effect is around 0.04% of household expenditure in rural areas and -0.05% in urban areas. The small magnitude of the effects can be attributed to the weak monetary policy transmission into consumer prices.

Figure 3 illustrates the second-order price effects. All households in both rural and urban areas are worse off through this channel. However, the small magnitude of the effect can better be interpreted as indifference. The weak pass-through from policy

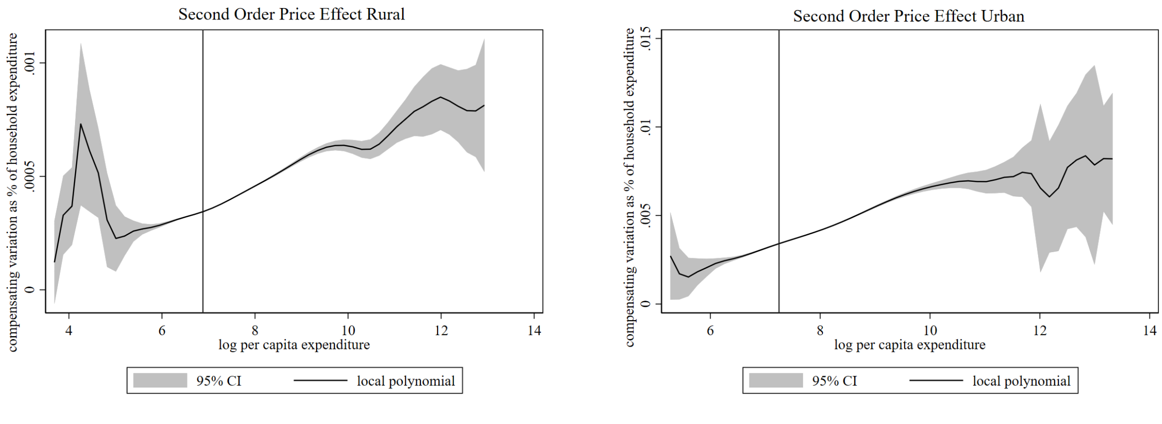

Figure 3: Second Order Price Effects

rate into prices, when multiplied with the weak co-movements among prices following equation 20, the composite effect becomes even weaker.

4.4.3 Elasticities of wage earnings

The elasticities of wage earning with respect to prices (γ_a, γ_m) are estimated using ordinary least square regressions on pooled-cross section data as specified in equation 21. The results are depicted in table 5 in the Appendix. The elasticities are the sum of the estimated coefficients for the respective variables. The joint significance of the coefficients is tested using F-tests, which is found to be statistically significant. Table 2 displays the elasticities of wage earnings with respect to the price of traditional and modern goods for different skill labors; it also reports the overall elasticities, i.e., aggregation over skills.

As discussed earlier, these general equilibrium relationships can not be interpreted theoretically; therefore, I offer the following intuitive explanations: In India, traditional goods are generally produced intensively using low-skill labor. Therefore, an increase in its commodity price leads to a decrease in the return on high-skill labor. On the other hand, modern goods are generally produced by intensively using high-skill labor. Therefore, an increase in the price of modern goods leads to a decrease in the return on low-skilled labor. However, in rural areas, due to the limited availability of high-skill labor, the share of low-skill labor in modern goods production can be higher, leading to a positive effect on its return.

Another way to look at this is, in rural areas, for traditional goods, as I move from low to high-skill labor, the wage elasticity decreases and becomes negative because tra-

Table 2: Estimated Elasticities of Wage Earnings with Respect to CPIs for Rural and Urban Households

Elasticity	Description	Rural	Urban
γ_a	w w.r.t. p_a	0.5469	3.2373
γ_m	w w.r.t. p_m	4.0852	0.7564
$\gamma_{edu1,a}$	w w.r.t. p_a for low skilled	1.109	4.158
$\gamma_{edu1,m}$	w w.r.t. p_m for low skilled	0.790	-3.658
$\gamma_{edu2,a}$	w w.r.t. p_a for semi skilled	0.617	0.709
$\gamma_{edu2,m}$	w w.r.t. p_m for semi skilled	1.255	0.609
$\gamma_{edu3,a}$	w w.r.t. p_a for high skilled	-0.179	-1.629
$\gamma_{edu3,m}$	w w.r.t. p_m for high skilled	2.040	3.805

ditional sectors majorly use low-skill intensive technologies. On the other hand, in rural areas, for modern goods, as I move from low to high skilled, the return increases consistently as modern goods are produced using relatively high-skill intensive technologies. Similarly, in urban areas, for traditional goods, the elasticity is highest for low-skill labor, while it is negative for high-skill labor; and, for modern goods, elasticity is highest for high-skill labor, while it is negative for low-skill labor.

Wage-earning shares (θ_t^js) are obtained from the predicted wage earnings. The results from the Mincer (1974) estimation are depicted in table 6 in the Appendix. I test the equality of the distribution function of original and predicted wage earnings using a two-sample Kolmogorov-Smirnov test. The test results are shown in table 8 in the Appendix. I also test the difference in the mean of the original and predicted wage earnings using a two-sample t-test. The results are shown in table 9 in the Appendix. These results indicate that the difference between original and predicted wage earnings is negligible; therefore, my predictions are reliable.

4.4.4 Labor income effects

Figure 4 depicts the welfare effect through the wage earning channel (it is also known as the *labor income effect*). Both rural and urban households are better off through

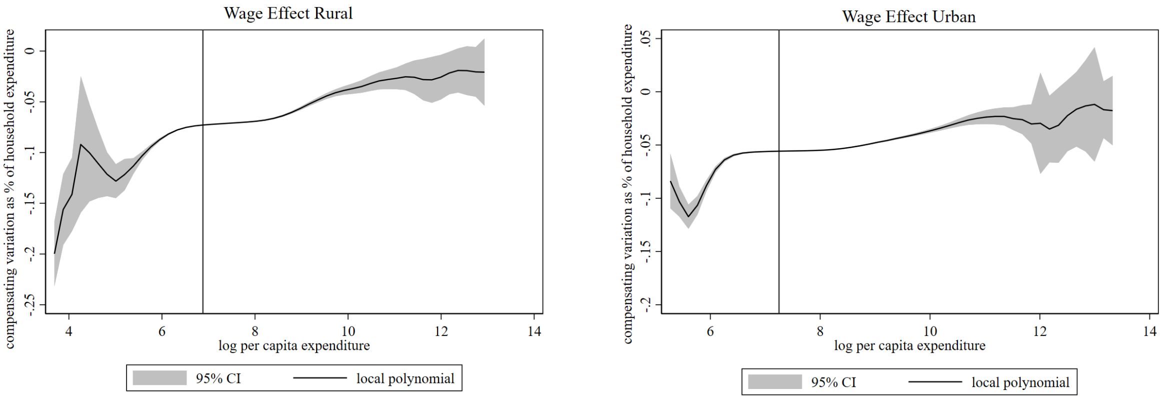

Figure 4: Wage Earning Effects

this channel, and the effect is pro-poor. Poorer individuals tend to rely more on wage earnings than the rich. A monetary policy tightening increases commodity prices in most cases (table 1), leading to an increase in wage-earning, and poorer individuals benefit the most. However, the composite effect is small due to weak monetary policy transmission into consumer prices. Even though γ's are high, low ϵ's reduce the magnitude of the welfare. The average effect is -0.1% of per capita consumer expenditure in rural areas and -0.05% in urban areas. Welfare effects across skills do not vary much in rural areas. However, it varies substantially in urban areas from -0.08% for low-skilled to 0.06% for high-skilled.

4.4.5 Total Indirect effect

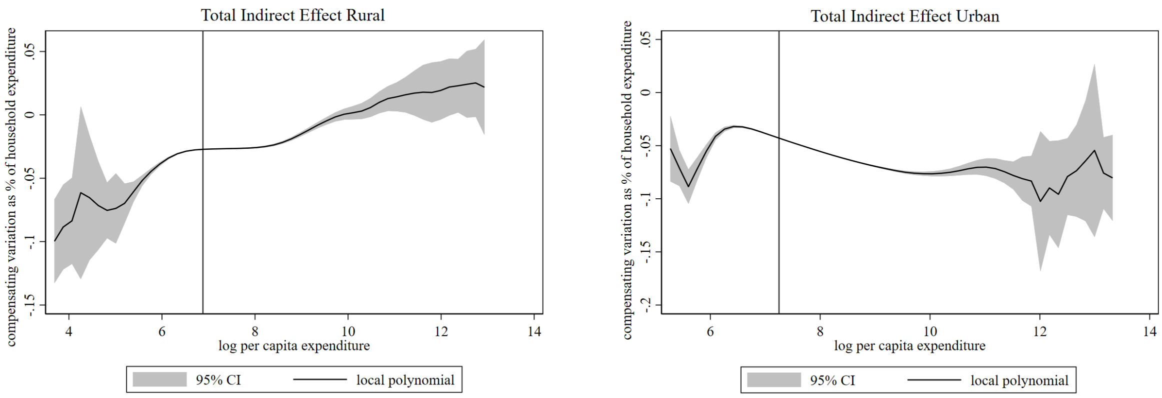

Figure 5: Total Indirect Effects

Figure 5 illustrates the total indirect effect due to the first- and second-order price effect and labor income effect. They are indirect effects because monetary policy influences household consumption indirectly through prices. The magnitude of the effect is on an average -0.03% for rural households and -0.05% for urban households. The mean monthly household expenditure in the sample is Rs.1656.1 in rural and Rs.3115.4 in urban areas. Therefore, a repo rate tightening from 4% to 5% leads to an increase in the welfare of a typical household in rural areas by Rs.0.50 and in urban areas by Rs.1.16 (in $2011-12$ constant prices). Monetary policy transmission into household consumption through indirect channels is, therefore, negligible.

4.4.6 Direct effect

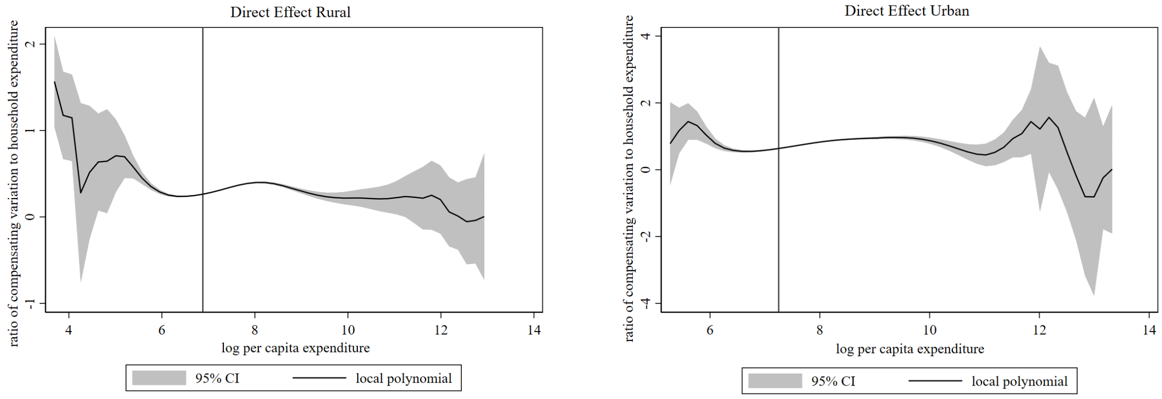

Figure 6: Direct Effects

The ratio of household financial assets to household monthly consumer expenditure s^j_{bt} are calculated from the predicted values of assets (b^j_t). The Kolmogorov-Smirnov test depicted in table 11 in Appendix and the two-sample t-test depicted in table 12 in Appendix evidence that the difference between original and predicted household financial assets is negligible; therefore, the predictions are reliable.

I obtain the ratio of compensating variation to household expenditure and fit local polynomials along the log per capita expenditure (figure 6). The magnitude of the welfare effect through the direct channel is larger than all other channels. The interest rates on deposits are largely controlled by the central bank; the effect on household consumption through this channel is, therefore, direct. The relatively higher magnitude of this channel is due to the large values of $s^j_{bt} = \frac{b^j_t}{e^j}$. b^j_t is the stock of all financial assets that a household posses at the date of the survey, which consists of all bank and non-bank deposits, deposits with post offices, microfinance, annuity, provident funds, etc.[13]. And e^j, on the other hand, is the monthly consumer expenditure of the same household. The ratio varies widely between 0.0262 and 391.2653 in rural households and between 0.1080 and 419.8332 in urban households. This leads to the welfare effect to vary between 0 and 14.87 in rural households and between 0.0041 to 15.95 in urban households. Note that these are the ratio of CV to e^j and not percentages, while the earlier graphs show CV as a percentage of e^j. The extremely high values correspond to the household lying beyond the 99^{th} percentile in the distribution. If these few extremely rich households are ignored, and the distribution is truncated at the 99^{th} percentile, the welfare effect varies between 0 and 1.57 in rural households and between 0.0041 to 3 in urban households.

4.4.7 Bias in the direct effect estimation

Note that the elasticity of household savings with respect to the real interest rate is positive. Therefore, the reduction in welfare due to an increase in the interest rate, despite the positive elasticity value, arises from the composite nature of the direct effect component. The simplification of the components $\left[s^j_{bt+1}\epsilon_{bt+1,r}\frac{dr_{bt}}{r_{bt}} - s^j_{bt}(\epsilon_{bt,r}+1)dr_{bt}\right]$ by assuming $s^j_{bt+1} = s^j_{bt}$ and $\epsilon_{bt+1,r} = \epsilon_{bt,r} = 0.20$, generates bias in the calculation. To obtain a rough idea of the magnitude of the bias, let's assume $s^j_{bt+1} \neq s^j_{bt}$ but $\epsilon_{bt+1,r} = \epsilon_{bt,r} = 0.20$. The magnitude of the direct effect then boils down to $\left[5 * s^j_{bt+1} - 1.20 * s^j_{bt}\right]$. That means for $\frac{s^j_{bt+1}}{s^j_{bt}} > 0.24$ this component is positive. In other words, if household financial asset holding in the next period does not decrease to less than 0.24 times of the current period financial asset holding, this component will be positive. However, if I eliminate s^j_{bt+1} entirely from the calculation, the direct effect will be welfare-inducing.

4.4.8 Aggregate effect

Total welfare effect is calculated by combining all the channels. The magnitude and direction of the direct effect determine the magnitude and direction of the total effect. Figure 7 depicts that households are worse off in response to the monetary policy tightening. The combined effect varies roughly between -0.0084 and 14.85 among rural households and between -0.003 and 15.95 among urban households. Truncating at the

[13] Debt & Investment Survey, Schedule 18.2, Visit 1, Block 12, "financial assets other than shares & debentures owned by the household as on 30.06.2012", item 11.

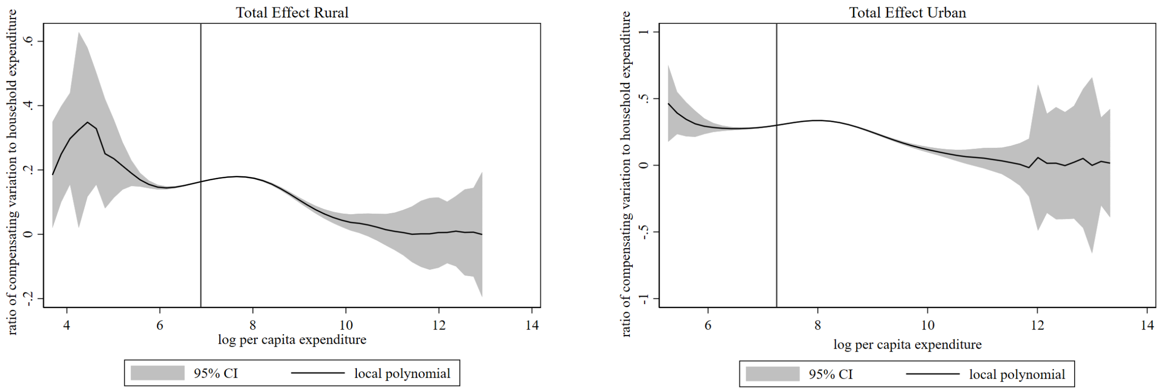

Figure 7: Total Effects

99^{th} percentile, the highest value is 0.36 for rural and 0.58 for urban households. The mean effects for rural and urban households are around 0.1 and 0.13. That incurs a welfare loss of Rs.165.61 for an average rural household and Rs.405.00 for an average urban household in $2011 - 12$ base prices due to the repo rate tightening from 4% to 5%.

One outstanding question is whether the direct and the indirect effect measures are comparable. While the indirect measures feature the share of consumer expenditure in the total household budget, the direct effect features the ratio of the financial asset holding to the household budget. The financial asset holding represents stock or accumulation of wealth by the households, while the budget shares are period-specific. Therefore, adding the direct and indirect components to obtain the total welfare effect seems abstract. Keeping aside the fact that they are mathematically derived following well-established literature, the objective of this paper is to propose a methodology that explicitly measures the welfare effect. Adding these two quantifies the overall effect on each household, providing a key figure for policy evaluation.

5 Conclusion

I explore an unconventional approach to evaluate the welfare effect of an arbitrary change in conventional monetary policy on households in India. The transmission channels that are derived from a general equilibrium model are estimated by extensive use of household surveys and rigorous econometric techniques. The measurement of welfare is built upon the concept of compensating variation.

I specifically estimate the welfare effects through consumer prices, labor income, and return on financial assets. I found weak and asymmetric monetary policy transmission into consumer prices. The welfare effects vary widely across rural-urban, the skill of labor, and the channels of transmission. An increase in the repo rate leads to a reduction in welfare through first-order price effects, second-order price effects, and direct effects, and an increase in welfare through labor income effects in rural households. In net, households are worse off due to the relatively higher magnitude of the direct effect, without which, although the effect is welfare-inducing, the magnitude is close to zero. For urban households, welfare increases through first-order price effects and labor income effects, and welfare reduces through second-order price effects and direct effects. The total indirect effect is welfare-inducing, but the magnitude is close to zero. Direct effect dominates all other effects, and the combined effect becomes welfare-reducing. Richer households in both rural and urban areas are mostly unaffected by the policy change.

Due to the limited data availability on different socio-economic variables in India, the welfare values are dated. However, the purpose of this study is to propose a methodology that can be used to reproduce these results as recent data becomes available.

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Declaration of competing interest

None.

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Appendix

5.1 Household Optimization Problem:

Households maximize expected lifetime utility subject to budget constraints, using the Lagrange method to obtain the optimal policy function,

$$\begin{aligned} V = \beta^t \Big[\frac{{c_{at}^j}^{1-\sigma_a}}{1-\sigma_a} + \frac{{c_{mt}^j}^{1-\sigma_m}}{1-\sigma_m} - \frac{{l_{Ht}^j}^{1+\psi_H}}{1+\psi_H} - \frac{{l_{Mt}^j}^{1+\psi_M}}{1+\psi_M} - \frac{{l_{Lt}^j}^{1+\psi_L}}{1+\psi_L}\Big] \\ + \lambda_t \left[\sum_i w_{nt}\, l_{nt}^{ij} + r_{bt}\, b_t^j + x_t^j - p_{at} c_{at}^j - p_{mt} c_{mt}^j - b_{t+1}^j\right] \end{aligned} \tag{28}$$

From the first order conditions I obtain,

$$\lambda_t = \beta^t \frac{c_{at}^{-\sigma_a}}{p_{at}},\ \lambda_t = \beta^t \frac{c_{mt}^{-\sigma_m}}{p_{mt}},\ \lambda_{t+1} = \frac{\lambda_t}{r_{bt}} \tag{29}$$

combining these, I obtain,

$$c_{at}^{-\sigma_a} = \frac{\beta}{r_{bt}} \frac{p_{at}}{p_{at+1}}\, c_{at+1}^{-\sigma_a} \tag{30}$$

similarly,

$$c_{mt}^{-\sigma_m} = \frac{\beta}{r_{bt}} \frac{p_{mt}}{p_{mt+1}}\, c_{mt+1}^{-\sigma_m} \tag{31}$$

equation 30 and 31 are the Euler equation for goods a and m.

5.2 Optimization Problem of Traditional Firms:

Traditional firms maximize profit for each period given the prices of inputs; they choose the optimal demand for each factor of production,

$$\Pi_t^a = p_{at} Y_t^a - w_{Ht}\, L_{Ht}^a - w_{Mt}\, L_{Mt}^a - w_{Lt}\, L_{Lt}^a - r_{kt} K_t^a$$

where, $Y_t^a = F(L_{Ht}^a, L_{Mt}^a, L_{Lt}^a, K_t^a)$ from the first order conditions I obtain,

$$p_{at} = \frac{w_{Ht}}{F_H} = \frac{w_{Mt}}{F_M} = \frac{w_{Lt}}{F_L} = \frac{r_{kt}}{F_k} \tag{32}$$

therefore,

$$p_{at} = f(w_{Lt}, w_{Mt}, w_{Ht}, r_{kt})$$

5.3 Optimization Problem of Modern Firms:

Modern firms maximize profit for each period given the prices of inputs; they choose the optimal demand for each factor of production,

$$\Pi_t^m = p_{mt} Y_t^m - w_{Ht}\, L_{Ht}^m - w_{Mt}\, L_{Mt}^m - w_{Lt}\, L_{Lt}^m - r_{kt} K_t^m$$

where, $Y_t^m = G(L_{Ht}^m, L_{Mt}^m, L_{Lt}^m, K_t^m)$ from the first order conditions I obtain,

$$p_{mt} = \frac{w_{Ht}}{G_H} = \frac{w_{Mt}}{G_M} = \frac{w_{Lt}}{G_L} = \frac{r_{kt}}{G_k} \tag{33}$$

therefore,

$$p_{mt} = g(w_{Lt}, w_{Mt}, w_{Ht}, r_{kt})$$

5.4 Interdependence of Prices:

The condition for labor market clearance is,

$$L_{nt}^a + L_{nt}^m = \sum_j \sum_i l_{nt}^{ij}\,, \quad n \in \{H, M, L\}$$

Combining this with equation 32 and 33 I obtain,

$$p_{at} = f_1(w_{Lt}, w_{Mt}, w_{Ht}, r_{kt})$$

and

$$p_{mt} = g_1(w_{Lt}, w_{Mt}, w_{Ht}, r_{kt})$$

5.5 Detailed Empirical Results

Table 3: Auto Regressive Distributed Lag Estimates among Consumer Price Indices and Interest Rate

	Model 1	Model 2	Model 3	Model 4
(Intercept)	0.0033	0.0084	-0.0135	-0.0262
	(0.0146)	(0.0059)	(0.0288)	(0.0198)
$(ln(CPI_{AL})_a)_t$		0.0167^{***}		
		(0.0034)		
$(ln(CPI_{AL})_a)_{t-1}$	1.5133^{***}			
	(0.0522)			
$(ln(CPI_{AL})_a)_{t-2}$	-0.5206^{***}			
	(0.0531)			
$(ln(CPI_{AL})_m)_t$	0.2359			
	(0.1433)			
$(ln(CPI_{AL})_m)_{t-1}$	-0.5067^{**}	1.0203^{***}		
	(0.2059)	(0.0572)		
$(ln(CPI_{AL})_m)_{t-2}$	0.2760^{*}	0.2362^{***}		
	(0.1411)	(0.0829)		
$(ln(CPI_{AL})_m)_{t-3}$		-0.2718^{***}		
		(0.0561)		
$ln(WACR)_t$	0.0053^{***}	0.0012^{**}	0.0017	0.0029^{*}
	(0.0017)	(0.0005)	(0.0016)	(0.0016)
$ln(WACR)_{t-1}$	-0.0039^{**}			-0.0011
	(0.0017)			(0.0018)
$ln(WACR)_{t-2}$				-0.0038^{**}
				(0.0015)
$(ln(CPI_{IW})_a)_t$				0.0425
				(0.0399)
$(ln(CPI_{IW})_a)_{t-1}$			1.4167^{***}	0.0066
			(0.0589)	(0.0700)
$(ln(CPI_{IW})_a)_{t-2}$			-0.6354^{***}	0.0311
			(0.0965)	(0.0750)

	Model 1	Model 2	Model 3	Model 4
$(ln(CPI_{IW})_a)_{t-3}$			0.2208^{***}	-0.0832
			(0.0598)	(0.0759)
$(ln(CPI_{IW})_a)_{t-4}$				0.0076
				(0.0753)
$(ln(CPI_{IW})_a)_{t-5}$				-0.0192
				(0.0739)
$(ln(CPI_{IW})_a)_{t-6}$				0.1306^{*}
				(0.0694)
$(ln(CPI_{IW})_a)_{t-7}$				-0.1024^{**}
				(0.0405)
$(ln(CPI_{IW})_m)_t$			-0.0140	
			(0.0161)	
$(ln(CPI_{IW})_m)_{t-1}$				0.9932^{***}
				(0.0549)
$(ln(CPI_{IW})_m)_{t-2}$				0.0268
				(0.0773)
$(ln(CPI_{IW})_m)_{t-3}$				-0.0469
				(0.0756)
$(ln(CPI_{IW})_m)_{t-4}$				-0.0908
				(0.0749)
$(ln(CPI_{IW})_m)_{t-5}$				0.0966
				(0.0748)
$(ln(CPI_{IW})_m)_{t-6}$				0.4194^{***}
				(0.0747)
$(ln(CPI_{IW})_m)_{t-7}$				-0.4251^{***}
				(0.0522)
Observations	286	285	285	281
R-squared	0.9998	0.9997	0.9997	0.9999

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$, Standard errors in parentheses

Note: Model 1 is ARDL estimation of log CPI AL for item a on log CPI AL for item m, log WACR, log ER, and log IIP. Model 2 is ARDL estimation of log CPI AL for item m on log CPI AL for item a, log WACR, log ER and log IIP. Model 3 and Model 4 are specified in the same way as Model 1 and Model 2, respectively but for IW instead of AL. Other controls include the exchange rate of Indian rupees to the US dollar and the index of industrial production. Optimal lag is selected using AIC and BIC criteria.

Table 4: Elasticities from ARDL and VAR Estimation

Component	Rural	Urban	Estimation Method
ϵ_{a,r_k}	0.0014	0.0017	ARDL
ϵ_{a,r_k}	-0.0035	0.0021	VAR
ϵ_{m,r_k}	0.0012	-0.0020	ARDL
ϵ_{m,r_k}	0.0011	-0.0001	VAR
$\epsilon_{a,m}$	0.0053	-0.0140	ARDL
$\epsilon_{a,m}$	0.1433	-0.0591	VAR
$\epsilon_{m,a}$	0.0167	0.1355	ARDL
$\epsilon_{m,a}$	0.0683	0.1629	VAR

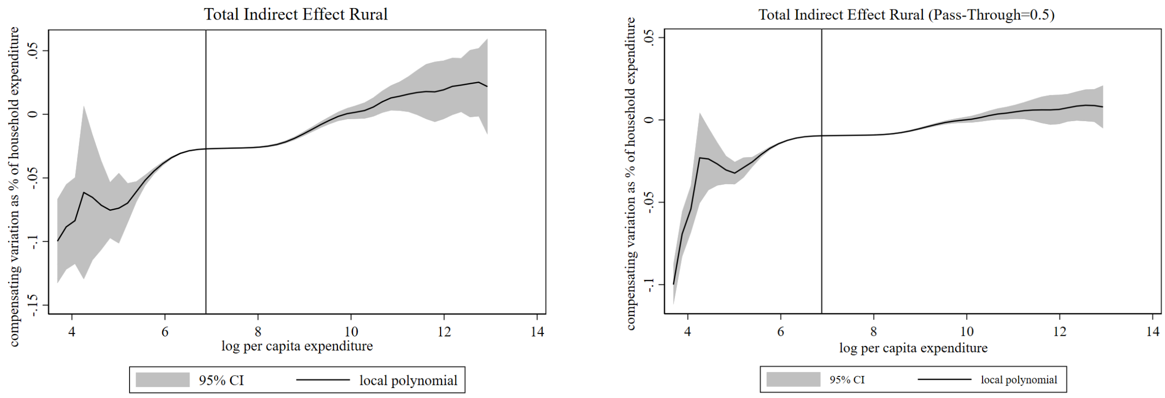

Figure 8: Change in Total Indirect Effects in Rural Areas Due to Change in Pass-Through from Repo Rate to WACR

Table 5: OLS Estimates of Log Wage Earning on Log Prices Interacted with Education Dummies

	Rural	Urban
$ln(CPI_{AL})_a * edu_L$	1.109***	
	(0.279)	
$ln(CPI_{AL})_a * edu_M$	0.617**	
	(0.269)	
$ln(CPI_{AL})_a * edu_H$	-0.179	
	(0.321)	
$ln(CPI_{AL})_m * edu_L$	0.790**	
	(0.375)	
$ln(CPI_{AL})_m * edu_M$	1.255***	
	(0.356)	
$ln(CPI_{AL})_m * edu_H$	2.040***	
	(0.420)	
edu_M	0.232	-3.684***
	(0.469)	(0.981)
edu_H	0.806	-7.093***
	(0.819)	(2.447)
$ln(CPI_{IW})_a * edu_L$		4.158***
		(1.310)
$ln(CPI_{IW})_a * edu_M$		0.709
		(0.713)
$ln(CPI_{IW})_a * edu_H$		-1.629
		(1.051)
$ln(CPI_{IW})_m * edu_L$		-3.658**
		(1.602)
$ln(CPI_{IW})_m * edu_M$		0.609
		(0.887)
$ln(CPI_{IW})_m * edu_H$		3.805***
		(1.289)
Constant	-2.683***	3.733**
	(0.592)	(1.582)
Observations	217,887	172,695
R-squared	0.378	0.316
State FE	YES	YES
Time FE	YES	YES
Clustered SE	YES	YES

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: Other controls include age, age squared, sex, activity status, NIC code for employment, religion, social group, and household type.

Table 6: OLS Estimates of Log Wage Earning on Education Levels, Age, and Age^2

	Log Wage Earning
Below primary education	$0.0480***$
	(0.0141)
Below secondary education	$0.0406***$
	(0.0137)
Secondary or above education	$0.2700***$
	(0.0159)
Age	$0.0300***$
	(0.0025)
Age^2	$-0.0003***$
	$(3.09e-05)$
Constant	$2.1750***$
	(0.1430)
Observations	75,274
R-squared	0.5423
State FE	YES
Time FE	YES
Clustered SE	YES

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: Other controls include sex of the member, NIC code for employment, religion, social group, household size, household type, and log of household consumption.

Table 7: Summary Statistics of Original and Predicted Wage Earning

Variable	Obs	Mean	Std. Dev.	Min	Max
original wage earning	495,016	312.3959	1578.698	0	703000
predicted wage earning	464,960	314.5695	689.1258	0	11338.55

Table 8: Two-sample Kolmogorov-Smirnov Test for Equality of Distribution Functions for Original and Predicted Wage Earning

Smaller group	D	P-value
1 :	0.4825	0.000
2 :	-0.0183	0.000
$Combined\ K-S$:	0.4825	0.000

Note: 1 tests the null hypothesis $D^+ = max_x(F(x) - G(x))$, 2 tests the null hypothesis $D^- = max_x(F(x) - G(x))$ and combined K-S tests the null hypothesis $D = max(|D^+|, |D^-|)$, where $F(x)$ and $G(x)$ are the empirical distribution functions for original and predicted wage earning.

Table 9: Two-sample t Test for Original and Predicted Wage Earning

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
1	495,016	312.3959	2.2438	1578.698	307.9981	316.7937
2	464,960	314.5695	1.0106	689.1258	312.5887	316.5503
combined	959,976	313.4487	1.2563	1230.923	310.9863	315.911
diff		-2.1736	2.5139		-7.1007	2.7535

diff = mean(1) - mean(2) t = -0.8646
Ho: diff = 0 degrees of freedom = 959974
Ha: diff < 0 Pr(T < t) = 0.1936
Ha: diff ! = 0 Pr($|T| > |t|$) = 0.3872
Ha: diff > 0 Pr(T > t) = 0.8064

Table 10: Summary Statistics of Original and Predicted Financial Assets

Variable	Obs	Mean	Std. Dev.	Min	Max
original savings	83,153	81,363.59	2,93,102.1	0	3,26,00,000
predicted savings	94,311	82,540.89	1,46,959.5	827.5735	37,73,663

Table 11: Two-sample Kolmogorov-Smirnov Test for Equality of Distribution Functions for Original and Predicted Financial Assets

Smaller group	D	P-value
1 :	0.3839	0.000
2 :	-0.0199	0.000
$Combined\, K - S$:	0.3839	0.000

Note: 1 tests the null hypothesis $D^+ = max_x(F(x) - G(x))$, 2 tests the null hypothesis $D^- = max_x(F(x) - G(x))$ and combined K-S tests the null hypothesis $D = max(|D^+|, |D^-|)$, where $F(x)$ and $G(x)$ are the empirical distribution functions for original and predicted financial assets.

Table 12: Two-sample t Test for Original and Predicted financial assets

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
1	83,153	81363.59	1016.436	293102.1	79371.38	83355.79
2	94,311	82540.89	478.538	146959.5	81602.96	83478.82
combined	177,464	81989.25	539.9097	227444.9	80931.04	83047.46
diff		-1177.303	1081.96		-3297.919	943.3133

diff = mean(1) - mean(2) t = -1.0881
Ho: diff = 0 degrees of freedom = 177462
Ha: diff < 0 Pr(T < t) = 0.1383
Ha: diff ! = 0 $\Pr(|T| > |t|) = 0.2765$
Ha: diff > 0 Pr(T > t) = 0.8617

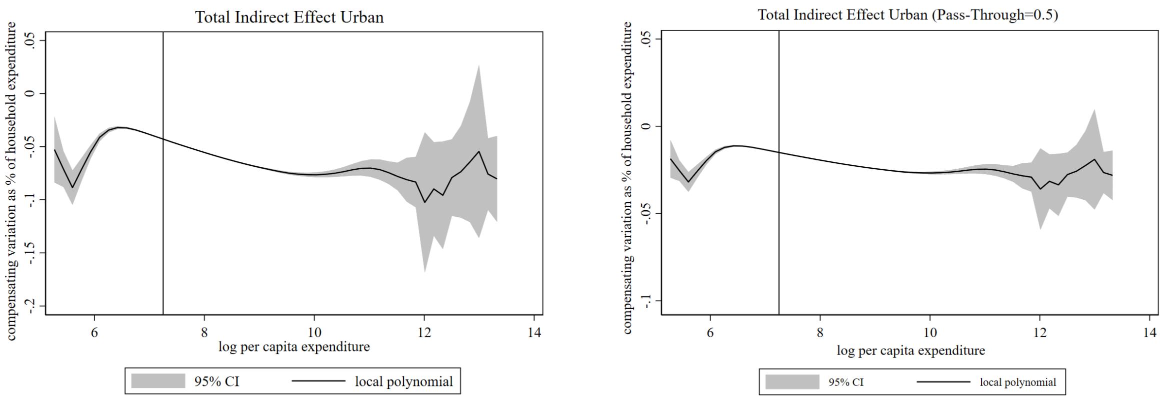

Figure 9: Change in Total Indirect Effects in Urban Areas Due to Change in Pass-Through from Repo Rate to WACR