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Impact of Monetary Policy Transmission on the Demographic in India: A Structural VAR Approach

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This study explores the relationship between monetary policy instruments and India's demographic structure, to understand how these instruments interact with the population composition. To trace the relationship, this study has considered annual data from 1993-2018. Using the structural vector autoregression (VAR) with restrictions and considering various macroeconomic variables, the study shows a significant relationship between the monetary policy variable represented by the repo rate and the demographic structure represented by the working-age population. Overall, the study concludes that demographic shifts affect monetary policy effectiveness.

I. Introduction

The world has gone through a significant demographic upheaval in the last several decades. A growing working-age population is a crucial determinant of economic prosperity. However, since the world's working-age population is shrinking while the non-working population is growing, there is the threat of an increase in the cost of care, thereby putting pressure on government-sponsored programmes like pension systems, medicare and other social security programs. According to United Nations demographics estimates, by the end of 2050, the old-age dependency ratio will be doubled. Although rising life expectancy reflects the success of the economy in medical advancements and in the public health sector, it also raises concerns about future economic prospects, the functioning of social security programs, and pension systems. Demographics do not directly dictate the course of economic growth, but act as a significant channel in determining an economy's development potential as demographic shifts affect the economy's demand and supply in both qualitative and quantitative ways.

The Life Cycle Hypothesis of consumption and saving (Ando & Modigliani, 1963) has impacted research into monetary policy mechanisms that incorporate the impact of age composition. Regarding the proponents of the Life Cycle Hypothesis posit that income varies over people's lifetime, and saving allows them to move income from those times in life when income is high to the times when income is low. Thus, people tend to accumulate their savings towards their retirement when working, and then spend whatever has been saved when they retire and grow old.

In the same vein, the conclusion could be drawn that an economy's national savings and age structure could be highly related to this. Thus, changes in demographics would have an impact on an economy by altering the balance between savings and investment, resulting in monetary variables such as inflation rate being adjusted (Canon et al., 2015), exchange rate (Kohli et al., 2020; Lee & Park, 2015; Rose et al., 2009) and interest rate (Kara & von Thadden, 2016; Padha et al., 2021; Park & Kim, 2012). The age distribution of a country's population is shown to be a crucial factor in the connection between monetary expansion and price increases, according to the research conducted by Kopecky (2022). In addition, recent studies conducted by Cravino et al. (2020), Cravino et al. (2020) and Auclert et al. (2021) establish an important relationship between monetary policy instruments and demographics.

India is one the fastest growing economies in this post-modernism era of global flux. Given its population size and considering life cycle patterns in economic activities, we are keenly motivated to understand how changes in the age-composition of India affect the performance of its monetary policy, particularly as no investigation has been done in the Indian context in this regard. The main thrust of this paper is to understand the impact of monetary policy instruments on India's demography. This research considers the repo rate as a monetary policy variable and uses a policy-restricted structural vector autoregressive model (SVAR) to determine how the working-age population in-

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fluences the response of inflation and unemployment to a policy rate shock over time.

II. Materials and Methodology

This study considers the repo rate ($Repo$) as the monetary policy variable. Inflation rate (Inf), unemployment rate ($Unra$) and exchange rate ($Exra$) are taken as responsive channels in order to trace the impact of policy rate shock. The population variable (Pop) being considered is the population of working age cohorts representing the demographic structure of the economy collectively, as the working-age cohorts are the major stakeholders in economic activities of an economy. In this study, the repo rate is considered a shock in the economy to evaluate its real impact on the demographic. We use annual data on the age composition of India, given by working age population and aggregate unemployment rate.

Firstly, in order to check the oddity of the variables used in the analysis, this study runs a unit root test as time series data is used. Augmented Dickey Fuller (ADF) test is used to determine variables' time series characteristics. Following that, to inspect how age composition affects the response of the inflation rate and unemployment rate to the monetary policy shocks, this study considers the impulse response function with one standard deviation shock in a SVAR environment.

A. Structural Vector-Autoregression

In order to understand the relationship between monetary policy instruments and India's demographic structure, the following SVAR is formulated.

$$RY_t = \alpha_0 + \alpha_1 Y_{t-1} + u_t \tag{1}$$

The generalized form can be represented as

$$RY_t = \sum_{j=1}^{n} \alpha_1 Y_{t-1} + u_t, \qquad u_t \sim N(0, K)$$

In the above generalized form, $Y_t(= Y_{1t},\ Y_{2t}, Y_{3t}, \ldots Y_{kt})$ is a $k \times 1$ vector of endogenous variables, $\alpha_1 \ldots \alpha_k$ is a $k \times k$ matrix of lag coefficients to be estimated on j^{th} lag, u_t is a $k \times 1$ vector of white noise innovation processes representing the structural shocks. R is a matrix that reflects the contemporaneous relationship among the endogenous variables.

Now considering the study , here vector Y_t has five variables which are ($Repo$), (Inf), ($Unra$), ($Exra$) and (Pop) and the system is represented as shown below.

$$\begin{aligned} &a_{11}Repo_t + a_{12}Inf_t + a_{13}Unra_t + a_{14}Exra_t + a_{15}Pop_t \\ &= \alpha_{10} + \alpha_{11}Repo_{t-1} + \alpha_{12}Inf_{t-1} + \alpha_{13}Unra_{t-1} \\ &+\alpha_{14}Exra_{t-1} + \alpha_{15}Pop_{t-1} + u_{Repo_t} \end{aligned} \tag{2}$$

$$\begin{aligned} &a_{21}Repo_t + a_{22}Inf_t + a_{23}Unra_t + a_{24}Exra_t + a_{25}Pop_t \\ &= \alpha_{20} + \alpha_{21}Repo_{t-1} + \alpha_{22}Inf_{t-1} + \alpha_{23}Unra_{t-1} \\ &+a_{24}Exra_{t-1} + \alpha_{25}Pop_{t-1} + u_{Inf_t} \end{aligned} \tag{3}$$

$$\begin{aligned} &a_{31}Repo_t + a_{32}Inf_t + a_{33}Unra_t + a_{34}Exra_t + a_{35}Pop_t \\ &= \alpha_{30} + \alpha_{31}Repo_{t-1} + \alpha_{32}Inf_{t-1} + \alpha_{33}Unra_{t-1} \\ &+a_{34}Exra_{t-1} + \alpha_{35}Pop_{t-1} + u_{Unra_t} \end{aligned} \tag{4}$$

$$\begin{aligned} &a_{41}Repo_t + a_{42}Inf_t + a_{43}Unra_t + a_{44}Exra_t + a_{45}Pop_t \\ &= \alpha_{40} + \alpha_{41}Repo_{t-1} + \alpha_{42}Inf_{t-1} + \alpha_{43}Unra_{t-1} \\ &+\alpha_{44}Exra_{t-1} + \alpha_{45}Pop_{t-1} + u_{Exra_t} \end{aligned} \tag{5}$$

$$\begin{aligned} &a_{51}Repo_t + a_{52}Inf_t + a_{53}Unra_t + a_{54}Exra_t + a_{55}Pop_t \\ &= \alpha_{50} + \alpha_{51}Repo_{t-1} + \alpha_{52}Inf_{t-1} + \alpha_{53}Unra_{t-1} \\ &+\alpha_{54}Exra_{t-1} + \alpha_{55}Pop_{t-1} + u_{Pop_t} \end{aligned} \tag{6}$$

The matrix form of the above system is given as

$$\begin{bmatrix} 1 & a_{12} & a_{13} & a_{14} & a_{15} \\ a_{21} & 1 & a_{23} & a_{24} & a_{25} \\ a_{31} & a_{32} & 1 & a_{34} & a_{35} \\ a_{41} & a_{42} & a_{43} & 1 & a_{45} \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 \end{bmatrix} \begin{bmatrix} Repo_t \\ Inf_t \\ Unra_t \\ Exra_t \\ Pop_t \end{bmatrix}$$

$$= \begin{bmatrix} \alpha_{10} \\ \alpha_{20} \\ \alpha_{30} \\ \alpha_{40} \\ \alpha_{50} \end{bmatrix} \begin{bmatrix} \alpha_{11} & \alpha_{12} & \alpha_{13} & \alpha_{14} & \alpha_{15} \\ \alpha_{21} & \alpha_{22} & \alpha_{23} & \alpha_{24} & \alpha_{25} \\ \alpha_{31} & \alpha_{32} & \alpha_{33} & \alpha_{34} & \alpha_{35} \\ \alpha_{41} & \alpha_{42} & \alpha_{43} & \alpha_{44} & \alpha_{45} \\ \alpha_{51} & \alpha_{52} & \alpha_{53} & \alpha_{54} & \alpha_{55} \end{bmatrix} + \begin{bmatrix} Repo_{t-1} \\ Inf_{t-1} \\ Unra_{t-1} \\ Exra_{t-1} \\ Pop_{t-1} \end{bmatrix} + \begin{bmatrix} u_{Repo_t} \\ u_{Inf_t} \\ u_{Unra_t} \\ u_{Exra_t} \\ u_{Pop_t} \end{bmatrix}$$

Now in order to derive reduced form VAR, multiply both sides of Equation (1) by R^{-1} ; we get

$$R^{-1}RY_t = R^{-1}\alpha_0 + R^{-1}\alpha_1 Y_{t-1} + R^{-1}u_t \tag{7}$$

We know that multiplying a matrix with its inverse gives an identity matrix i.e., $R^{-1}R = I$, where I is the identity matrix. Thus, the above equation can be written as

$$Y_t = Z_0 + Z_1 Y_{t-1} + e_t \tag{8}$$

where vector Y_t depends on lag of itself and the forecast error e_t. The matrix R here also indicates the forecast errors of VAR, e_t and the structural shocks u_t i.e., $e_t = R^{-1}u_t$. In reduced form VAR, e_t is the linear makeup of u_t.

Structural VAR is basically a conceptually constructed framework and is non-observable. Thus, it cannot be computed directly. As we have time series or history of variables, we use these to estimate the VAR. Following that, the regression of each variable is run against its lag and the lag of other variables included in the VAR. Hence, we get the coefficient Z and the forecast error e_t.

Starting from the reduced form VAR estimation, our goal is to get the structural model that isolates the purely exogenous shocks and responds to the variables of interest. To do this, we would need to get matrix R, or more precisely, we need to restrict matrix R.

Get R and multiply the reduced form VAR by R to get the structural model, shocks and contemporaneous channelization among the variables.

$$RY_t = RZ_0 + RZ_1 Y_{t-1} + Re_t \tag{9}$$

$$RY_t = \alpha_0 + \alpha_1 Y_{t-1} + u_t \qquad (\because RR^{-1}\alpha_0 = \alpha_0) \tag{10}$$

After getting the structural model, we need to impose restrictions on contemporaneous relationships among endogenous variables of the structural model. This what identification is about. Identification means imposing restrictions on matrix R based on economic intuition.

So, SVAR with imposing short-run restriction is given as

$$R = \begin{bmatrix} 1 & 0 & C(7) & 0 & C(13) \\ 0 & 1 & C(8) & C(11) & C(14) \\ C(1) & C(4) & 1 & 0 & C(15) \\ C(2) & C(5) & C(9) & 1 & C(16) \\ C(3) & C(6) & C(10) & C(12) & 1 \end{bmatrix}$$

And SVAR with imposing long-run restriction is given as

$$R = \begin{bmatrix} 1 & 0 & 0 & C(8) & C(11) \\ 0 & 1 & C(6) & C(9) & C(12) \\ C(1) & C(4) & 1 & 0 & C(13) \\ C(2) & 0 & 0 & 1 & C(14) \\ C(3) & C(5) & C(7) & C(10) & 1 \end{bmatrix}$$

Table 1. Results of unit root test

Variables	ADF (Level)		ADF (First Difference)	
	Constant (P — Value)	Constant & Trend (P — Value)	Constant (P — Value)	Constant & Trend (P — Value)
Repo	0.0087	0.0905	0.0004***	0.0013***
Inf	0.1338	0.0110	0.000***	0.0001***
Unmp	0.5990	0.2472	0.0255***	0.0835**
InEx	0.8390	0.7461	0.0010***	0.0062***
Popw	0.9570	0.1781	0.0003***	0.0024***

Note: This table reports ADF unit root test results. *** and ** indicates statistical significance at the 1% and 5% levels, respectively.

Table 2. VAR lag length selection criterions.

Lags	AIC	SC	HQ
0	0.432020	0.678866L	0.494101
1	0.275734	1.756814	0.648222
2	-1.121162***	1.594150	-0.438269***

This table reports lag length criterion based results. *** indicates statistical significance at the 1% level.

III. Econometrics Results and Discussion

This study uses the Akaike Information Criterion (AIC), Schwarz's Information Criterion (SIC), and Hannan-Quinn Information Criterion(HIC) to determine the optimal lag length for the VAR model. Considering these criteria the optimal lag length turns out to be 2. To examine the time series traits of variables considered in the analysis, we conduct unit root tests The ADF test shows that all variables, *Repo*, *Inf*, *Unra*, *Exra*, and *Pop* are stationary at I(1). *Repo*, *Inf*, *Exra*, and *Pop* are significant at the 5% level whereas *Unra* is significant at the 10% level.

A. Estimation of SVAR for Short Run Restrictions

We have discussed the matrix with short run restriction earlier in Section II. The matrix is represented as

$$S=\begin{bmatrix} . & Repo & Inf & Unra & Exra & Pop \\ Repo & 1 & 0 & C(7) & 0 & C(13) \\ Inf & 0 & 1 & C(8) & C(11) & C(14) \\ Unra & C(1) & C(4) & 1 & 0 & C(15) \\ Exra & C(2) & C(5) & C(9) & 1 & C(16) \\ Pop & C(3) & C(6) & C(10) & C(12) & 1 \end{bmatrix}$$

Now the estimated matrix with coefficient values is given as

$$S=\begin{bmatrix} 1 & 0 & -6.339896 & 0 & -4.037263 \\ 0 & 1 & 16.24683 & 1.469397 & 10.56553 \\ -0.101010 & 0.056936 & 1 & 0 & 0.539517 \\ -0.698480 & 0.410654 & 7.148152 & 1 & 3.965317 \\ -0.185562 & 0.126049 & 1.723454 & 0.259399 & 1 \end{bmatrix}$$

The coefficient values obtained are represented in Table 3.

Considering the output from matrix S, we find that the coefficients' values for the shock's impact on *Pop* from *Repo*, *Inf*, *Unra,* and *Exra* are significant. With a shock in the repo rate (monetary policy control variable), its impact is significantly transferred to the working-age groups, which means that the working class is responsive to the shocks in the policy rate. The impact of the shock is highly negative on *Pop* in the short-run as shown by the coefficient value (-4.037263). This finding is similar to Cravino et al. (2020), Cravino et al. (2020) and Kopecky (2022).

B. Estimation of SVAR for Long-run Restrictions

The matrix F imposed with long-run restriction has also been discussed earlier in Section II , and the matrix is represented as

$$F=\begin{bmatrix} . & Repo & Inf & Unra & Exra & Pop \\ Repo & 1 & 0 & 0 & C(8) & C(11) \\ Inf & 0 & 1 & C(6) & C(9) & C(12) \\ Unra & C(1) & C(4) & 1 & 0 & C(13) \\ Exra & C(2) & 0 & 0 & 1 & C(14) \\ Pop & C(3) & C(5) & C(7) & C(10) & 1 \end{bmatrix}$$

The estimated matrix with coefficient values is then given as

$$F=\begin{bmatrix} 1 & 0 & 0 & 2.937215 & -1.923777 \\ 0 & 1 & -8.111631 & -13.64615 & 0.439337 \\ -0.300726 & -0.011206 & 1 & 0 & 0.865437 \\ 0.167861 & 0 & 0 & 1 & -0.524561 \\ -0.327495 & -0.027185 & 0.772721 & -0.483892 & 1 \end{bmatrix}$$

The coefficient values obtained are represented in the Table 4.

Considering the output of matrix F, we find that the impact of the shock on *Pop* from *Repo*, *Unra*, and *Exra* turn out to be significant, whereas in the case of *Inf* it turns out to be insignificant. Also, the impact of demographic shocks on *Repo* turn out to be significant. So, based on that, it can be said that matrix F has long-run restriction. Over time, the impact of shock in the repo rate has significant effects on the working-age population. As witnessed from the matrix, the impact of shock on *Pop* is negative, represented by the coefficient value (-1.923777). Even in this case, Pop is negatively affected by shock, although to a lesser extent than that caused by short-run constraints. These findings are consistent with the findings of Auclert et al. (2021) and Stephen et al. (2020).

IV. Conclusion

Our study revolves around tracing the direction of the interaction between demographic changes and monetary policy tools. We conclude that the shock in policy rates has a significant impact on the working-age population variable (which, for the purposes of this study, represents the demographic structure), and that this impact has a negative effect on the working-age population variable. This con-

Table 3. Structural VAR estimates

	Coefficient	Std. Error	z- Statistic	Probability
C(1)	-0.101010	0.093654	-1.078545	0.2808
C(2)	-0.698480	0.751231	-0.929780	0.3525
C(3)	-0.185562	0.160352	-1.157214	0.2472
C(4)	0.056936	0.155809	0.365419	0.7148
C(5)	0.410654	1.093718	0.375466	0.7073
C(6)	0.126049	0.200473	0.628754	0.5295
C(7)	-6.339896	2.451572	-2.586054	0.0097***
C(8)	16.24683	10.45665	1.553731	0.1202
C(9)	7.148152	1.949300	3.667036	0.0002***
C(10)	1.723454	0.518550	3.323604	0.0009***
C(11)	1.469397	1.796597	0.817878	0.4134
C(12)	0.259399	0.081132	3.197253	0.0014***
C(13)	-4.037263	1.707367	-2.364614	0.0180***
C(14)	10.56553	6.366176	1.659635	0.0970**
C(15)	0.539517	0.161728	3.335950	0.0009***
C(16)	3.965317	1.212054	3.271567	0.0011***

Note: This table reports results obtained using the structural VAR model. *** and * indicates statistical significance at the 1% and 5% levels, respectively.

Table 4. Structural VAR estimates

	Coefficient	Std. Error	$z-$ Statistic	Probability
C(1)	-0.300726	0.143442	-2.096497	0.0360***
C(2)	0.167861	0.072017	2.330836	0.0198***
C(3)	-0.327495	0.118907	-2.754201	0.0059***
C(4)	-0.011206	0.032607	-0.343683	0.7311
C(5)	-0.027185	0.096274	-0.282372	0.7777
C(6)	-8.111631	2.464636	-3.291209	0.0010***
C(7)	0.772721	0.125526	6.155858	0.0000***
C(8)	2.937215	0.976310	3.008487	0.0026***
C(9)	-13.64615	2.302084	-5.927739	0.0000***
C(10)	-0.483892	0.126812	-3.815813	0.0001***
C(11)	-1.923777	1.110844	-1.731815	0.0833**
C(12)	0.439337	5.793302	0.075835	0.9396
C(13)	0.865437	0.215622	4.013672	0.0001***
C(14)	-0.524561	0.268953	-1.950377	0.0511**

Note: *** and * indicates statistical significance at the 1% and 5% levels, respectively.

clusion can be drawn because the shocks in policy rate are from short to medium term time horizon.

In placing the long-run restrictions, the impact of shocks on the working-age population is also negative. This study is only a step towards understanding the interaction between monetary policy and the demographics of the economy, in this case, for India.

Based on the relationship between monetary policy and demographic structure (represented by the working-age population), which was drawn through empirical analysis, the government should keep rolling out new incentive schemes from time to time in order to keep working cohorts population of different sectors motivated and above a certain benchmark. This study suggests that the working-age population is the key economic growth and prosperity driver. Thus, our study demands rich demographic data for deeper insights, which can lead us to better understand the macroeconomics of demography.

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