Chapter 5

Exchange rate, domestic prices and their interconnections: A macroeconomic perspective

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5.1. Background

Chapter five deals with the relationship between exchange rate movements and domestic prices for the Indian economy across the period 1991-92 to 2021-22 at the aggregate level and focuses on four imperative dimensions of the Exchange Rate Pass-Through (ERPT) process: first, it estimates the extent to which domestic prices react to exchange rate changes; second, the nature of domestic inflation is analyzed within a macroeconomic perspective by incorporating information on both the price and real sectors while also focusing upon the extent of the immediate and long-run pass-through; third, the stability of the ERPT to domestic prices is estimated in a time-varying coefficient framework to investigate if the price impact of exchange rate has remained stable or shifted over time; fourth and lastly, the dynamic interaction of exchange rate and domestic prices is evaluated within a Structural Vector Auto Regression (SVAR) framework and richer insights on the nature of the price and real impacts emanating from the exchange rate shocks are evaluated. This chapter extends the analysis undertaken in chapter four and expands the scope of pass-through analysis by allowing exchange rate to interact with domestic prices while examining key macroeconomic hypotheses that could be shaping the transmission of price shocks from the external sector to the domestic economy.

The fundamental concern of ERPT analysis is to understand, evaluate and delineate the ways in which in domestic inflation is impacted by external sector movements that are embodied in the exchange rate variations. Exchange rate changes can induce price, or quantity of both forms of impact for an economy that actively engages itself in international trade and financial activities. The quantity impact in turn may emanate from the price impact itself that is induced by variations in the value of currency in the foreign exchange rate market. Strong price impact of exchange rate changes can result into increased inflationary momentum and can interfere with the efforts of the monetary policy authority in maintaining price stability. This concern is all the more pronounced when the country under consideration has adopted a managed floating regime instead more rigid systems such as a hard peg or purely fixed regime. Under these circumstances, the "fear of floating" (Bianchi and Coulibay, 2023)[1] is much more accentuated as monetary policy is burdened with the dual challenges of maintaining a stable exchange rate versus stable domestic prices. The awareness about the actual quantum of pass-through to native prices can thus enable more robust monetary policy designs that can strike a fine balance between the dual goals of exchange rate stability and domestic price stability while allowing the growth momentum to maintain a high pace. At the heart of the ERPT analysis lies the role of external sector variations in shaping the domestic price structure and its evolution across space and time. Given the fact that managing inflation is the forte of Central Banks globally, the ways in which exchange rate can interfere in the efforts to build a stable inflationary impetus occupies the principal concern of exchange rate pass through analysis.

Inflation is a complex phenomenon. While monetary policy plays a critical role in shaping the process and pace of inflation, there are a large number of factors that have been ascertained as vital to holistically understanding how inflation occurs and which economic forces can stabilize or destabilize it. With increasing integration of economies on trade and financial fronts, and the fact that economies have gradually been shifting to more flexible exchange rate regimes, the theory of inflation has consequently been expanded to account for macroeconomic forces emerging from international sources in terms of international markets and the macroeconomic disturbances in major economies. While the macroeconomic literature on inflation has argued that it is in large part determined by its inertia and monetary policy variations, other factors such as external demand and supply shocks, exchange rate movements, and oil price shocks have also been pivotal in shaping a sizeable portion of the variations in inflation. For a small open economy such as India, the role of non-monetary external factors such as oil price and exchange rate variations is even more pronounced due to the weakness of its currency in international markets, and the large dependency on imports for capital inputs as well as crude oil, both of which tend to be supplied by countries that are generally not price-takers in the international arena. The large size of the aggregate import basket of India with the predominance of critical capital inputs including crude oil, expose the domestic macroeconomic stability to external shocks whose implications can be catastrophic as evidenced during the Balance of Payments crisis of the 1990s. Imports, thus serve as an important channel through which uncertainties in the external sector can be transmitted to domestic inflation via exchange rate changes.

The early focus on ERPT was generally directed towards how exchange rate could impact import prices at disaggregate and aggregate levels, and thereby play a meaningful role in trade balance adjustment process. The shift from fixed to floating regimes among the actively trading economies after the collapse of the Bretton Woods system was accompanied by the expectations that floating regimes would allow better international adjustment as the exchange rate movements could reflect the price signals emanating from international markets much more efficiently. The variations in exchange rate could then rapidly induce appropriate restructuring of trade prices and subsequently allow trade balance adjustment in the countries that had adopted a floating regime. Empirical analysts were rather perplexed to find that expected equilibrating role of exchange rate in inducing the required trade balance adjustment was sub-optimal in the sense that the trade quantities remained fairly immune to the exchange rate variations. This apparent "adjustment puzzle" (Menon, 1995) ignited the interest in the issue of incomplete price impact of exchange rate even under flexible regimes where currency was allowed to largely reflect the market movements with very limited interventions from the Central Banks. The initial explanations focused on explaining the extent of exchange rate pass-thorough to trade prices via the elasticity approach wherein the pass-through elasticity was linked to trade elasticities. This approach was soon found unsatisfactory in explaining the bulk of evidences (Menon, 1995). At the same time, the Pricing to Market (PTM) by Japanese firms ignited particular interest in pass-through effects of exchange rate to trade prices (Feenstra, 1987; Marston, 1989).

The price impact of exchange rate on trade prices formed the primary impetus on this subject matter. The elasticity approach to explaining ERPT was later superseded by an industrial organization approach whose foundations were laid in the works of Dornbusch (1987) and was soon followed by large number of studies elaborating and extending the fundamental arguments laid in the paper[2]. Dornbusch developed a model of pricing for the imperfectly competitive exporting firm and rationalized the empirical evidence of incomplete ERPT by introducing market imperfections such as differences in market power, product differentiation and other dimensions. The author explained the degree of pass-through in terms of the substitutability between domestic and imported goods and thus proposed a 'substitution approach' to rationalizing the incomplete pass-through. A large number of studies thereafter developed the imperfect markets model of explaining ERPT such as Baldwin (1988), Marston (1989), Froot and Klemperer (1989), Betts and Devereux (2000), among others which ignited a lineage of analysts who developed the so-called "microeconomic approach" to ERPT analysis (Lopez-Villavicencio and Mignon, 2016)[3].

An alternative perspective also developed on the issue of pass-through analysis, namely the so-called macroeconomic approach whose genesis are generally traced back to the works of

Taylor (1999, 2000), Laflèche (1996), among several others. The fundamental thesis of this approach lies in linking nominal rigidities to ERPT and the authors argued that pass-through was endogenous to monetary policy and the inflationary environment itself. This even led to the creation of the so-called "Taylor's hypothesis[4]" Works such as Goldfajn and Werlang (2000), Clarida et al. (2001), Baqueiro (2003), Deveruex et al. (2003), among others were rapid to develop reliable evidence in favour of the Taylor hypothesis. It is largely in this approach that the proper study of the impact of exchange rate on domestic inflation can be traced to. While there were large number of debates on the inflationary impacts of exchange rate regimes long before these works came on the stage, the proper and sole focus on the issue of ERPT as a macroeconomic subject in itself was laid down by these works. The framework of the import price pass-through was thus extended and due consideration was given to the impact of exchange rate on domestic prices. The mechanism that can explain the price impact of exchange rate variations on imports has generally been termed as the first stage pass-through, while the impact of currency movements on domestic prices is considered as the full pass-through. Expectedly, the transmission of inflationary impulses from imports to domestic price is construed as the second stage pass-through.

The idea of ERPT is thus extended in this chapter to account for the full pass-through effects of exchange rate variations. Alterations in the exchange rate can impact not only the trade prices, but there is further spread of the price impact to domestic price structure, either via import prices, the so-called stage one pass-through, or perhaps via other mechanisms[5] such as export prices, trade quantities, asset prices, and others (Laflèche, 1996). The literature has generally ascribed the impact of exchange rate variations on domestic prices to the transmission function played by the import prices. It is argued that the inflationary impact of exchange rate is generated by the extent to which import prices can affect prices further down the value chain in the economy. The sensitivity of various prices to import prices will determine, in large part, the actual implications that exchange rate changes can bring for domestic prices and inflation[6]. The literature has thus found the classification of the complete ERPT process into stage one and stage two pass-through as a useful operational tool in empirical analysis. However, the impact of currency changes on domestic prices continues to be primary focus of the pass-through literature globally.

As discussed in chapter four earlier, the issue of ERPT is one component in the larger debates on the nature and determinants of inflation. The theory of inflation has evolved considerably in the last few decades, and the Classical-Keynesian controversy in macroeconomic analysis has given rise to newer approaches to analyzing the issue of inflation. What is inflation and what factors drive its momentum in an open economy context? These questions underlie the crux of the ERPT literature. Increased trade and financial openness along with gradual integration of economies into the international financial architecture has led to larger focus on how can the traditional closed economy models of inflation analysis be modified to account for the dimension of openness. Furthermore, the shifts in the exchange rate regimes and the more pronounced adoption of the flexible regimes in increasing number of economies, fuelled the need to more robustly examine the role of exchange rates in encouraging inflationary momentum. The notion of pass-through thus had to break away from its earlier focus on trade prices and account for a richer set of price variables to fully appreciate the inflationary implications of exchange rates. However, this shift occurred largely under the belief that it is the variations in import prices that can cause price reactions from other prices down the aggregate supply chain. Hence, the examination of import price pass-through remains a fundamental concern while studying the larger price impacts of exchange rate alterations. Chapter four has examined the import price issue and provided a macroeconomic perspective on the subject matter in the Indian context during the period 1991-92 to 2021-22. Consequently, chapter five takes up the larger issue of the implications of exchange rate variations for domestic prices and specifically focuses upon wholesale and consumer price inflation.

5.2. Primary concerns

The first and foremost issue in the analysis of the linkages between exchange rates and inflation is to define the phenomenon of inflation itself. Inflation is a rich and complex phenomenon and any attempt to capture it through a rigid definition is ought to invite criticism and disagreement. “There is no lack of definitions of inflation” (Frisch, 1984, pp. 2), and this leads to the need for locating the essence of what inflation is. The broad agreement is captured in Frisch (1984) who suggests several characteristics that the correct definition of inflation should possess. First, inflation is not a one-time or short-run increase in aggregate price level. Second, the cyclical variations in the general price level should generally not be construed as inflation as it is largely “when price increases are irreversible” that a meaningful rise in general price level can be located. Third, inflation is concerned with aggregate level increases in price level rather than changes in prices of individual commodities or groups of commodities. While such price movements are useful for intra and inter industry analysis, the macroeconomic analysis demands generalized aggregate level price increases for inflation to occur. Lastly, the author stresses that not every increase in the general price level should be considered inflation and only when there is substantial reaction from economic agents that a meaningful phenomenon of inflation can be discerned. These characteristics can be summarized into the definition that "Inflation is a process of continuously rising prices, or equivalently, of continuously falling value of money" (Laidler and Parkin, 1975, pp. 741).

One of the early theories that attempted to explain inflation was the Quantity theory of money. In its various forms[7], the quantity theory exemplified the monetary nature of inflation by juxtaposing the rise in aggregate price levels with increase in the supply of money by the Central Banks. This model has remained the cornerstone of the rich evolution in the macroeconomics of inflation. The thesis that "inflation is always and everywhere a monetary phenomenon" (Friedman, 1996, pp. 17) is largely considered to be the cornerstone of what inflation is. Inflation from this perspective is a generalized increase in price level caused by monetary expansion. The idea that inflation is determined by monetary factors rather than real factors remains at the heart of the debates between the New Classicals and the New Keynesians. In the long run, the dominance of the monetary nature of inflation is not challenged by either school but the short to medium run nature of inflation is a matter of dispute. While the approaches associated with the Classical school consider inflation as emerging from non-real factors, particularly from monetary expansion, both in the short and long runs, the Keynesian schools allow the possibility of inflation being determined by non-monetary forces at least in the short and medium runs. The lack of independence between inflation and real macroeconomic factors allows the possibility of capturing richer dynamics of inflation that may emerge from the monetary sector, or the real sector, or from a complex interaction between the both.

Hence, the debates on inflation theory are more attuned to the debate on what causes inflation. If a rigid idea of inflation being either a real or a monetary phenomenon is strictly ascribed to, then the need to investigate the nature of inflation and its causes would be much more homogenous than what the empirical evidence points today. The fact that the disagreements on the causes of inflation – whether they are monetary, real or both, persists till date in the macroeconomic literature, is testimony of the complexities involved in explaining what inflation is. The broad consensus thus has been to capture inflation process in terms of either cost-push or demand-pull approaches (Vernengo, 2007). The cost-push approach treats inflation as largely a supply-side phenomenon while the demand-pull approach rationalizes inflation as emerging from the shifts in the aggregate demand. While monetary policy is almost invariably a part of these inflation models, other dimensions affecting the inflation movements are also captured[8].

These complexities are accentuated once the need for incorporating open economy features in the analysis of inflation are realized. Increasing financial openness, integration and interdependencies have made it inevitable to account for not only the factors emerging in domestic sector but also on the external front. Supply-side changes in the form of oil price movements or demand-side variations emerging from factors such as expansion in Global trade or the World Gross Domestic Product (GDP) can cause macroeconomic imbalances in an economy which necessitate Balance of Payments adjustment and subsequently changes in the domestic macroeconomic equilibrium. Consequently, inflation, output and employment are expected to adjust to the newer macroeconomic equilibrium thereby giving rise to additional factors that need to be accounted by monetary and fiscal policies. The Central Banks in economies with fixed exchange rate regimes are constrained in their ability to contain the external sources of inflation in large part due to the 'impossible trinity'. However, increasing number of economies have been shifting to the floating regime and the monetary policy authority in these economies can tackle the external inflationary sources. This provides an impetus to understand the extent to which external factors can impact domestic inflation, and the issue of ERPT provides the central organizing framework to address this subject matter.

The challenges posed by external channel for domestic inflation is an even larger concern for economies that are characterized as small open economies. Such economies are generally described as possessing high import-dependency, price-taking behavior in the international markets, smaller magnitude of share in the global trade flows and continuously increasing degree of financial integration into the global economy. Indian economy can be considered as possessing these broad features and the macroeconomic literature has treated India as a small open economy in examining the issue of pass-through. The nature of pass-through portrays very different dynamics when considered from a small open economy perspective as compared to when large open economy frameworks are employed. Generally, analyst had imposed the price taking behavior on small open economies and expected the pass-through to trade prices to be complete. The logical extension of this belief was that pass-through would be complete for domestic prices also. As elaborated in chapter four, this belief can be considered a rather realistic representation of how the price impact emanating from exchange rate variations has behaved for the Indian economy. The pass-through was found to be complete, and in some cases even when more than complete in the previous chapter, indicating that the broader characterizations associated with small open economies is true for the Indian economy as far as the pass-through to import prices are concerned. What is not immediately evident is whether the findings of chapter four can be logically extended to presume complete pass-through to domestic prices also? That is the fundamental concern in this chapter.

As discussed in chapter four, the early attempts at examining the ERPT issue was dominated by the studies focusing on role of exchange rates in trade balance adjustments. One of the earliest works in this context can be traced to Armington (1969) who proposed a multilateral trade approach but imposed restrictive assumptions about substitution and price elasticities which was then improved upon by Magee (1973). Magee's work accounted for the issue of pass-through to not only import prices but also to domestic prices within the Mundell-Fleming model. These analysts focused upon the real impact of the nominal exchange rate variations while presuming that the price impact of exchange rates on trade prices was complete. It is assumption that allowed the meaningful rationalization of the Marshall-Lerner conditions and hence enabled the examination of the real impacts of exchange rates. However, in the pursuit of the real impacts emerging from currency movements, the price impact issue somehow was relegated in the presumption of complete pass-through. This optimism regarding complete pass-through was a concomitant of the "strong faith in the adjustment mechanism embodied in the elasticity approach" (Patra and Patnaik, 1994, pp. 285). This optimism was short-lived and the adoption of floating regimes resulted in continued international imbalances, giving rise to the "adjustment puzzle" (Menon, 1995). These observations were complemented with the empirical findings of the fulfillment of the Marshall-Lerner conditions across the countries and thus the inability of floating regimes to enable rapid and efficient adjustment could not be explained from the traditional perspectives. It is in these concerns that the systematic empirical testing of the actual degree of pass-through to trade prices began actively. The 'fear of floating' (Bianchi and Coulibay, 2023) emerged as a serious policy concern and the analysis of ERPT had to be extended to account for domestic prices also. One issue was very clear during these times; the "degree of pass-through cannot emerge from a priori reasoning" (Patra and Patnaik, 1994, pp. 288).

Hence, ERPT to domestic prices is a critical issue and still reflects the fundamental early debates on the efficacy of the floating regimes. Since the adoption of the Liberalized Exchange Rate Management System (LERMS), India has been following a managed floating stance on the issue of exchange rate movements[9]. While the trend in the exchange rate is not directly controlled, the RBI actively attempts to manage the variability of the exchange rate. With the exchange rate being market determined with occasional interventions to smoothen out excess variability, there is a large scope for exchange rate variations to pass into the domestic price structure through the price channel, and through 'quantity channels' (Laflèche, 1996). Literature has focused on the issue of ERPT to trade prices, particularly to import prices, since the economic reforms in India and the findings on this account have been elaborated in chapters two and four. The findings on account of the pass-through to domestic prices in the Indian context since reforms has been that it is incomplete and that it reduces across the pricing chain beginning from import prices down to the consumer prices. Albeit, it is not possible to generalize the diverse studies through a direct comparison due to methodological differences, but even when due consideration is given to the econometric differences among the studies, the economic conclusion of incomplete price impact of exchange rate on domestic prices remains true. The debates persist on the actual extent of incompleteness and the factors that may have caused this. The amount of evidence on the inflationary consequences of exchange rate variations in the Indian context are scarce. Compared to the issue of import price pass-through, there is very limited evidence to allow a meaningful generalization of the debates and disagreements on the subject matter. Furthermore, among the evidence that exists in the Indian setting, there is no clear agreement on how much should the extent of pass-through be in the Indian context, even when it is presumed to be incomplete, and what macroeconomic factors could explain the apparent incompleteness in this regard. It is in these dimensions that the primary motivations of this chapter emerges.

The first task of this chapter is to empirically estimate the extent of price impact emanating from exchange rate variations in the short-run and long-run. As discussed in chapter four, the process of pass-through can undergo significant change once sufficient time is allowed for the initial exchange rate change to work out its price and quantity effects. Thus, there may be a difference between the short and long run pass-through effects of exchange rate alterations. Literature in the Indian context has generally found that the inflationary impact of exchange rate increases over time but the increase does not seem to be drastic. The 'incompleteness hypothesis' remains true even in the long-run. This chapter examines the inflationary impact of exchange rate changes by adopting a modified Phillips curve approach and develops two baseline models that capture the inflation dynamics in India from two different perspectives within the same underlying theoretical model. Dynamic partial adjustment models are estimated to estimate the extent of pass-over from currency variations changes to domestic inflation, where exchange rate is measured by both the nominal rupees per US Dollar exchange rate and the more comprehensive Nominal Effective Exchange Rate (NEER). The single equation partial equilibrium approach adopted to address this matter provides a parsimonious perspective on the pass-through effects of exchange rate while accounting for key macroeconomic dimensions of the inflation process itself. [10]

The estimated coefficient of ERPT are further examined for their sensitivity and robustness to alternative speficaitions which are derived from the variations of the underlying theoretical model and also from the different perspectives on the pass-through issue evident from the literature within the Indian setting. An attempt is thus made to provide a range of pass-through estimates and gauge whether the pass-through is indeed incomplete and if so, then the extent to which it is not complete within different analytical perspectives. These exercises are undertaken by employing both the bilateral exchange rate and the NEER. Both the short-run and the long-run pass-through estimates are presented. Moreover, the analysis of pass-through to domestic prices is undertaken while examining the nature of inflation process itself. This is necessitated by the fact that it is the inflation function, i.e. the equation relating inflation to exchange rate, which needs to be utilized to derive the estimate of ERPT coefficient. Accounting for what determines inflation is a momentous task and any approach that limits itself to partial equilibrium analysis will have to tackle the problems in capturing a highly dynamic process such as inflation into a single equation that can sufficiently capture these complexities. This chapter recognizes this facet and hence undertakes the estimation of the pass-through coefficient under different specifications to allow the complexities of inflation process to emerge in its different forms and thereby assess if pass-through behaves wildly under these alternative specifications. If the extent of pass-through is broadly stable even under different specifications that capture different dimensions of the aggregate inflation process, perhaps this could indicate the robustness of the findings and justify the parsimonious nature of the two baseline models. These matters form the second primary concern of this chapter.

The third issue that has motivated this chapter lies in the debates on the stability of exchange rate pass through coefficient across time, particularly in the light of the frequent shifts in the exchange rate and monetary policy regimes during the study period of 1991-92 to 2021-22. As already discussed in chapter four[11], the nature of economic relationships are generally expected to be stable across time so as to allow the clear identification of the underlying economic process and generalize it across time and space. In the presence of structural instability in an economic process, the linear models of pass-through relationships may not be sufficient to capture the inflationary dynamics at play. Such models would perhaps throw a biased picture on the extent of pass-through effects from currency alterations because the juxtaposed relationship would itself be undergoing a shift over time. Stable coefficients are thus necessary to make broader inferences from the estimated relationships. If the ERPT coefficient is unstable over time, then the inferences about its completeness and determinants in linear models would become difficult to solely rely upon. Alternatively, if the pass-through coefficient has remained stable over the study period, it can provide additional credence to the single equation linear models that are frequently employed to estimate the pass-through coefficients in the Indian and also international literature. These dimensions motivate the third primary concern of this chapter.

Exchange rate pass-through process is not a unidirectional process. There are feedbacks, interactions and dynamic interrelationships between exchange rate, domestic prices and other macroeconomic processes that may create complexities that partial equilibrium single equation models may not be able to capture satisfactorily. Furthermore, exchange rate and domestic prices can interact in a bidirectional manner with feedbacks and lagged impacts that require a dynamic modelling which can permit such interactions while estimating the extent of pass-through. The impact of exchange rate on domestic prices can change across the aggregate distribution chain as one moves closer to the retail price structure. Literature has time and again pointed out that the pass-through lowers as one moves from import prices to consumer prices. The examination of this hypothesis requires an approach that can allow richer dynamism than what single equation models can permit[12]. Accordingly, the issue of the dynamic impact of exchange rate variations on domestic prices is undertaken within a Structural Vector Auto Regression (SVAR) framework while endogenizing exchange rate, wholesale prices, consumer prices and output over the entire study period. The use of relevant exogenous variables that capture important policy shifts, external and domestic shocks that may affect the dynamic interactions between exchange rate and domestic prices are also incorporated into the SVAR framework. This allows ascertaining the impulse responses of domestic prices and output growth to exchanger rate shocks while accounting for their feedbacks and the impact of important supply-side and demand-side exogenous forces. Thereafter, the forecast error variance decompositions of the domestic price variables with respect to the shocks in exchange rate and other endogenous variables are also examined. Important analytical and policy insights are also derived from this exercise. These topics occupy the fourth and final concern of this chapter.

5.3. Alternative perspectives on the theoretical model in literature

The theory of ERPT is much richer when the attention is shifted from import price pass-through to the larger price impacts of exchange rate variations. The analysis of pass-through in the context of domestic prices is subsumed under the rubric of the macroeconomics of inflation. A theoretical model of inflation which is capable of incorporating open economy features suitable for a small open economy like India can is necessitated in the present context. The theory of inflation is a large and complex theoretical arena. There have been vast number of empirical perspectives and a large number of theoretical debates on what determines the inflation and which kind of model can capture the dynamics of inflation robustly across time and space. Macroeconomic literature presents different perspectives on this issue. There are several approaches in studying the nature of inflation process: the monetarist approach which stresses on money supply growth as the primary determinant of inflation, the Keynesian view which focuses on the demand-pull and cost-push factors, the structuralist approach that locates supply side real macroeconomic factors as the primary cause of inflation, the Phillips curve approach, and its more recent concomitant – the open economy New Keynesian Phillips Curve (Dua and Goel, 2021). Literature in the Indian context has utilized all these major approaches. Thus, one may broadly begin the search for a suitable approach to capture ERPT by examining the major evidences in recent time in the Indian setting. The literature, however, is scarce and despite the immense implications of this matter for monetary, exchange rate and even fiscal policies, "there is hardly any existing literature examining aggregate… pass-through for India" (Ghosh and Rajan., 2007b, pp. 373).

The literature in the Indian context, even though limited, provides useful indications of the nature of pass-through process from an empirical perspective. Ghosh and Rajan (2007a) is an early attempt in recent times in estimating the pass-through effects of exchange rates for domestic prices. The authors utilized the law of one price relationship to derive their fundamental pass-through equation at the aggregate level. The inflation function was then specified with one demand-side and one supply-side macroeconomic factor, namely by the Index of Industrial Production for demand-side shocks, and the US Producer Price Index and World CPI for capturing the supply-oriented shocks in the pass-through process[13]. Ghosh and Rajan (2007b) also utilized the similar framework for specifying the inflation equation to estimate the pass-through relationship. Raj et al. (2008) examined the domestic price pass-over from currency variations using a Vector Error Correction Model and specified their inflation function in terms of import prices, Rupee-US Dollar exchange rate, real GDP, call money rate, and capital flows. The specification was not derived from any *a priori* theoretical structure. The juxtaposing of the variables into the pass-through structure was rather *ad hoc*. This approach has been popularly used in the Indian context wherein at least two variables are always included – viz. the domestic price variable as a function of exchange rate. Other control variables are introduced into the equation as per the choice and understanding of the analyst. Generally, justification for the inclusion of the variables and the exclusion of other important factors is not provided in this approach.

Saha and Zhang (2010) examined ERPT to domestic prices using a Vector Auto Regression (VAR) approach with Cholesky decomposition to the variance matrix of the reduced-form residuals and identified the structural shocks by defining the ordering of the variables. They included six endogenous variables, namely – oil price inflation, interest rate, industrial output, import price, bi-lateral exchange rate and CPI for India, China and Australia. The authors specified their model and identified the variables by referring to previous literature. One may consider this approach to identification of variables as the 'literature-based' approach as against the purely *ad hoc* approach wherein no *a priori* justification is provided for identification of the variables. Sohrabji (2011) estimated the ERPT using a VAR model with oil prices, food prices, output gap, exchange rates, consumer price and interest rate as the endogenous variables. The authors specified the variables and their relationship by appealing to some of the previous literature. As evident in a large number of time-series empirical exercises on pass-through issue in India, the specification of the model emerged from previous literature, and a detailed justification of the rationale for the same is subsumed in the reference to the literature.

Kapur and Behera (2012) estimated the monetary transmission mechanism in India while constructing a large macroeconomic model of the real and monetary sectors of the Indian economy. They incorporated a Phillips curve relationship to derive the aggregate supply curve in an open economy context by also incorporating exchange rate as one of the determinants of the domestic inflation. Inflation was measured by the WPI in their study. This study adopted a systematic theoretical approach to derive the inflation function though which ERPT was estimated. The primary difference between the earlier studies and this study lied in the systematic choice of control variables while estimating the pass-through relationship. The variables other than exchange rate emerged from the well-established backwards looking open economy version of the Phillips Curve. The authors juxtaposed the Phillips Curve relationship as the aggregate supply curve in their analysis but incorporated output gap also which reflects the demand side pressures on inflation[14]. On broadly similar lines, Patra and Kapur (2012a) and Patra and Kapur (2012b) examined the issue of ERPT to domestic inflation in India within their broader examination of modelling the monetary policy transmission mechanism in India. The authors specified a so-called hybrid Phillips Curve by incorporating three aspects of inflation within the inflation function itself. Such a conception of the Phillips Curve emerges from the larger debates in the New Keynesian School in open economy macroeconomics of inflation analysis. The authors included the one-period forward-looking term of inflation and specified as the current period expectation of the future inflation, and one-period backward-looking term of inflation. In other words, both the backward-oriented and forward-oriented inflation dynamics were incorporated along with additional control variables. Thereafter, this hybrid version of Phillips curve was augmented into open-economy terms by introducing the bilateral rupee-US Dollar exchange rate. The coefficient of the exchange rate in this framework signified the ERPT relationship. This paper presented a well-defined theoretical model in terms of a hybrid open economy Phillips curve equation. Such an approach characterizes several studies in the recent time within the Indian setting.

Ranadive and Burange (2015) examined the issue of pass-through effects of exchange rate on import and domestic prices using a VAR model comprising crude prices, output gap, currency fluctuations, rate of interest, stock of money, and domestic prices, among others, as endogenous variables. Structural shocks were identified by suitably assembling the variables and using Cholesky decomposition approach. The variables were specified without providing details of the theoretical rationale of endogenizing them into the VAR system. Perhaps, one may consider this as an illustration of the *ad-hoc* approach explained earlier. Ozkan and Erden (2015) studied the ERPT phenomenon for large sample of countries including India using Dynamic Conditional Correlation-Generalized Autoregressive Conditional Heteroskedasticity (DCC-GARCH) to estimate the time-varying pass-through to CPI inflation and its determinants within a panel framework. The authors identified the variables based on the structure of the new open economy macroeconomic models of inflation that incorporate imperfections in markets such as staggered pricing and monopolistic competition. A sizeable amount of literature was reviewed and the authors identified exchange rate volatility, trade openness, inflation volatility and output gap as the key factors in their estimation of the ERPT relationship and its determinants. The theoretical model was developed on lines of the new open economy macroeconomic literature in this paper.

Jašová et al. (2016) estimated the extent of price impact from exchange rate for panel of 22 emerging economies and 11 advanced economies for the period 1994 to 2015 using quarterly data. The authors developed their empirical model within the New-Keynesian Phillips curve setup by incorporating inflation expectations along with country-specific output gap, world output gap and oil prices in the inflation equation. The NEER was employed to represent the exchange rate while inflation was measured by CPI. Carrière-Swallow et al. (2016) estimated ERPT using input-output analysis for 31 advanced and 31 emerging economies. The authors identified the variables based on the reduced-form approach to the specifications of the inflation function as per Campa and Goldberg (2005). They identified oil price inflation, food inflation, output gap, producer price index, lagged term of inflation and NEER as the factors determining inflation rate within which the pass-through coefficient was estimated.

Behera et al. (2017) examined the impact of exchange rate on domestic inflation within a Phillips curve framework that accounted for both the supply and demand side macroeconomic factors that determine the behavior of core and headline CPI inflations in India. They take into account output gap, exchange rate, oil prices, food prices, Minimum Support Prices (MSP), and rainfall. They augment the Phillips curve function for inflation inertia by incorporating open-period lagged inflation term. The authors used the new CPI-Combined index to measure inflation rate while exchange rate was measured by both the bilateral rupee-US Dollar exchange rate and the NEER to check for robustness of results. Forbes et al. (2017) estimated pass-through for 26 advanced and emerging economies including India and decipher the importance of the major macroeconomic factors in explaining the stability of ERPT over time. Headline CPI was employed to proxy inflation while exchange rate was measured by the NEER. The authors specified the inflation equation using the reduced form specification in Campa and Goldberg (2005) and others who extended it later. The authors identified world export prices, real GDP growth rate, and NEER as the factors determining inflation. The coefficient of all the lagged terms of NEER provided the estimate of the long-run ERPT while the coefficient of the current period value of exchange rate represented the short-run pass-through. The authors thus employed the standard macroeconomic model of Campa and Goldberg[15] and did not incorporate inflation inertia or expectations while estimating the pass-through coefficient.

Mendali and Das (2017) elaborated the extent of pass-through to domestic inflation in India using a VAR model integrating the currency value, inflation of oil rate, output gap and others as endogenous variables. Structural innovations were identified through appropriate ordering of variables and using the Cholesky decomposition to the variance matrix of reduced form residuals. Mendonça and Tiberto (2017) studied the pass-through issue in the context of the empirical implications of monetary policy credibility for pass-through in a sample of 114 countries including India. They employ a large number of macroeconomic variables in terms of domestic inflation measured by CPI, volatility of inflation, per capita GDP, ratio of M2 to GDP, financial openness, trade openness, output gap, and budgetary balance as proportion of GDP. The authors define ERPT as the first difference of the sum of log of WPI and log of bilateral exchange rate. This variable was employed in interaction with the monetary credibility index constructed in the study while examining the determinants of inflation. López-Villavicencio and Pourroy (2017) investigated the impact of inflation targeting regime on ERPT for a sample of 48 advanced and emerging countries including India. Inflation was measured by the CPI while exchange rate was proxied by the NEER. The authors identified the exchange rate, GDP, and OECD producer price index as key macroeconomic factors explaining the inflation phenomenon in their sample countries. There was no clear identification strategy specified in this paper for choosing these variables and perhaps a very general parsimonious inflation function was specified.

Bhattacharya and Rit (2018) estimated the pass-through effects of nominal bilateral exchange rate on CPI inflation in India and used the producer price index as a proxy for supply side shocks and GDP to represent the demand side shocks into the inflation equation. The authors adopted this specification from the previous work of Ghosh and Rajan (2007). Kassi et al. (2019) focused upon the issue of asymmetric pass-over from currency variations for six emerging economies including India using a non-linear ARDL model. The authors specified the inflation equation in terms of CPI inflation, bilateral exchange rate and oil price inflation and identified these variables based on previous works of Delatte and López-Villavicencio which was published in 2012, and Brun-Aguerre et al. (2016). Examining the issue of asymmetric pass-through, Patra et al. (2018) estimated the impact of exchange rate shocks on CPI inflation in India by developing a theoretical model on lines of the mark-up variations approach of Campa and Goldberg. The authors derived the consumer price inflation equation via substituting the import price equation into the producer price function and thereafter replacing the expanded producer price equation in the consumer price equation. The analysis was based on the new open economy standard mark-up-based pricing model. NEER was used to measure exchange rate while the new combined CPI was employed to proxy inflation. The study identified foreign cost conditions, measured by the ratio of NEER and CPI to the REER, domestic demand pressure as measured by domestic GDP, domestic costs by the Purchasing Manager Index (PMI) for India, foreign demand by the OECD IIP and commodity prices by the West Texas Intermediate (WTI) crude oil price.

Ha et al. (2019) analyzed the pass-through impact of exchange rate on consumer price inflation in 55 countries including India by employing a Factor-Augmented VAR (FAVAR) model. The global factors were represented by global inflation rate, global output growth and oil price inflation. Country-specific variables included inflation rate, output growth, changes in NEER, and monetary policy interest rates. Patra et al. (2020) estimated the pass-through coefficients in 17 emerging economies. The authors employed the theoretical model used earlier in Patra et al. (2018). Domestic inflation was measured by CPI, exchange rate was measured by the NEER, and domestic demand was proxied by the IIP. Balcilar and Usman (2021) focused upon the issue of exchange rate and oil price pass-through in BRICS countries. Inflation was measured by the CPI while exchange rate was proxied by the nominal bilateral exchange rate. Additionally, the paper identified output growth as measured by the IIP, and oil prices as control variables in the pass-through equation.

Balcilar et al. (2019) estimated the asymmetric pass-through for BRICS economies using a single equation Vector Smooth Transition Auto Regressive (VSTAR) model. The authors chose oil price, NEER, CPI and IIP to model the pass-through relationship. Dua and Goel (2021) scrutinized the determinants of inflation in India wherein exchange rate was employed as one of the variables in the inflation equation. Using the insights from previous literature, they located demand side factors that included exchange rate, growth in money supply, and output gap, and factors such as international oil and food prices represented the supply side shapers of inflation behavior. These factors were identified by reviewing the major approaches to analyzing inflation and the past literature. Bhat and Bhat (2021) examined the issue of asymmetric ERPT for India using an open economy Phillips curve framework to specify the inflation equation and identify the key factors to be incorporated into the pass-through estimation. Monetary policy variations and oil price inflation were used as control factors in the inflation equation.

5.4. Theoretical Model

The summarization of the major studies examining the nexus between exchange rate variations and domestic inflation provide several insight that provide useful indications on the nature of the pass-through process in India and the major variables that are ascertained as necessary in the estimation of the pass-through coefficient. The theoretical models adopted in the Indian context in the last two decades may be categorized into several types. First, there are the ad-hoc models that specify the variables for the inflation equation based on the subjective understanding of the analyst without detailed justification on their inclusion. Second approach has been to identify each individual variable of the pass-through equation by locating their rationale in the previous literature. Here, analysts have justified the inclusion of macroeconomic variables mainly on the basis of their frequent use in the past literature. The third strategy in identifying the variables in this regard has been to utilize the reduced-form specifications that are well-established and standardized in the international literature. The mark-up pricing model of Campa and Goldberg (2005) seems to be one of them. Another well-established theoretical model in reduced-form is that of Goldberg and Hellerstein (2008) that has been frequently employed in the Indian context.

While these specifications are meant for import price pass-through analysis, analysts are able to derive the domestic inflation equation through them. The fourth approach that appears to be recently gaining momentum in the Indian setting is to utilize a modified open economy Phillips curve equation to specify the inflation equation and identify the macroeconomic variables to be included in the same. Several variants of the Phillips curve are available in the literature.

The basis of the Phillips curve approach were laid down in Phillips (1958) who proposed that unemployment and changes in money wages were meaningfully related wherein unemployment could explain the behavior of money wages inversely. The fundamental thesis of this paper led to the creation of an entire school of thought that extended this idea to reflect the short-run trade-offs between inflation and growth which remains at the heart of macroeconomic analysis till date. Though debates have raged over its efficacy and empirical concerns have been raised on the alleged flattening of this trade-off curve in advanced economies during the recent times (Blanchard, 2016). However, it continues to be "the workhorse model for understanding inflation dynamics" (Behera et al., 2017, pp. 3) at aggregate levels. The basic Phillips curve equation has gone through a large range of metamorphosis since its inception in the original article by A. W. Phillips (Motyovszki, 2013). The immediate evolution after the original thesis was proposed, fructified in the works of Hicks (1937) and its incorporation into the neoclassical synthesis by Hicks and Samuelson both. This perhaps led to the recognition of the Phillips curve as an economic relationship that holds in the short-run.

The phenomenon of 'stagflation' led to re-questionings of the foundations of the Phillips curve hypothesis proposed in the neoclassical synthesis. The next evolutionary moment for this economic idea was in the works of Friedman (1968) and thereafter in Phelps (1967) who stressed on the role of expectations in determining the intensity of the trade-off[16]. This led to the creation of the expectations-augmented Phillips curve approach. The earlier approach to expectations formulation was adaptive wherein past inflation rates were expected to impact current inflation in a geometrically declining manner (Humphrey, 1985). The rational expectations criticism of Phillips curve and its subsequent modifications occurred in the works of in Lucas (1972, 1973) and Sargent & Wallace (1975)[17]. It is after the developments in 1975 that different approaches emerged and a wedge remained between these approaches (Gordon, 2011). Lastly, the more recent development has emerged in the New Keynesian Phillips Curve (NKPC) which juxtaposes inflation as a positive function of two key factors: first, the future expected inflation that agents would form in advance, and second, the output gap (Clarida et al, 2001). This approach to Phillips curve has been further extended to account for open economy features by incorporating exchange rate, trade openness, and financial openness to allow the external factors influence domestic inflation. There is a large body of literature that has defended as well as criticized this approach to inflation analysis. Some of the important criticisms of the NKPC have been proposed by established analysts like Paul Krugman, Gregory Mankiw, and Blanchard and Gali (2007), among others. The primary criticisms of these authors have been on account of inconsistencies in the NKPC formulation and their assertion that the empirical fit of this framework has been poor, particularly in the light of persistence of inflation. Ólafsson (2006) summarizes the voluminous debates on this approach and argues that despite its limitations, it is feasible to augment this framework by incorporating backward-looking expectations, open economy features and utilizing this approach for small-scale macro models of inflation.

This approach has been actively adopted in the Indian context in recent times as highlighted below. A major problem in utilizing the NKPC models is their strong dependency on micro foundations while assessing aggregate relationships. The underlying microeconomic assumptions regarding nominal rigidities, wage-setting behavior of firms in the economy, labour market frictions, and other pertinent aspects necessitate careful application of this model for aggregate analysis. The integration of open economy features further complicates the matter by allowing local price setting being additionally impacted by the "choice of currency, competition from abroad and ERPT into the prices" (Ólafsson, 2006, pp. 68). Nonetheless, these complexities do exist in the real world and inflation analysis cannot shy away from such complexities. The major criticisms of the different incarnations of the Phillips curve approach have largely been on ground of the unrealism of their underlying assumptions. The positivist thesis of Friedman (1953) might provide a perspective on this matter. He argues that achieving complete 'realism' in assumptions would violate the very need for modelling. Ideally, the assumptions should provide "good approximations to reality, and the only way to know that is by examining a model's implications" (Ivarola, 2018, pp. 419). The empirical exercises in the Indian context provide ample evidence of the ability of Phillips curve approach in explaining inflation process.

In the Indian context, one can locate the use of Phillips curve approach in estimating pass-through relationship in the works of Dholakia (1990), Srinivasan (2004), Dua and Gaur (2009), various works by the RBI, Paul (2009), Patra and Ray (2010), Kapur and Patra (2000), Singh et al. (2010), and Mazumder (2011)[18]. Recent works on this account include Kapur and Behera (2012), Patra and Kapur (2012a, 2012b), Jašová et al. (2016), Behera et al. (2017), Dua and Goel (2021), and Bhat and Bhat (2022). These studies provide the central organizing framework for the specification of the baseline theoretical models of this study. Consequently, the fundamental relationship based on which the inflation function is specified in this study are contained in equation one below:

$$\pi = \beta_0 + \beta_1 OGAP + \varepsilon \qquad \text{.....(1)}$$

Where, π is the rate of inflation of domestic prices, OGAP is the output gap and ε is the error term. This equation captures the fundamental relationship contained in the closed economy version of the New Keynesian Phillips curve as explained earlier. Inflation is modelled as emerging from variations in the output gap that reflects the real variations in the economy via the deviations of actual output from its potential level. It is expected that increases in OGAP would increase the inflation due to higher aggregate demand pressure and a fall in this variable would allow a fall in the inflation due to reduced demand pressure at the aggregate level. However, another fundamental dimension of the Phillips curve relationship is to incorporate expectations into its fold. Without the specification of the expectations formulation, it is difficult to operationalize equation one for empirical analysis and the specification will remain incomplete. Hence, the expectations augmented Phillips curve is shown in equation two below:

$$\pi_t = \beta_0 + \beta_1 OGAP + \beta_2 E(\pi_{t+1}) + \varepsilon \qquad \text{....(2)}$$

Equation two represents the basic version of the Phillips curve augmented for expected inflation. The forward-looking nature of this Phillips curve is visible in the specification of the expectations term. Macroeconomic literature in the Indian context has actively debated the true nature of expectations formation in the Phillips curve framework and "the limited evidence in the Indian context finds support for a backward-looking specification of the Phillips curve…" (Patra and Kapur, 2010, pp. 31). The bulk of evidence in the Indian setting has favoured the existence of adaptive expectations in inflation determination though some studies, such as Patra and Kapur (2012), have also adopted a so-called hybrid Phillips curve specification where both the forward-looking and backward-looking expectations are incorporated. However, even these studies have found evidence largely favouring a backward-looking adaptive expectations formulation as superior to other alternatives. Inflation has shown considerable inertia and persistence in the Indian analytical milieu. The present study thus incorporates the inertia and adaptive nature of expectations in the determination of inflation through equation three below:

$$\pi_t = \beta_0 + \beta_1 OGAP + \beta_2 \pi_{t-n} + \varepsilon \qquad \text{.....(3)}$$

Equation three expresses current inflation rate as a function of output gap and past inflation where if the value of 'n' is one, then one can obtain a purely adaptive expectations augmented inflation equation. If 'n' is larger than one, then there is evidence of high persistence of inflation with longer memory (Gil-Alana and Gupta, 2019) implying that considerably past information continue to impact current inflation rate. In this study, it is assumed that inflation would largely have a shorter memory and thus the immediate past inflation may impact current inflation rate, and inflation levels of deeper past would not have any impact on current inflation. This is an empirical question and thus alterative specifications will also be tested to test whether there is a high or a lower degree of inflation persistence in India. The equation three above captures the inflation process in a closed economy framework. Indian economy, however, is increasingly integrating into the international goods and financial markets. This has led to an increase in the openness of the economy. While Indian economy has shifted towards increasing openness, the nature of the economy is captured by a small open economy model, given the high dependency on imports, limited market power of its exporters in the international markets, price taking behavior in the imports sector as found in chapter four, and a smaller share in the global trade flows. The estimation of ERPT warrants that external factors are incorporated into the equation three above, thus yielding the equation four as below:

$$\pi_t = \beta_0 + \beta_1 OGAP + \beta_2 \pi_{t-1} + \beta_3 EX + \varepsilon \qquad \text{....(4)}$$

Equation four encompasses the effects of external sector on domestic inflation via the exchange rate channel. The coefficient of the exchange rate variable is the ERPT coefficient in the broad sense. Equation four represents a specification that has been used in the literature quite frequently. However, it is an incomplete specification as it does not account for the local realities and the nature of inflation specific to the Indian economy. Inflation in India is in large part driven by monetary policy. The strong connection between monetary policy and the inflation movement in India has been well-established in the empirical macroeconomic literature. The debate has increasingly shifted towards the way in which monetary policy should be captured in the inflation process. On the hand, there are proponents who suggest that money supply captures monetary policy dynamics much better than any other alternative. The monetarist tradition in macroeconomics and its later developments have focused on the variations in money supply as the representative of monetary policy. The essence of the quantity theory of money continues to dominate in this approach. However, there is a second approach also in the Indian context that focuses on the role of interest rates in impacting inflation. Mohanty and John (2015) note that the shift to the repo rate and the adoption of the weighted average call money rate as the operating target has increased the importance of incorporating interest rates in inflation functions, i.e. in equations that attempt to model inflation at the aggregate level. Consequent to both these approaches, the two baseline models adopted in this chapter incorporate both these perspectives of looking at monetary policy.

Another important dimension of inflation in India is the high oil dependency of the economy. This aspect was examined in chapter four and it was found that a large bulk of the aggregate imports basket of Indian contains crude oil expenditure. Our dependency on imports of crude oil creates an important channel through which inflationary pressures from external sector movement can percolate into the domestic inflation, even independently of the exchange rate channel. The impact of oil prices on domestic inflation has been termed as oil price pass-through in the macroeconomic literature in India (Bhanumurthy et al., 2012). Any specification of inflation function that does not account for the oil price pass-through channel may overestimate the extent of ERPT itself as the domestic inflationary momentum is built not only via the exchange rate channel but also via the effects of oil price variations on the domestic price structure. Moreover, the literature surveyed in the previous sections reveal that oil price inflation has been significantly and strongly impacting domestic inflation in India, whether inflation is looked from the angle of import prices, wholesale prices or consumer prices. The high dependency on imported crude oil and the use of this commodity as a critical input in a large number of industries makes it inevitable to account for oil price behavior in estimation of domestic inflation. Hence, the World Crude oil price is incorporated into the inflation equation[19].

This chapter also incorporates three important qualitative macroeconomic changes in the Indian context that are expected to impact inflation. The first is the introduction of the Flexible Inflation Targeting (FIT) by the RBI. This is represented by the variable D_{FIT}. The report of the RBI on the need and feasibility of FIT was submitted by the Expert Committee in January 2014. However, the RBI adopted it in October 2016. While there have been several other changes in the monetary policy regime such as the shift to multiple indicators approach in 1998, the adoption of repo as the monetary policy rate in 2011, among others, adoption of FIT was a landmark change in the Indian context. Macroeconomic literature is replete with evidence on the ability of inflation targeting regimes in reducing the level of inflation as well as its variability, and lending increased credibility to the monetary policy actions. It has also been found that the FIT regime has helped reduce the inflation level in India (Patra et al., 2018). However, very few studies even in the recent times have incorporated this important policy change into pass-through estimation. Hence, the present chapter accounts for the structural change brought by the formal adoption of the FIT in India by incorporating a dummy variable that takes the value of one for periods after 2nd Quarter of 2016-17 and a value of zero for periods before that. There are two perspectives on this matter that have been accounted into the estimation exercises later. First, a traditional dummy variable is specified with values 'zero' and 'one'. Second, following the interventional analysis approach contained in Enders (2014), an alternative approach is also adopted to specify the dummy variable in terms of gradual structural change where in the dummy takes the value of 0.25 from third quarter of 2014-15, when the FIT report was submitted to the RBI, 0.75 from third quarter of 2015-16 onwards and 1 from third quarter of 2016-17 when it was formally adopted by the Central Bank. This approach implies that the shift to the FIT regime was not sudden but gradual[20]. Furthermore, the Taylor's hypothesis ingrained in the pass-through literature since Taylor (2000) can also be tested by incorporating this dummy variable into the inflation equation. It is expected that the sign of this coefficient will be negative and significant, signifying the gains from shift to the explicit inflation targeting regime. If it is not significant, then perhaps there might not be sufficient evidence of lowering in the inflationary environment after the adoption of this policy.

The second is another shift in the monetary policy regime in May 2011 when the RBI adopted the repo rate as the monetary policy rate with the Weighted Average Call Money Rate (WACR) as the operating target. This is represented by the variable D_{MOPT}. It embarked a new era for the monetary policy formulation and provided a much more transparent, coherent and reliable framework which expectedly should have induced credibility gains. This change was a permanent change and not a one-time event. Hence, it is incorporated into the inflation equation by specifying a dummy variable that takes the value of one from the first quarter of 2011-12 and zero before that. With this variable, two significant monetary policy shifts are accounted into the pass-through estimation equation.

Third and last, a critical event during the study period and which created a havoc globally was the COVID-19 pandemic[21]. This is represented by the variable D_{PAND}. While the pandemic in itself does not portray direct implications for inflation, the subsequent series of lockdowns to prevent the spread of the pandemic may be construed as a domestically induced supply side shock. The sudden abruptions in economic activity increased the uncertainties in economic decision-making. With a large scale halting of production, scarcity of necessary items and critical inputs across major industries saw an increase. There are at least two ways of perceiving this event in terms of the implications for inflation. First, the halt in the economic activities which was unexpected and sudden, could have induced high scarcity of essential items for regular consumption. Naturally, the prices could be expected to rise in the aftermath of the lockdowns. Second, after allowing sufficient time for economic adjustments to occur, economy could slip into the grips of a recession, causing prices to fall. The immediate impact of the pandemic would largely be in favour of a rise in inflation reflecting the increased uncertainties in economic processes and higher scarcity of consumption goods, as also important capital inputs. The impact of the pandemic is expected to possess a longer memory given that such shocks do not recede quickly and create economic ripples that require time for complete adjustments to take place. The economy went through a deep recession with a large contraction of the GDP and the subsequent recovery through appropriately designed policy responses, the uncertainties created by the pandemic and the economic distortions induced by the same would not recede away rapidly. Hence, the period from 1st quarter of 2020-21 is valued at one while the period before the same is valued at zero[22].

Thus, two baseline models are specified in this chapter to capture the macroeconomic aspects of the inflation process and to examine the degree of pass-through in this context. Equations 5 and 6 reflect these two theoretical perspectives.

$$\boldsymbol{\pi_t = \beta_0 + \beta_1 OGAP + \beta_2 EX + \beta_3 MP_1 + \beta_4\, OILP + \beta_5 D_{MOPT} + \beta_6 D_{FIT} + \beta_7 D_{PAND} + \beta_8 \pi_{t-1} + \varepsilon} \quad \text{....(5)}$$

$$\boldsymbol{\pi_t = \beta_0 + \beta_1 OGAP + \beta_2 EX + \beta_3 MP_2 + \beta_4\, OILP + \beta_5 D_{MOPT} + \beta_6 D_{FIT} + \beta_7 D_{PAND} + \beta_8 \pi_{t-1} + \varepsilon} \quad \text{....(6)}$$

Equations five and six represent the two perspectives of analyzing inflation that are adopted in this chapter[23]. The first baseline mode, equation five, incorporates the money supply variable – M3 signified by MP_1. The second baseline mode, equation six, uses the WACR, a proxy for the short-term interest rate, to represent monetary policy movements. This is signified by MP_2. It is necessary to recognize the fact that the WACR is an operating target and the RBI monitors its movements to ascertain the immediate impact of its actions. Hence, in contemporaneous sense, WACR is the outcome of monetary policy rather than a reflection of the same. However, the lagged values of this variable can signify the monetary policy movements and their impact on current inflation rate. It is possible to allow lagged relationship between the changes in the short-term interest rate and its impact on inflation rate. As explained later, quarterly data are employed in this chapter. Given the higher frequency of data as compared to annual information, quarterly lags are feasible and permissible between monetary policy response and inflation movements. Thus, appropriate lag is determined for this variable through an empirical assessment. The expectation is that higher interest rate should result in lowering of inflation, albeit with some lags, if not instantaneously.

Lastly, the lagged term of inflation, i.e. the dependent variable itself, reflects the dynamic partial adjustment approach adopted in this chapter. Both the baseline models incorporate the inertia in inflation and reflect the backwards-looking Phillips curve relationship. As noted earlier, the bulk of evidence in the Indian context points towards a backward-looking inflation model providing better explanation of inflation than the forward-looking specification[24]. However, the length of the lagged inflation term is not specified a-priori in these baseline models to allow the testing of alternative specifications in this regard[25].

Given the analytical set up as narrated above, the next section describes the data environment of this study, the major variables employed, their sources and the choice of the time period.

5.5. Data, variables and sources

The data utilized in this chapter are sourced from official sources and represent aggregate secondary macroeconomic information. The nature of macroeconomic data, issues pertaining to aggregation, the importance and pitfalls in employing such data in economic analysis and other pertain pressing dimensions were evaluated in section 4.7 of chapter 1 earlier.

In this chapter, the primary variables of interest are inflation and exchange rate. Literature on the Indian context has used a host of measures to measure inflation at the aggregate level. On the one hand are the studies that have employed WPI as the measure for domestic price changes. On the other hand there are studies using the CPI as a proxy for domestic price changes. The evidence in the recent time has highlighted the increasing importance of the new combined-CPI as the preferred variable for measuring inflation process. There have been some studies that measured inflation by Producer Price Index, but the evidence is extremely scarce on this account. The final measure of inflation has been the aggregate GDP deflator. The choice between WPI and CPI is critical as both represent the price structure at different levels of the distribution chain (Ranadive and Burange, 2015). While wholesale prices reflect the bulk transactions being undertaken largely among different producers and other bulk traders, the consumer prices reflect the price variations experienced at the retail front where buyers and sellers trade the final goods with generally limited influence on the price formulation process. Indeed, literature on the ERPT issue has treated WPI and CPI as two different price variables reflecting different kinds of price variations in terms of the markets under consideration and the economic agents being covered. Consequently, the commodity composition of both the indexes also differs. These dimensions were already discussed in chapter four.

This chapter uses the WPI as the preferred measure of inflation and thus engages in the analysis of pass-through on wholesale price inflation. The official definition of WPI states that it "measures the average change in the prices of commodities for bulk sale at the level of early stage of transactions" (Ministry of Commerce and Industry, 2017, pp. 4). Furthermore the prices utilized are "ex- factory price for manufactured products, mandi price for agricultural commodities and ex-mines prices for minerals" (Ministry of Commerce and Industry, 2017, pp. 4). Movements in these prices are reflective of inflation at the stage between production and retail distribution and captures the price formation process which is located roughly in the middle of the distribution chain. In cross-sectional terms, these prices represent inflationary momentum between its importation into the economy via import price pass-through and the final culmination into the retail price structure. Wholesale prices can thus be a useful indicator of inflation at the level of production as well as at the stage of final retail distribution.

Inflation of import prices can lead to higher wholesale price inflation. Changes in relative prices of imported goods and their domestic substitutes can induce expenditure switching tendencies as buyers would shift to the lower-priced domestic substitutes. If the elasticity of substitution is low, which can be the case with imported capital inputs, the increased prices of imports would reflect in the costs of production of domestic producers which could propel a pass-over of the increased costs further down the distribution chain. If the elasticity of substation is high, then the large shift towards domestic substitutes could lead to demand-pull inflation further down the pricing chain, leading to higher inflation at the wholesale level. The end result in both the cases is an increase in the csonsumer prices and their subsequent culmination into aggregate demand and thereafter into output. The pass-over from currency variations to domestic prices would generally occur through import price variations. However, there can be a quantity channels too that can transmit exchange rate variations to domestic prices (Laflèche, 1996).

This study employs the WPI for All Commodities with base 2011-12. The decision to avoid employing the CPI index was primarily because on the one hand the new-CPI index is not available for backwards period, and on the other hand the CPI variable on which data for the sample period is available happens to be the CPI for Industrial Workers[26]. The consumption basket of this index is far from representative of the retail consumption basket of a typical citizen. Hence, the WPI was found to be more appropriate in these circumstances.

The other critical variable for the chapter is the exchange rate variable. Both the nominal exchange rate, i.e. the bilateral Rupee-US Dollar exchange rate and the more comprehensive NEER have been employed in the literature. The bilateral exchange rate with respect to the US Dollar represents the actual market movements of the currency's value. The variations in this variable are reflective of actual economic behavior of agents as they engage in international trade and financial activities. Furthermore, a large part of India's imports are invoiced in the US dollar (Gopinath, 2017)[27]. However, attention is also invited to the fact that a large part of this dominance of the US dollar emerges from its role as a vehicle currency in several trading partners of India

(Chen et al., 2022). The use of a currency as a vehicle currency can show apparently large 'dependency' on a currency while its frequent usage is primarily to establish value of other currencies which may be having thin foreign exchange markets. Literature has reflected on the frequent use of the bilateral exchanger rate. However, "this is adequate as long as the invoicing currency is either the importer's or the exporter's currency…. if the currency of invoicing is in fact a vehicle currency, then using the bilateral exchange rate may be inappropriate" (Chen et al., 2019, pp. 26).

Secondly, the implications of a currency for the import prices and domestic prices of a country are not determined solely on the basis of how frequently it is used as an invoicing currency. This is particularly true when there are multiple invoicing currencies or there are non-US Dollar vehicle currencies (Chen et al., 2019). The volume of trade with other countries is equally important to determine the impact of the foreign exchange rate on domestic prices. Though, the US Dollar dominates the currency invoicing in India's imports, the final implications of exchange rate for import prices is also based on the nature of trade that India has with other countries. If the volume of trade is itself low, then the impact of exchange rate changes on trade prices (including import prices) may not be sizeable. The impact on import prices of exchange rate change is thus conditional upon both the currency in which imports are invoiced and the volume of trade that an economy undertakes with other countries. Import prices are thus explained by both the exchange rate and trade volumes, and accounting for both these dimensions is essential to capture the "fair value of a currency" (Guria and Sokal, 2021, pp. 35). The Nominal Effective Exchange Rate is defined as "an index of the weighted average of bilateral exchange rates of home currency vis-à-vis currencies of trading partners, with weights derived from their shares in the trade basket of the home currency" (Guria and Sokal, 2021, pp. 35). The multilateral nature of trade becomes all the more crucial in an aggregate level study. Indeed, "for aggregate study, effective exchange rate is more suitable" (Mendali and Das, 2017, pp. 153). Lastly, the relevance of the effective exchange rates compared to the bilateral exchange rate is testified by the fact that "it more closely summarizes the set of relative price adjustments that can be expected to" shape the domestic prices (Carrière-Swallow et al., 2016, pp. 6)

Hence, this chapter adopts both the nominal bilateral exchange rate and the 36-currency trade-weighted NEER[28] with base 2004-05[29] for the examination of ERPT to domestic prices at the aggregate level. Both these exchange rates throw different perspectives on the same issue – the ERPT phenomenon. While the bilateral rate helps to capture the impact of actual market movements in the foreign exchange market on domestic prices, the NEER allows a more comprehensive and holistic perspective on how the value of INR has fluctuated while accounting for the trade volume dimension. As seen later, the extent of pass-through is slightly larger when the NEER is employed instead of the bilateral rate.

Other than these two core variables, the present chapter employs several macroeconomic information. Oil price variable is defined as the per barrel world crude oil price and is sourced from the World Bank database on Commodity Market prices, the so-called "Pink Sheet". The sources of data on WPI, CPI, and various exchange rates are already explained in section 4.5 of chapter four. Data on the WACR and TBILL are obtained from the Database on the Indian Economy of the RBI. Trade data are obtained from the Directorate General of Foreign Trade's online database as well as from IMF's 'Direction of Trade Statistics'. The data on food prices are based on the WPI for food commodities with base 2011-12 and are obtained from the same source as the parent WPI data. Volatility of inflation and exchange rate are estimated in terms of the moving standard deviation of monthly data on WPI, CPI, bilateral exchange rate, the NEER, and food inflation. In cases where instead of quarterly data, only monthly data were available, the monthly information were averaged appropriately to derive the quarterly estimates. The choice of the study period is from 1991-92 to 2021-22 and the rationale for this choice was already delineated in section 4.3 of chapter one.

Lastly, the study employs the output gap variable across the baseline models and their alternative specifications. Output gap represents the deviation of actual output from its trend level and represents the variations in unemployment inversely. The primary debate on this variable lies in the estimation of the potential output component, which is an unobservable variable and thus requires statistical estimation. There are several approaches through which this issue can be addressed. One approach is to estimate a simple linear trend through a trend regression and consider the fitted value from this regression as the potential output. This would imply that the potential output is linear in nature. Such an assumption may not always be true particularly when there are slow but important shifts in the long-run behavior of the economy. The second approach is to estimate a moving long-period average of output data and treat it as potential output. The third approach could be to estimate a non-linear trend by including polynomial terms of the trend function in the linear trend regression equation and account for non-linear trend also. The third approach to use smoothing techniques such as simple moving and exponential moving averages. The last approach is to estimate the potential output by using fileting techniques, among which the Hodrick-Presscot filter is the most frequently employed technique in the pass-through literature. Other common linear filtering methods include the Butterworth filter, Wiener–Kolmogorov filter, along with several other non-linear filters (Pollock, 2013). The fundamental aim of these filters is to estimate the signal, which in present context is the trend component, by extracting out the cyclical component, which is the noise component in the present setting, from observed time series by imposing a particular form of data generating process on the actual data. The motive behind filtering is "to remove unwanted components from a stream of data so as to enhance the clarity of the components of interest" (Pollock, 2013, pp. 95).

Assuming y_t is the actual time series, a_t is the trend component and c_t is the cyclical component, equation seven presents the assumed decomposition structure which is additive in nature[30]. Equation eight on the other hand represents the minimization problem under which this method estimates the trend component.

$$\mathbf{y_t = a_t + c_t} \qquad \text{....(7)}$$

$$\mathbf{min_{a(t)}\{\sum_{t=1}^{T} (y_t - a_t)^2 + \lambda \sum_{t=2}^{T-1} [(a_{t+1} - a_t) - (a_t - a_{t-1})]^2\}} \qquad \text{....(8)}$$

Equation eight represent shows two components in the minimization problem. First is the term on the left-hand side that represents the minimization of the deviation of original actual series from its trend. The second component represents "the curvature of the estimated trend" (OECD, 2019). Hence, there are two major goals to be achieved in the HP-filter as represented by the two components of the equation eight. Naturally, there is a trade-off between these two goals. The parameter λ represents this trade-off. The value of this parameter will be reflected in the smoothness of the estimated trend. Higher is the value of this parameter, the smoother will be the estimated trend, and vice-versa. With regards to quarterly data as employed in this chapter, the value of λ is assumed to be 1600. This value has become a rule-of-thumb following the recommendations of the Hodrick and Prescot themselves in their original paper. A common concern with using the HP-filter is the higher sensitivity of the estimated trend to shocks at the end

– points of the sample period (Baxter and King, 1999; OECD, 2019). One approach to dealing with this issue is to trim the starting points and end points of the sample period (OECD, 2019). In summary, the HP-filter provides an operationally useful approach to estimating the long-term behavior of a time series and utilizing it allows easier comparability of results with extant literature which has frequently used this approach[31].

5.6. Descriptive statistical estimates and time series properties of the chosen variables

This section summarizes the descriptive statistics and key time-series dimensions of the variables used in the chapter. Table 5.1 presents the descriptive estimates of the macroeconomic variables employed in this chapter. Inflation has remained high during the sample period as evident by the mean values of WINF and CINF which are estimated at 5.66% and 6.79% respectively. Wholesale and consumer inflations have shown higher variability but the frequencies of very large deviations from the mean seem to have been very less as indicated by their near-normal excess kurtosis. The skewness of WINF is low but that of CINF is slightly high, though it seems that both have had a fairly similar intensity of shape of momentum during the sample period. Among the domestic inflation variables, FINF has shown highest variability and its skewness is also higher than wholesale and consumer inflations. The vagaries and uncertainties of agricultural production in India, especially the deviations of actual rainfall from its normal level could have been responsible for this behavior of food inflation.

The variable OILINF has shown the largest variability as indicated by its CV at 341.64% with a high skewness. World oil prices are compositely determined by a large number of demand and supply side variables, and the international oil market is substantially volatile. The price discovery process in the international oil market is also not symmetrical due to different oligopolistic players imposing their dominance through price manipulations too. The OPEC cartel is particularly known for these kind of practices. Furthermore, international geopolitics had been very volatile during the sample period and oil prices tend to be strongly influenced by supply-side bottlenecks created due to events such as trade wars between large nations, blockages to the important international sea routes, strong competition from the US Brent crude oil to the OPEC oil supplies, among other factors. High level and variability in oil prices can become a source of instability in the inflationary momentum in India due to large dependency on oil imports.

Shifting the attention to exchange rate variables indicate that the Indian rupee has largely been depreciating across the study period as shown by the mean values of 3.43% and -1.60% of RSUSDG and NEERG in table 5.1. The consistent depreciation of the rupee, whether looked at from perspective of the US Dollar or the more composite NEER shows the persistence in the fall of value of the INR in against major currencies. This also opens up the question of how this depreciating tendency of the rupee has translated into inflationary implications for the Indian economy.

NEER has shown a larger variability which is expected as it is composed of several currencies whose absolute and relative movements will implicate the overall index's movements. The minimum and maximum values of the inflation and exchange rate variables indicate episodes of large deviations from the mean on both the ends. The minimum value of the oil price variable particularly stands out at -53.71%.

Table 5.1: Descriptive statistical estimates of the macroeconomic variables across the entire sample period

Statistic	**WINF**	**CINF**	**FINF**	**OILINF**	**RSUSDG**	**NEERG**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Mean	5.66	6.79	6.28	10.29	3.43	-1.60
SD	3.96	3.38	5.01	35.17	6.97	4.93
CV	69.96	49.71	79.70	341.64	203.15	-307.49
Max	16.08	17.86	20.94	126.28	24.96	10.32
Min	-5.51	-0.49	-2.14	-53.71	-12.61	-14.50
Skew	-0.02	0.50	0.74	0.67	0.56	-0.44
Kurt	3.31	3.27	3.32	3.74	3.72	3.08
JB Statistic	0.50	5.37*	8.28**	12.07***	8.85***	3.69
Observations	122	122	87	122	119	114
Statistic	**WINFVOL**	**CPINFVOL**	**FINFVOL**	**NEERVOL**	**NMONG**	**RMONG**
	(7)	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**
Mean	1.71	1.43	3.34	4.03	15.06	9.06
SD	0.86	0.95	1.96	3.24	3.85	4.52
CV	49.96	66.71	58.63	80.53	25.53	49.89
Max	4.81	5.66	7.84	18.38	23.28	20.11
Min	0.50	0.47	0.50	1.22	6.30	-6.38
Skew	1.70	1.86	0.30	2.94	-0.08	-0.46
Kurt	5.80	6.94	2.10	12.06	2.32	4.34
JB Statistic	96.23***	145.60***	4.20	540.47***	2.45	13.32***
Observations	119	119	87	111	121	121

Table 5.1 *(continued)*					
Statistic	**RGDPG**	**WACR**	**TBILL**	**TOPEN**	
	(13)	**(14)**	**(15)**	**(16)**	
Mean	6.55	7.55	6.36	31.23	
SD	4.39	4.06	1.69	8.37	
CV	67.06	53.75	26.56	26.81	
Min	21.55	26.96	10.22	49.18	
Max	-23.37	3.17	2.82	17.06	
Skew	-2.91	2.51	-0.07	-0.08	
Kurt	23.83	10.91	2.58	1.97	
JB Statistic	1987.38***	460.37***	0.80	4.82*	
Observations	102	126	100	106	

Notes: 1. SD is Standard Deviation, CV is Coefficient of Variation, Skew is Skewness, Kurt is Kurtosis; 2. All data are expressed in percentage except WPINFVOL, CPINFVOL, FINFVOL, and NEERVOL; 3. Statistics are for the common sample ranging from 1991:Q1 to 2022:Q2; 4. Number of observations are different for the variables due to data availability. 4. Growth rates are on year-on-year basis for the quarterly data. **Source**: Author's estimation.

An interesting point to note is that the bilateral exchange rate has behaved non-normally as indicated by the JB-statistic of RSUSDG while NEERG has behaved symmetrically during the study period. This has important implications for employing both the variables in estimating the pass-through as shown later in the empirical exercises. The volatility indicators for domestic inflation show fairly similar behavior as far as wholesale inflation volatility and consumer inflation volatility are concerned. Both variables show prevalence of frequently large deviations from the mean as indicated by their kurtosis estimates. Food inflation volatility has rather been more coherent and well-anchored to its mean path as show by the excess kurtosis of FINFVOL which is lower than that of WINFVOL and CINFVOL. Both, WINFVOL and CINFVOL have displayed non-normal behavior as indicated by the JB-Statistic of these variables while FINFVOL has behaved normally. The volatility in NEER has been high and characterized by high kurtosis and skewness. The behavior of exchange rate variations itself has been unstable over the sample period. The high frequency of large deviations around the mean path indicates the inflationary impulses being generated by exchange rate movements, again opening up the issue of how these impulses have been transmitted into the domestic inflation in India.

When attention is paid to the other macroeconomic variables, it is seen that both the nominal and real money supplies have grown positively during the period with the real money supply indicating larger variability. It may not be an overstatement to suggest that we reside in permanently inflationary society and this fact is testified by the consistently increasing prices during this period as reflected by the mean values of WINF and CINF as well as by the continuous expansion of the money supply. The quantity theory of money juxtaposes that expansionary monetary policy will inevitably translate into higher inflation. During the sample period, exchange rate has depreciated consistently while money supply has also grown unabated. It is thus important to account for both these dimensions in the inflation process to ascertain the source contributing the highest to the inflationary momentum in India. Nominal money supply has displayed symmetrical distribution of its growth across the period while real money supply has displayed non-normal behavior. Perhaps, the normality of nominal money supply growth reflects the stability in the behavior of monetary policy, indicating consistent growth without large disruptions that could have contributed to abnormal skewness or kurtosis. While monetary variables are important for understanding inflation, at least in the short to medium runs, real variables also play a pivotal role by generating demand side impulses that could have serious implications for inflationary momentum in India. RGDPG, the growth in aggregate real GDP, has been positive throughout the period with mean value of 6.55%. The growth experience, however, has been challenging for India as indicated by the high kurtosis and a negative and high skewness. It is a well-established fact that the growth path of emerging economies are driven by uncertainties and policy challenges that require not only immediate but also long-term prudent interventions. India's growth has been characterized by frequent large deviations from the mean path as implied by the heavy tails of its distribution.

During the study period, a large number of events have unearthed on economic, political and international fronts that could have produced this behavior from economic growth of India. The BoP crisis, subsequent structural adjustment programme, the Asian Financial Crisis, World trade slowdowns, wars between major trading blocs, the global financial crisis, agricultural uncertainties, the pandemic, are among some of the most important shocks for the domestic growth path of India. These events could have been responsible for the high kurtosis and high and negative skewness of our growth experience. Despite these, India has been able to sustain a real growth rate of 6.55% during the period which indicates massive expansion throughout the period, and perhaps another source of inflationary momentum. The other remaining variables include the short-term interest rates and trade openness. WACR has shown prevalence of large abnormal experiences during the period as shown by its high kurtosis while TBILL variable has been fairly symmetrical.

India's trade openness, defined as the ratio of total real trade to real GDP, has shown sizeable increase during the period with mean value of 31.23%. Its variability has been fairly low as indicated by its CV at 26.81%. In an increasingly open economy, the external shocks tend to transmit faster and stronger to domestic macroeconomic outcomes. Hence, this variable may also be an important source of inflation in India, along with exchange rate, inflation persistence, inflation and exchange rate volatilities, and money supply growth.

The interconnections of the variables are better reflected in Table 5.2 which presents the correlation structure among the variables employed in this chapter. The relationship of WINF is found to be high and significant with OILINF. Oil price inflation has strong inflationary consequences in India though what is termed in the literature has 'oil price pass-through' phenomenon (Bhanumurthy et al., 2012). The high positive correlation at 0.63 between WINF and OILINF is also statistically significant. There may be causal links between these two variables and as examined later, there is a sizeable pass-through from oil price movements to domestic inflation in India. The correlation of wholesale inflation with consumer and food price inflations is fairly moderate, though significant. Momentum built at the wholesale level tends to be passed further into the pricing chain.

Consistent with fundamental beliefs of monetary theory of inflation, the correlation of money supply variables is high with wholesale inflation at 0.43 and -0.54 respectively for nominal and real money supplies. After oil price inflation, money supply seems to have a high correlation with wholesale price inflation. This relationship is weak when looked from the perspective of CINF which has a correlation of only 0.32 with NMONG and a negligible correlation with RMNOG. In similar sense, WACR has a higher and statistically significant correlation with WINF while there is no significant correlation with CINF. It is apparent that the wholesale inflation better reflects the monetary factors. Most importantly, real GDP growth has a statistically significant and positive correlation with WINF while it is insignificant with CINF, indicating better reflection of real sector in wholesale inflationary momentum. Consistent with the literature on consumer price inflation dynamics in India, FINF has much higher and strongly positive correlation with CINF than WINF. Food price inflation tend to be rapidly and sturdily reflected in the retail price structure due to their high contribution in the average consumption basket and perhaps the low price elasticity of demand for food items which results in larger Passover to consumer prices.

Table 5.2: Correlation structure among the selected macroeconomic variables

Variables	WINF	CINF	FINF	OILINF	RSUSDG	NEERG
CINF	0.34***					
FINF	0.38***	0.85***				
OILINF	0.63***	-0.03	-0.02			
RSUSDG	-0.10	0.25**	0.08	-0.48***		
NEERG	-0.27**	-0.27***	-0.11	0.14	-0.83***	
WINFVOL	0.001	0.48***	0.44***	-0.20*	0.29***	-0.16
CPINFVOL	0.17	0.22**	0.35***	-0.03	0.05	-0.03
FINFVOL	-0.09	0.32***	0.40***	-0.19*	0.18*	-0.09
NEERVOL	0.19*	0.17	0.20*	0.14	0.06	-0.12
NMONG	0.43***	0.32***	0.40***	0.21*	-0.04	-0.11
RMONG	-0.54***	-0.01	0.02	-0.41***	0.06	0.14
RGDPG	0.28***	0.15	0.20*	0.40***	-0.38***	0.30***
WACR	0.20*	0.18	0.05	-0.04	0.33***	-0.27**
TBILL	0.16	0.20*	0.04	0.02	0.24**	-0.16
TOPEN	0.33***	0.61***	0.48***	0.14	0.27**	-0.31***
Variables	**WINFVOL**	**CPINFVOL**	**FINFVOL**	**NEERVOL**	**NMONG**	**RMONG**
CPINFVOL	0.32***					
FINFVOL	0.25**	0.58***				
NEERVOL	0.29***	0.35***	0.29***			
NMONG	0.13	-0.09	-0.39***	0.24**		
RMONG	0.13	-0.24**	-0.27***	0.04	0.53***	
RGDPG	-0.04	-0.09	-0.11	-0.01	0.17	-0.10
WACR	-0.11	-0.14	0.07	-0.02	0.05	-0.15
TBILL	-0.10	-0.19*	0.13	0.001	-0.04	-0.19*
TOPEN	0.36***	0.30***	0.49***	0.45***	0.09	-0.22**
Variables	**RGDPG**	**WACR**	**TBILL**			
WACR	0.14					
TBILL	0.24**	0.92***				
TOPEN	0.20*	0.39***	0.48***			

Notes: 1. ***, **, and * imply significance levels of 1%, 5%, and 10% respectively; 2. The sample period in this period is 2000:Q4 to 2020:Q4 to ensure a balanced sample.

Volatilities in inflation represented by WINFVOL, CINFVOL and FINFVOL have statistically no meaningful correlation with WINF, but they share a significant correlation with CINF. Contrastingly, exchange rate volatility as captured by NEERVOL has a significant and weakly positive correlation with WINF but not with CINF. In a similar vein, it can be observed that exchange rate variable NEERG has theoretically expected direction of correlation with both WINF and CINF and both are statistically significant. The bilateral exchange rate, represented by

RSUSDG, while sharing the expected sign of correlation, is significantly associated with CINF rather than WINF. This may perhaps be a reflection of the higher ability of NEER in explaining variations in wholesale inflation, while that of the bilateral exchange rate in explaining movements in consumer inflation[32]. One possible explanation for this finding may be that the imports of consumption goods occupy much larger space in the consumption basket while capital imports including oil imports occupy a larger place in wholesale basket. Capital and oil imports may be emerging from countries that do not solely rely on the US dollar or may perhaps only be using it as a vehicle currency. Thus, the movements in a larger basket of currencies is able to better explain the inflationary momentum at wholesale price level. The consumption imports on the other hand may be emerging from sources that largely employ the US Dollar and thus the bilateral exchange rate is able to capture inflation dynamics at consumer level. Both NEERG and RSUSDG are strongly correlated implying similar movements in the value of the Indian currency whether looked from the viewpoint of the bilateral or the more comprehensive effective exchange rate. This is also expected as movements in the US Dollar tend to impact other currencies also due to the dominance of this currency not only in invoicing but also as the currency to which many currencies are aligned by their respective monetary authorities.

Other macroeconomic variables present a broadly coherent picture with most of the variables showing either low and significant correlation or statistically insignificant correlation. This is essential because high correlations among possible regressors would cause information repetition in the regression estimation. Low correlations among regressors is a reflection of unique and independent information content that each of these variables can bring into the macroeconomic model. Furthermore, econometrically, it is necessary to incorporate regressors that are not correlated with each other to avoid the problem of multicollinearity and possible autocorrelation. The broad prevalence limited or no association between the potential regressor variables is a testimony of the important role that each of these variables can play in the estimation of ERPT.

Lastly, before embarking on empirical estimations, it is necessary to ensure that the data employed possess time series properties that render them suitable for econometric analysis. Stationarity of the chosen variables is a necessary condition before utilizing them in regression framework using the Ordinary Least Squares and the SVAR model. Stationarity implies mean reversion and thus shocks will tend to even out and the variable would move on a stable path (Jalil and Rao, 2019). When the data are not mean-reverting, their behavior can be unstable and highly sensitive to shocks. This may not allow the modelling of meaningful co-movements among variables and detecting causal connections as noise in the data could overpower the signal. There is a vast literature on the issue of non-stationarity and its econometric implications for estimated coefficients and their stability, reliability and consistency. These issues were discussed in section 4.6 of chapter four. While not repeating the same issues again, it is important to note that several of the macroeconomic variables used in this study are transformed into first difference of their logarithmic values. The final form in which each variable is to be employed is primarily based on stationarity considerations and also the requirements of the theoretical model employed in this chapter. Furthermore, by log-differencing the key variables in this chapter, namely the wholesale price inflation and exchange rates, consistency can be achieved between the ERPT estimates in the previous chapter and the current chapter[33].

Congruent with the modern practice in empirical macroeconomic literature and also the approach adopted in the previous chapter, three different stationary tests are employed in this chapter also. The first is the Augmented Dickey-Fuller test which hypothesizes unit root in its null hypothesis. The second is the Phillips-Perron test which also specified existence of a unit root in its null hypothesis. The third test is the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test which specifies stationarity in its null hypothesis. Hence, the interpretation of KPSS test is inverse of the test statistics for the other two tests. Each of these stationarity tests reflect a different perspective of examining the same issue. By using multiple tests, the nature of each variable is rigorously explored with no room left for methodological sensitivity to distort the findings. The results of the stationarity tests are presented in Table 5.3.

Table 5.3: Stationarity tests for the selected variables

Sr. No.	**Variable**	**ADF-test**	**Phillips-Perron test**	**KPSS test**	**Final remark**
1	ΔInWPI	-2.95**	-7.50***	0.28	Stationary
2	ΔInCPI	-7.87***	-7.93***	0.35	Stationary
3	ΔInFPI	-2.56$^{\$}$	-8.01***	0.23	Stationary
4	ΔInOILWB	-8.07***	-8.67***	0.05	Stationary
5	ΔInBEX	-6.70***	-8.52***	0.07	Stationary
6	ΔInNEER	-4.60***	-9.69***	0.06	Stationary

Table 5.3 *(continued)*					
7	InWVOL	-3.34***	-3.74***	0.32	Stationary
8	InCVOL	-3.69***	-2.80*	0.20	Stationary
9	InFVOL	-2.22	-1.54	1.62***	Non-Stationary
10	InNEERVOL	-2.19	-2.81*	0.31	Stationary
11	ΔInNM3	-1.48	-7.88***	0.97**	Stationary as per Test-II
12	ΔInRM3	-2.72*	-7.26***	0.43*	Stationary
13	ΔInRGDP	-9.96***	-16.18***	0.09	Stationary
14	InWACR	-4.11***	-4.12***	0.99***	Stationary
15	InTBILL	-2.39	-2.39	0.17	Non-Stationary

Notes: $ implies significant at 11%; For the ADF test and Phillips-Perron test, p-values are one-sided and based on MacKinnon (1996). The critical values for the KPSS test statistic are based on Kwiatkowski et al. (1992). All the variables have been deseasonalized in their level form using appropriate methodology. The correlations between the deseasonalized and non-seasonalized series are very high and positive, and they are statistically significant at 5% level. There is no evidence of statistical difference between the mean values and variances of the deseasonalized and non-seasonalized series at 5% level of significance. **Source**: Author's estimation.

The form of the variables presented in Table 5.4 corresponds to the form chosen to be employed in this chapter. Each variable was first tested for stationarity in its actual level form. If stationarity assumption was rejected in level form, then other transformations were attempted. The transformations where the series were found to be stationarity are reported in Table 5.4. Despite further transformations, InFVOL and InTBILL do not lend themselves to stationary behavior. It was thus decided to avoid using these variables. The nominal money supply variable was found to be stationary based on the Phillips-Perron test and despite the indications of non-stationarity from other two tests, this variable is critical for the issue of ERPT within the single equation framework. Another possibility could have been to use of real money supply instead of the nominal money supply. This is also undertaken in the alternative specifications for robustness checks. However, deflating nominal money supply would require a price index and largely all the price indexes tend to be correlated with each other. Hence, there could be a danger of measurement error in this approach. Thus, the nominal M3, i.e. ΔInNM3 is employed to represent MP^1 as expressed in Equation 5. Instead of InTBILL, the variable InWACR is employed to represent MP^2 in Equation 6.

5.7. Empirical Estimations

This section presents the main empirical findings of the chapter. The estimated models from equations five and six are presented in section 5.7.1. The extent of ERPT in India to domestic inflation is captured by the coefficient of the exchange rate variable and the same are pitched through the two baseline models. Thereafter, in the same section, alternative perspectives are presented on the issue of pass-through while incorporating different specifications that reflect factors other than the ones incorporated in baseline models that may have implications for inflation in India. These alternative specifications also enable the assessment of robustness of the estimated pass-through coefficient. If the estimated coefficient remains broadly within a well-anchored range, then the findings assume much more reliability. Section 5.7.2 looks at the issue of ERPT to domestic inflation using annual data instead of quarterly data. Use of different frequencies of data may cause differences in the behavior of pass-through due to different nature of cyclical, seasonal and trend components at different frequencies.

Section 5.7.3 investigates the issue of stability of pass-through relationship across the study period. As discussed at length in sections 47 and 4.8.4 in chapter four, the time-varying nature of pass-through coefficient is investigated for the present case. This is undertaken from two perspectives: first, a rolling regression approach his utilized; and second, a linear time-varying coefficients model on the lines of Schlicht (2021) is also used for examining the stability issue. Lastly, section 5.7.4 examines the issue of ERPT in a SVAR framework to trace the impulse responses of wholesale and consumer price inflations to structural shocks in exchange rate and traces the relative contribution of the different shocks in explaining the total forecast error variance of inflation in India.

5.7.1. Extent of exchange rate pass-through to domestic prices in India

This section presents the results of the estimated model using equation five. The variables are stationary and each of the variable has been explained in section 5.3 earlier. The empirical specification of equation five is shown below in Equation 9[34].

$$\Delta \mathbf{InWPI} = \beta_0 + \beta_1 \mathbf{OGAP} + \beta_2 \Delta \mathbf{InNEER} + \beta_3 \Delta \mathbf{InNM3}_{t-2} + \beta_4 \Delta \mathbf{InOILP} + \beta_5 \Delta \mathbf{D}_{\mathbf{PAND}} + \beta_6 \Delta \mathbf{InWPI}_{t-1} + \varepsilon \quad \text{....(9)}$$

In equation nine, ΔInWPI is the log difference of wholesale price index for all commodities as defined in section 5.3 and 5.4. OGAP is the output gap variable estimated using logarithmic value of the quarterly constant price aggregate GDP at market price with base year 2011-12. It was found to be stationary in level form itself. The variable is defined as the difference between actual output and the potential output. The potential output component is proxied by the trend estimated via the HP-filter. NEER represents the Nominal Effective Exchange Rate for the 36-currency trade-weighted index with base 2004-05. The information on this variable is available on monthly basis and thus the quarterly average of this monthly data have been used in the present setting. ΔInNM3 represents the nominal money supply variable. ΔInOILP represents the world oil price inflation and reflects the supply side shocks emanating from global commodity markets as well as the inflationary implications of crude oil due to its important role in the aggregate imports basket of India. Furthermore, crude oil is a critically important capital input in a large number of industries. Hence, its usage is warranted to comprehensively capture the behavior of aggregate inflation in India. It is anticipated that increased oil prices will translate into higher inflation at home. D_{PAND} represents the dummy variable as explained in section 5.3. Lastly, the lagged value of inflation variable, i.e. the independent variable is included to incorporate partial adjustment mechanism in the model. This also allows the estimation of the long-term pass-through coefficient following the approach adopted in chapter four. It is expected that inflation will display inertia and thus the sign of this variable is anticipated to be positive.

Table 5.4: Anticipated behavior from the coefficients in equation one

Sr. No.	Variable	Expected Sign
1	OGAP	+
2	ΔInNEER	-
3	ΔInNM3$_{t-2}$	+
4	ΔInOILP	+
5	D_{PAND}	+/-
7	ΔInWPI$_{t-1}$	+

Source: Author's estimation.

The expectations of the impact of these variables on domestic inflation are contained in Table 5.4. Increase in output gap is expected to increase the inflation momentum. The mechanism behind this relationship is generally explained in terms of the demand-pull pressures that deviations of the economy from its potential level can impose on prices. Within the augmented[35] open economy new Keynesian framework, if the economy is functioning over its potential level, capacity constraints can cause increases in aggregate demand to produce price impact rather than quantity adjustments (Dua and Goel, 2021). This would build up the upwards pressure on domestic prices leading to higher inflation. Furthermore, within the Phillips curve setting, higher output gap also represents reduced unemployment, indicating rise in employment and subsequently robust aggregate demand. This could cause demand-pull inflation and hence the coefficient is expected to show a positive sign. The second variable is the exchange rate variable and the NEER is used to measure it in the baseline specifications, though robustness checks are made by using the bilateral rupee-US Dollar exchange rate also as shown in Table 5.5. As explained earlier in section 5.3, the theory of ERPT necessitates that exchange rate depreciations induce inflationary momentum while appreciating exchange rate should allow disinflation. Given that the NEER is defined in terms of number of foreign currency units per unit of INR, the expected sign is negative, which reflects the above mentioned expectations. Incorporation of the exchange rate variable in the baseline Phillips curve models augment them with open economy features.

Monetary policy is captured by the nominal supply of money in terms of the M3 measure. It is represented by ΔInNMON. The rationale for employing this measure was examined in section 5.6 earlier in this chapter. The expected sign is positive. As shown later, the use of the nominal M3 rather instead of the real M3 resulted in the model where dummy variables for FIT regime and the introduction of the operating target became insignificant. Hence, those dummy variables were excluded from the final estimated model reported in Table 5.5. The dummy variable accounted in equation nine is D_{PAND} and as explained earlier in this section, it represents the impact of the recent COVID-19 pandemic and the subsequent lockdowns that created a supply side shock due to sudden abruption of production activities. While it is plausible to expect that the pandemic and resultant lockdowns generated a supply side shock, it is also possible to conceptualize this variable as inducing a recession and thus reduce the inflation. Both the possibilities are perhaps equally likely and thus both the signs are expected on this variable.

The results of the estimated model are presented in Table 5.5. The coefficients represent relationships in log-difference form and thus their interpretation may be done in percentage terms to lend easier interpretation to their values. Inflation changes by 1.4% impact for every 10% change in OGAP, indicating a positive effect of demand pressure on prices. The sign is thus as expected. Demand forces have continued to play an important role in shaping inflation at least from the perspective of short-run dynamic of inflation. Money supply is strongly impacting inflation as seen by the coefficient value of 0.29. For every 10% increase in money supply, inflation increases by 2.9%. In other words, a 100% increase in money supply would lead to approximately 29% increase in inflation as per the estimated model. Inflation continues to be dominated by monetary factors and this finding testifies the deep impact of the RBI's policy actions on inflationary momentum. Another critical source that builds up the inflationary pressure in the economy is oil price inflation. As discussed earlier, increases in oil prices percolate into domestic prices via the imports channel as well from other channels such as the increase in the oil subsidy burden on the Government and possible tax increases due to the same. There may be even more complex mechanisms at work as found by Bhanumurthy et al. (2012) in the Indian context, but largely, the imports channel seems to be the primary carrier of the inflationary impulses of oil price rise.

Table 5.5: Extent of ERPT to domestic inflation for the period 1996:Q1 to 2022:Q1

Dependent Variable is ΔInWPI						
Sr. No.	**Variable**	**Coefficient Value**	**Standard error**	**t-ratio**	**Expected Sign**	**Estimated Sign**
0	Constant	-0.003	0.004	-0.832	NA	
1	OGAP	0.14***	0.037	3.696	+	+
2	ΔInNEER	-0.18***	0.044	-4.022	-	-
3	$\Delta InNM3_{t-2}$	0.29***	0.103	2.812	+	+
4	ΔInOILP	0.04***	0.007	4.996	+	+
5	D_{PAND}	0.02***	0.004	3.824	+/-	+
6	$\Delta InWPI_{t-1}$	0.26***	0.072	3.622	+	+
R^2 = 0.57				**F-statistic = 21.78***		
Number of observations = 105						

Notes: 1. ***, **, and * imply significance levels of 1%, 5%, and 10% respectively. **Source**: Author's estimation.

The impact of the pandemic is positive and significant implying that this event may have acted as a supply side shock by disrupting production and distribution of a large number of goods and services, causing a sudden rise in scarcity of these commodities, inducing a rise in the momentum of already increasing prices. Indian economy was already experiencing inflation before the pandemic, and the immediate impact of the lockdowns and other necessary policy measures was to increase the inflation, though the rise was small. Since the pandemic, the momentum of inflation has increased slightly and it appears to have persisted over time. The lagged term of inflation shows the expected behavior. Inflation in India has strong inertia and displays adaptive expectations with backward-looking dependency (Dua and Goel, 2010; Patra et al., 2018; Dua and Goel, 2021). Literature has repeatedly found the backwards-looking Phillips curve formulation to be better at explaining the inflation behaviour in India, which is further testified by the findings reported in table 5.5. The inertia of inflation also provides evidence on its persistence. Persistent inflation tends to build a nourishing ground for higher pass-through (Taylor, 2000; Gagnon and Ihrig, 2004).

The primary coefficient of interest is the ERPT coefficient which is estimated at -0.18, indicating that a 10% depreciation of the Indian currency against the basket of the 36 currencies leads to 1.8% increase in the inflation rate. The pass-through to domestic prices is thus incomplete. It is also considerably lower than the pass-through to import price inflation as found in the previous chapter. The price impact of exchange rate tends to reduce as one moves deeper into the pricing chain in an economy (Ranadive and Burange, 2015; Mendali and Das, 2017). This can occur because of several reasons. One rationale may be that there is a gradual absorption of price impulses emanating from exchange rate changes at different stages in the distribution chain. It is possible to conceptualize economic agents at each stage in the aggregate distribution chain as absorbing some part of the inflationary impact of exchange rate that is transmitted via the import price pass-through or even through other channels such as the changes in aggregate demand due to expenditure switching (Laflèche, 1996). This kind of behavior can occur if the behavior of agents at each stage in the distribution chain are driven by objectives other than profit maximization. This may include maintaining the market share in the downstream chain, or perhaps factors such as menu costs may prevent frequent price revisions. Through this perspective, the producers, i.e. firms, the wholesalers, and the retailers may be conceptualized as absorbing the inflationary impact of exchange rate into their markups and not passing it over into the downstream prices. They may be motivated by market considerations or other objectives such as sustaining in a competitive environment. The sum total of their actions may culminate into the lowering of pass-through from its importation via the import-price pass through phenomenon.

Another rationalization of this finding can be that there are nominal rigidities due to factors such as menu costs, switching costs and other local transaction costs. Such constraints may prevent complete pass-through of the inflationary impact from exchange rate changes into the domestic price structure. An important source of such rigidities can be policy interventions. A sizeable part of the imported inflation in India emerges from oil price variations (Raj et al., 2008). The Government of India bears a large portion of this rise though oil subsidies given to the firms engaged in importing and sales of crude oil and its derivatives domestically. It may be possible that the fiscal interventions to prevent an oil price – inflation spiral keeps the overall pass-through lower. However, this argument relies on the idea that a large part of exchange rate variation is imported into India through an increase in oil prices in domestic currency terms. There are non-oil items also which may inflate due to exchange rate pressures. Fiscal interventions are generally geared towards controlling the negative inflationary impact of international oil price variations, but exchange rate changes can impact not only the oil prices in local currency, but also the non-oil items which have a much larger share in India's total import basket. Thus, it seems that nominal rigidities and absorption at different stages in the aggregate distribution chain are playing an important role in ensuring a lower pass-through to domestic prices relative to the import prices.

In summary, there are four prominent sources of inflation in India, as evident in the estimates reported in table 5.5. The first is the inertia of inflation itself expressed by its lagged coefficient. The second is the money supply. The third factor is the ERPT, and the fourth contributing factor is output gap. This model is able to capture both the demand-side and supply-side factors influencing inflation and the consequent estimate of pass-through coefficient is coherent as appropriate control variables are accounted for. The need to account for control variables is necessary to operationalize the fundamental equation that juxtaposes inflation as a function of exchange rate (Ghosh and Rajan, 2007c). The contribution of ERPT is significant in explaining the behavior of inflation since the reforms. Exchange rate has remained an important and persistent source of upwards price pressure and signifies the implications of trade openness for an emerging economy India which is consistently integrating itself in the international financial architecture.

From the econometric as well as the theoretical points of view, it is necessary to ensure that the estimated pass-through coefficient is stable to alternative specifications. Particularly, one would be interested in ascertaining the changes in pass-through coefficient when alternative exchange rate variables are employed. As discussed earlier, several substitutable specifications are introduced to gauge the behavior of pass-through coefficient when additional control variables are employed and particularly when the nominal bilateral rate is used instead of the NEER. Lastly, the issue of long-run and short-run pass-through impacts from exchange rate variations is among the chief concerns of this chapter. These dimensions are addressed in Table 5.6.

Table 5.6: Alternative perspectives on ERPT in India vis-à-vis the first baseline model

Coefficient	Model 1	Model 2	Model 3	Model 4
Constant	-0.003 (-0.832)	-0.003 (-0.872)	-0.004 (-1.195)	-0.004 (-1.343)
OGAP	0.14*** (3.696)	0.12*** (3.050)	0.11*** (3.152)	0.09** (2.578)
ΔlnNEER	-0.18*** (-4.022)	-	-0.15*** (-3.537)	-
ΔlnRSUSD	-	0.10*** (2.658)	-	0.09** (2.629)
$\Delta lnNM3_{t-2}$	0.29*** (2.812)	0.29*** (2.673)	0.23** (2.238)	0.24** (2.315)
ΔlnOILP	0.04*** (4.996)	0.04*** (5.165)	0.04*** (6.216)	0.05*** (6.323)
$\Delta lnFPRI_{t-1}$	-	-	0.21*** (4.075)	0.21*** (4.114)
D_{PAND}	0.02*** (3.824)	0.015*** (3.399)	0.01*** (3.672)	0.01*** (3.250)
$\Delta lnWPI_{t-1}$	0.26*** (3.622)	0.28*** (3.683)	0.28*** (4.172)	0.29*** (4.184)
$\mathbf{ERPT_{short\text{-}run}}$	18%	10%	15%	9%
$\mathbf{ERPT_{long\text{-}run}}$	24%	14%	21%	13%
R^2	0.57	0.53	0.69	0.68
F-statistic	21.77***	18.72***	26.93***	24.63***
Observations	105	105	89	89

Notes: 1. ***, ** and * indicate significant at 1%, 5% and 10% levels of significance; 2. Values in the brackets indicate t-ratios. **Source**: Author's estimations.

Table 5.6 presents the results of alternative specifications that replace the NEER with the bilateral Rupees per US Dollar rate as well as take into consideration another variable affecting inflation, viz. the food inflation variable. The food inflation variable is measured by the WPI for food articles. Naturally, it is a part of the composite WPI index employed as the dependent variable in the estimated equations. The use of this variable in current period terms may thus result into construing an identity relation as a behavioral relation. Hence, the first lag of this variable is used to partially avoid this issue. The rationale for including food inflation into the inflation equation is to recognize the vagaries, uncertainties and volatilities introduced by the food markets in the aggregate inflation movements. Inflation in India is driven not only by fuel price pressures but also by food prices. Higher food inflation tends to seep into the distribution chain by impacting the consumption of a large proportion of population, which may cause an increase in the cost of living and hence in the price of labour. This may translate into higher retail inflation as captured by the CPI. If inflation is persistent, which is the case with India, such price rises may induce escalation of prices in the wholesale markets due to the inertia in inflation. Furthermore, higher retail prices may signal wholesale markets of the inflationary environment and perhaps may motivate firms to further increase the prices to capture larger markups. Models 3 and 4 present the baseline model augmented for food inflation variable, while Models 1 and 2 present the baseline model as show in table 5.5 and further augmented with the bilateral rate instead of the effective index.

It can be observed in table 5.6 that the pass-through coefficient of NEER is higher than that of the bilateral rate, which is consistent with the expectations as the NEER is a more comprehensive measure and allows the pass-through from not only the US Dollar but also other currencies, while accounting for the trade pattern that India has with its major trading partners. The fit of the model also improves when lagged food inflation is accounted for and the coefficient is high and statistically significant, indicating its importance in shaping the inflation process in India. The wedge between the pass-through coefficient from the NEER and the bilateral rate may be indicative of the fact that Indian economy is exposed to inflationary impacts emanating not only from its currency's value against the US Dollar but also other major currencies. Hence, ignoring the NEER may result into underestimation of the true extent of pass-through. Furthermore, the NEER also indicates the impact of change in India's trading composition in terms of its trading partners, on inflation via the exchange rate channel. Because the effective exchange rate adjusts the bilateral rate for trade-shares of the corresponding countries, exchange rate variations are adjusted for trade-share patterns and provide a unique perspective of pass-through phenomenon, which the simple bilateral rate may not be able to yield. However, one may argue that the bilateral rate represents the 'true' extent of market movements in the value of India's currency and thus using it will provide a 'purer' measure of pass-through, unhindered by distortions caused by trade-patterns. Hence, both the variables are employed and results are presented here.

Estimates of the short-run pass-through which is defined as the immediate impact of exchange rate on inflation, and long-run pass-through which is defined as per the framework of Koyck (1954) and Nerlove (1958) and explained in section 4.7 in chapter four, are also contained in table 5.6. The long-run pass-through is consistently higher than the short-run pass-through, indicating that once adjustments are permitted over time, relatively larger portion of the exchange rate changes are passed into the domestic prices. However, whether short-run or long-run, the pass-through remains incomplete. This indicates that the 'incompleteness hypothesis' remains true in both the immediate period as well as after sufficient adjustments are incorporated into the pass-through process.

While the monetary policy variable is captured by money supply in the first baseline model as shown in equation five, the same model is augmented with a proxy for the short-term interest rate represented by the WACR, whose rationale was already examined in section 5.3. The empirical model is shown by equation 10. The results with this alternative measure of monetary policy are presented in Table 5.7.

$$\Delta \mathbf{InWPI} = \beta_0 + \beta_1 \mathbf{OGAP} + \beta_2 \Delta \mathbf{InNEER} + \beta_3 \Delta \mathbf{InOILP} + \beta_4 \Delta \mathbf{InWACR}_{t-3} + \beta_5 \Delta \mathbf{InD}_{FIT} + \beta_6 \Delta \mathbf{D}_{PAND} + \beta_7 \Delta \mathbf{InWPI}_{t-1} + \varepsilon \quad \text{....(10)}$$

One of the important recent works that have focused on the role of WACR in impacting inflation is Parab (2022) who utilizes this variable as a proxy for short-term interest rate while estimating pass-through of exchange rate to consumer prices using an Auto Regressive Distributed Lag (ARDL) model. The author did not find evidence of a significant impact from this variable on inflation in the short-run but found sufficient evidence of its long-run negative impact on inflation. Coincidently, the author found a significant impact from WACR on inflation in the third lag while using quarterly data. In the present chapter, the short-term interest rate was also found to have a statistically significant impact from the third quarter onwards, and given the previous evidences, it seems that there is a lag of 6-9 months before this interest rate variable is able to affect domestic inflation. In equation 10, an additional dummy variable is also incorporated indicating the impact of the FIT regime on inflation whose rationale were laid down in section 5.3 and 5.4. The expected signs of the variables in equation 10 are shown in table 5.7.

Table 5.7: Expected behavior from the coefficients in equation one

Sr. No.	Variable	Expected Sign
1	OGAP	+
2	ΔInNEER	-
3	ΔInOILP	+
4	$InWACR_{t-3}$	-
5	D_{FIT}	-
6	D_{PAND}	+/-
7	$\Delta InWPI_{t-1}$	+

Source: Author's estimation.

The expectations of the variables have been explained earlier in the previous baseline model as well in sections 5.3 and 5.4. D_{FIT} represents the important change in monetary policy regime in India with the shift to the Flexible Inflation Targeting from October 2016 onwards. The importance of this variable and its relevance for testing the Taylor's hypothesis is already elaborated in sections 4.8.6 and 4.9 in chapter four. Pursuant of the ideas laid in those sections, it is expected that the introduction of FIT has brought gains for the economy in terms of a lowering of inflation since its adoption. Hence, the expected sign is negative on this account. Furthermore, WACR is expected to have a negative impact on inflation, indicating that RBI's monetary policy impulses are able to bring down inflation through a robust monetary policy transmission process.

Table 5.8 presents the estimates of equation 10. The model provides similar fit and explanatory relevance. The variable WACR has a statistically significant negative impact but the impact is low. For every 10% increase in the short-term interest rate, inflation comes down by 0.1%. The effect of the introduction of FIT has brought credibility gains for the RBI by reducing the average level of inflation since its adoption by 1.00%. The significant impact of this variable on inflation is consistent with recent literature and provides some evidence on the Taylor's hypothesis as provided by Patra et al. (2018), Mukherjee and Coondoo (2019), and Patra et al. (2020), among some other.

Table 5.8: Alternative perspectives on ERPT in India vis-à-vis the baseline model in equation two

Dependent Variable is ΔInWPI						
Sr. No.	**Variable**	**Coefficient Value**	**Standard error**	**t-ratio**	**Expected Sign**	**Estimated Sign**
0	Constant	0.02***	0.006	2.938	+	+
1	OGAP	0.15***	0.039	3.748	+	+
2	ΔInNEER	-0.18***	0.044	-4.131	-	-
3	ΔInOILP	0.04***	0.007	5.238	+	+
4	$InWACR_{t-3}$	-0.01*	0.003	-1.727	-	-
5	D_{FIT}	-0.01**	0.005	3.266	-	-
6	D_{PAND}	0.02***	0.005	3.266	+/-	+
7	$\Delta InWPI_{t-1}$	0.24***	0.074	3.215	+	+
R^2 = 0.57				**F-statistic = 18.63*** **		
Number of observations = 105						

Notes: ***, **, and * imply significance levels of 1%, 5%, and 10% respectively. **Source:** Author's estimation.

However, Bhat et al. (2022) examined the issue of pass-through using non-linear smooth transition model and did not find any favourable evidence for the Taylor's hypothesis in India. This study, however, does find evidence in favour of the Taylor's hypothesis, suggesting that the commitment to lowering the inflation helps to reduce the inflation level itself.

Table 5.9: Alternative perspectives on ERPT in India vis-à-vis the baseline model in equation two

Coefficient	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	0.02*** (2.938)	0.02*** (2.944)	0.01*** (4.761)	0.01*** (4.076)	0.004** (2.421)	0.004** (2.119)
OGAP	0.15*** (3.748)	0.12*** (3.029)	0.14*** (3.531)	0.12*** (2.874)	0.13*** (3.451)	0.11*** (2.806)
ΔInNEER	-0.18*** (-4.131)	NA	-0.16*** (-3.547)	-	-0.17*** (-3.686)	-
ΔInRSUSD	-	0.11*** (2.807)	-	0.09** (2.327)	-	0.10** (2.557)
ΔInOILP	0.04*** (5.238)	0.04*** (5.466)	0.04*** (5.434)	0.05*** (5.583)	0.05*** (6.973)	0.06*** (6.965)
$\Delta InFPR_{t-5}$	-	-	-	-	0.12** (2.225)	0.13** (2.407)
$In(WACR)_{t-3}$	-0.01* (-1.727)	-0.01* (-1.865)	-	-	-	-
ΔInM0	-	-	$0.013^{\$}$ (1.651)	0.02** (2.206)	0.014* (1.959)	0.02** (2.469)
D_{FIT}	-0.01** (-2.497)	-0.01** (-2.205)	-0.01** (-2.122)	-0.01* (-1.814)	-0.004 (-1.427)	-0.004 (-1.273)
D_{PAND}	0.02*** (3.266)	0.02*** (2.734)	0.02*** (3.514)	0.02*** (3.023)	0.02*** (3.185)	0.01*** (2.677)
$\Delta InWPI_{t-1}$	0.24*** (3.215)	0.26*** (3.290)	0.31*** (4.023)	0.34*** (4.304)	0.34*** (4.703)	0.36*** (4.814)
$ERPT_{short\text{-}run}$	18%	11%	16%	9%	17%	10%
$ERPT_{long\text{-}run}$	24%	15%	23%	14%	26%	16%
R^2	0.57	0.54	0.57	0.54	0.70	0.68
F-statistic	18.63***	16.01***	18.54***	16.42***	22.16***	19.65***
Observations	105	105	105	105	84	84

Notes: 1. ***, ** and * indicate significant at 1%, 5% and 10% levels of significance; 2. Values in the brackets indicate t-ratios. **Source**: Author's estimations.

Pursuant of the approach in the previous section, several alternative specifications are tested here to gauge the sensitivity of pass-through estimate to different control variables as well as to understand the short-run and long-run impacts of exchange rate alterations on domestic prices. These results are provided in Table 5.8. Model 1 presents the estimated results from table

5.7 itself. The short-run coefficient indicates 18% change for every 100% change in exchange rate while in the long-run it increases to 24%. Model 2 is model one with NEER replaced by the bilateral rate. Here, the immediate pass-through is 11% while in the long-run it is 15%. Models 3 to 6 incorporate the M0 measure of money supply to proxy monetary policy, wherein Models 5 and 6 also incorporate the food inflation variable. The results are very much consistent with the previous results reported tables 5.6 and 5.7. Long-run pass-through is consistently higher than short-run pass-through but remains incomplete, and the bilateral exchange rate shows lower price impact of exchange rate than the nominal effective index.

5.7.2. Extent of exchange rate pass-through for annual data

The nature of pass-through may differ with the frequency of data employed in the study. More granular data can allow incorporation of dimensions which cannot be captured by lower frequency data. Similarly, lower frequency data such as annual data provide a more stable framework to estimate the price impact of exchange rate by suppressing the seasonal and the irregular fluctuations and thus allow more meaningful longer run variations to be incorporated into the model. The literature in the Indian context has largely relied on the quarterly or monthly information for estimating the degree of pass-through to domestic inflation. It is equally interesting to investigate the kind of dimensions that emerge from annual information. Furthermore, such an exercise will also allow better comparability of the results from this chapter with the findings from the previous chapter. In such a framework, it is possible to utilize the time-varying import price pass-through coefficient from the previous chapter and examine if higher import price pass-through tends to increase the inflation rate, and also to see if it affects the findings on domestic price pass-through when used as an additional control variable in the inflation equation. The hypothesized model at the annual level is also similar to the specifications contained in equations five and six. However, the dummy variables for FIT regime, and the adoption of the WACR as the operating target along with repo as the monetary policy rate were not found to be significant. Consequently, it was decided to keep the model parsimonious while capturing a sizeable variation in the behavior of inflation. The empirical model for estimation of ERPT to domestic inflation using annual data is shown in equation 11. The period covered ranges from 1991-92 to 2021-22.

$$\mathbf{\Delta InWPI = \beta_0 + \beta_1 \Delta InWCPI + \beta_2 \Delta InOILP + \beta_3 \Delta InNEER + \beta_4 \Delta InM3 + \beta_5 ERPT_m}$$

$$+ \beta_6 D_{PAND} + \beta_7 \Delta InWPI_{t-1} + \varepsilon \quad \text{....(11)}$$

Compared to the baseline models for the quarterly data, here, some additional determinants of inflation are introduced. The first one is the $ERPT_m$ variable. This is the time-varying ERPT coefficient for import prices estimated in the previous chapter. The underlying idea is to see if higher pass-through to import prices leads to higher inflation. The expected sign is positive in this case, but a more comprehensive debate relates to the estimated value. If the value of this variable is equal to unity or in the neighborhood of the same, then the findings in the previous sections would require much different explanations. Higher impact of the pass-through to import prices on domestic inflation could occur largely via the price channel itself, though quantity channel is also possible. The large bulk of import price pass-through is percolated into the domestic price structure via its impact on producer, wholesale and consumer prices, finally culminating into the disaggregated retail price structure.

However, the finding from the previous sections indicate that the ERPT to domestic inflation is incomplete even in the long-run. Hence, it is expected that the impact of $ERPT_m$ will be low and incomplete. Additionally, this specification takes into account the WCPI variable[36] which represents the Global inflationary environment. Increases in the global inflationary environment are expected to accentuate inflation in India, possibly through the ERPT channel. It is possible that increased inflationary momentum at the global scale results in increased costs of major import supplying nations of India, inducing them to pass-over this 'cost-push' inflation to India's import prices.

Table 5.10: Extent of ERPT to domestic inflation for annual data during the period 1993-94 to 2021-22

Dependent Variable is ΔInWPI						
Sr. No.	**Variable**	**Coefficient Value**	**Standard error**	**t-ratio**	**Expected Sign**	**Estimated Sign**
0	Constant	0.02	0.027	0.886	+	+
1	ΔInWCPI	0.03**	0.013	2.470	+	+
2	ΔInOILP	0.05***	0.018	3.024	-	-
3	ΔInNEER	-0.17*	0.088	-1.924	+	+
4	ΔInM3	0.23*	0.132	1.776	-	-
5	$ERPT_m$	$0.02^{\#}$	0.013	1.539	-	-
6	D_{PAND}	0.03*	0.015	1.929	+/-	+
7	$\Delta InWPI_{t-1}$	0.30*	0.155	1.945	+	+

R^2 = 0.75		**F-statistic = 9.05*** **
Number of observations = 29		
$ERPT_{short\text{-}term}$ = 17%		**$ERPT_{long\text{-}term}$** = 24%

Notes: 1. ***, **, and * imply significance levels of 1%, 5%, and 10% respectively. 2. # implies significant at 13% level. 3. The same model was estimated within the linear time-varying coefficient framework and consistent with the findings for quarterly data, there was no evidence of a sizeable instability in the pass-through coefficient. **Source**: Author's estimation.

The results in Table 5.9 show that ERPT is largely the same even when looked at from the perspective of annual data. Both the short-run and long-run pass-through are broadly similar to the findings in the previous sections. Pass-through remains incomplete even in the long-run. The impact of import price pass-through coefficient is weak, both economically and statistically. It is however consistent with the finding that the pass-through to domestic prices is low, as found in the current and previous results in this chapter. The major drivers of inflation in this framework are the inertia in inflation, i.e. its lagged value, money supply growth and ERPT. Consistent with the findings on quarterly data, in relative terms, ERPT remains an important source of inflationary momentum in India during the study period.

5.7.3. Perspectives on the stability of the aggregate pass-through coefficient

Pursuant of the issues investigated in section 4.7 and 4.8.4 of chapter four, this section assesses the stability dimension of ERPT to domestic inflation from two perspectives. The first approach is to use a time-invariant coefficients approach which is provided by the rolling regression framework. The second approach is to use time-varying coefficients models, as used in chapter four. The issues related to rolling regression method and the varying-coefficients model of Schlicht (2020, 2021, 2022) have been elaborated in section 4.7 of chapter four.

Similar methodological framework is adopted in this section, but the issue of interest is the pass-through coefficient for domestic inflation measured by the WPI inflation. The baseline model contained in equation five and estimated via equation nine is utilized in the rolling regression framework. The rolling window is defined on lines similar to the approach adopted in chapter four. However, due to the quarterly nature of data, the rolling duration is of four quarters while the starting point is kept fixed.

Table 5.11: Estimates of the ERPT coefficient for rolling windows for the baseline model two

Rolling Periods		**Lower limit of 95% confidence interval**	**ERPT Coefficient**	**Upper limit of 95% confidence interval**
1996: Q1	2006: Q1	-0.36	-0.21	-0.07
1996: Q1	2007: Q1	-0.31	-0.19	-0.07
1996: Q1	2008: Q1	-0.34	-0.23	-0.13
1996: Q1	2009: Q1	-0.30	-0.19	-0.08
1996: Q1	2010: Q1	-0.28	-0.16	-0.05
1996: Q1	2011: Q1	-0.28	-0.17	-0.05
1996: Q1	2012: Q1	-0.22	-0.11	0.00
1996: Q1	2013: Q1	-0.21	-0.10	0.01
1996: Q1	2014: Q1	-0.24	-0.14	-0.04
1996: Q1	2015: Q1	-0.25	-0.15	-0.05
1996: Q1	2016: Q1	-0.24	-0.15	-0.05
1996: Q1	2017: Q1	-0.27	-0.17	-0.07
1996: Q1	2018: Q1	-0.26	-0.16	-0.06
1996: Q1	2019: Q1	-0.25	-0.16	-0.07
1996: Q1	2020: Q1	-0.25	-0.16	-0.07
1996: Q1	2021: Q1	-0.25	-0.16	-0.07
1996: Q1	2022: Q1	-0.25	-0.15	-0.06
		Descriptive Estimates		
Mean		**SD**		**CV**
-0.16		0.03		-20.22

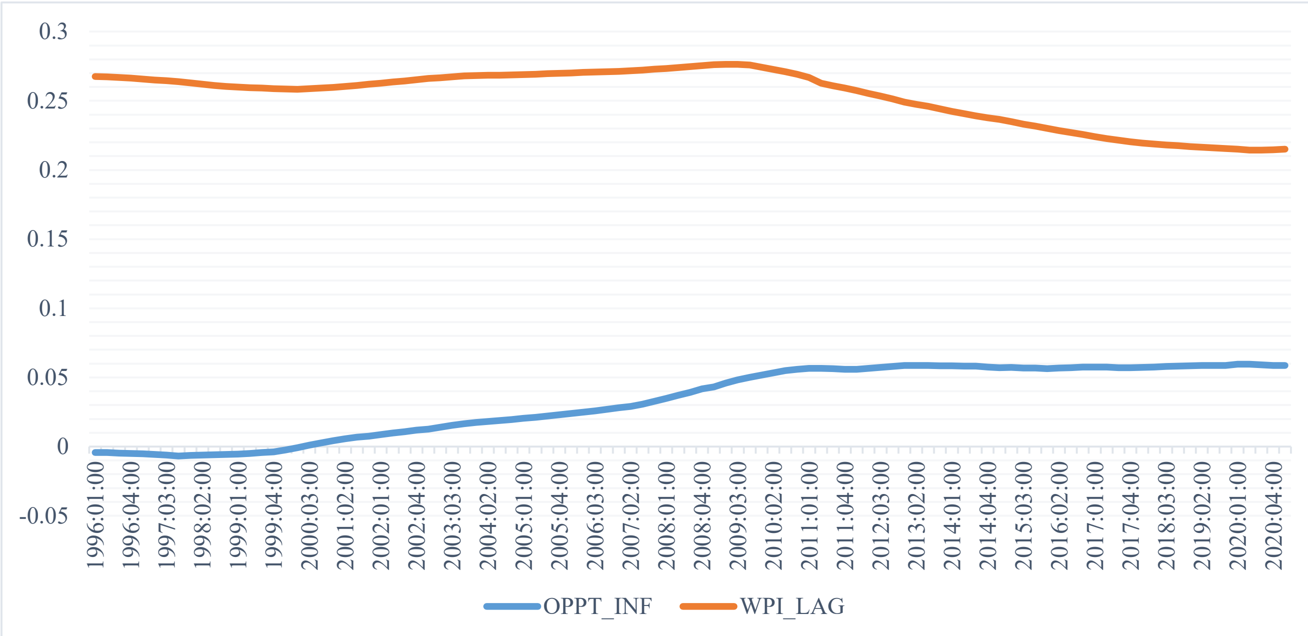
Notes: ERPT (Exchange Rate Pass-Through) coefficient for domestic inflation are estimated using Rolling Regression for the core model without the dummy variables. *** indicates significant at 1% level. **Source**: Author's estimation.

The results from the rolling regression approach are portrayed in Table 5.11. The estimated results show that the average pass-through has been 16% while the dispersion in the same has been approximately 20%. It is evident that there has been considerable stability of pass-through coefficient during the sample period. In particular, 2015-16 onwards, one observes pass-through being tightly anchored to the range of 15% to 17%. It is apparent that pass-through has displayed slight episodic instability until 2015-16, after which it has largely remained constant.

While rolling regression framework is useful to examine the stability of regression coefficient, they "do not entirely rule out the possibility of shifts in a specific sub-sample, especially when shifts are frequent, and they impose limits on the degrees of freedom" (Patra et al., 2014, pp. 137; Zanin and Marra, 2011). Hence, a more rigorous framework is necessitated for proper understanding of the stability dimension. In particular, it is pertinent to ask if stability in pass-through might behave differently were a more rigorous econometric framework to be adopted that is capable of handling temporal variations across each point in the sample period. Such an approach is available via the Varying-Coefficients framework of Schlicht (2021) which has already been examined and delineated in sections 4.7 and 4.8.4 of chapter four. The coefficients of the baseline model contained in equation 9 are now permitted to vary over time. The estimated time-varying coefficient of ERPT did not show any variation across the sample period. Hence unlike recent literature such as Patra et al. (2018), we do not find any evidence of a time-variant pass-through coefficient. The value remained constant at around -0.18. Different variations of the model were tested including the specification where only the pass-through coefficient was allowed to vary over time. However, the result remained the same and pass-through coefficient showed time-invariance under all such specifications. There is thus strong evidence indicating that the pass-through coefficient has remained stable over time.

However, the oil price pass-through coefficient showed consistent increase across time amongst all other variables, while the coefficient of lagged inflation term showed a fall across the period. As show in Figure 5.1, the impact of oil price inflation on domestic inflation has increased over time and remained broadly stable since 2011. It is evident that oil price inflation has been increasingly occupying a larger role as the chief external channel of importing inflationary momentum in India. As pass-through has remained stable across time, increases in external pressure on domestic inflation if any, must have emerged from other channels and oil price pass-through appears to be primary source on this account.

Figure 5.1: Time-variant oil price pass-through and inflation persistence in India



Notes: OPPT_INF is the coefficient of Oil Price Pass-Through to domestic inflation; WPI_LAG is the coefficient of lagged inflation term, i.e. the impact of past inflation on current inflation **Source:** Author's estimation.

On the contrary, the inertia in inflation has reduced over time, possibly indicating the fall in persistence of inflation since the reforms. Oil price variations have been a critical external source of inflationary push in India. The fall in persistence of inflation may also be indicative of the RBI in stabilizing the inflation and ensure long-term price stability. The stability of ERPT coefficient also provides credence to the single-equation estimates presented earlier. The stability of pass-through testifies the robustness of inferences on short-run and long-run behavior of pass-through undertaken earlier in this chapter.

5.7.4. Dynamic impact of exchange rate on domestic prices in India

The use of single equation partial equilibrium models in the previous sections provide evidence on the incompleteness of pass-through in both the short-run and long-run. Despite testing variations of the baseline models, pass-through to domestic prices remained incomplete and low. Furthermore, stability analysis revealed that the price impact of exchange rate has been highly stable, indicating a largely time-invariant behavior across the sample period. It was also located that inflation is primarily determined by monetary policy, its inertia and exchange rate variations.

Within the parsimonious perspective laid in earlier sections, external sector has played a critical role in shaping the path of inflation in India since the reforms.

However, there are some concerns that single equation models are not capable of adequately handling. First, the feedback effects embodied among the interrelations between macroeconomic variables is largely suppressed by single-equation models, which primarily work on the ‘ceteris paribus’ assumption. Exchange rate variations impact domestic prices, but the nature of this impact is different when looked from a single-equation partial equilibrium approach versus when allowance is made for interactions and feedbacks among both the variables. While the theoretically ‘pure’ impact is provided through the single equation models, it is equally important to understand how both would interact if they were permitted to contemporaneously impact each other along with more other macroeconomic variables. Such an impact from exchange rate on domestic prices would reflect a more realistic assessment of pass-through relation that corresponds to how actual markets and economies interact. Second, the ‘ceteris paribus’ assumption cannot be relaxed when employing the single-equation approach. Hence, more flexible approaches are required to handle this requirement.

Third, feedback effects can change the nature of pass-through process drastically and such a perspective cannot be obtained from the traditional econometric approaches. Fourth, the true nature of ‘dynamism’ in the pass-through relationship cannot be captured solely by the lagged terms of either the inflation or exchange rate. The dynamic relationship between them may be further shaped by interactions within and across other macroeconomic variables. Such an analysis is not feasible in the traditional frameworks. Fifth, each movement in exchange rate variable is treated as exogenous in the single equation models. The important distinction between ‘change’ and ‘shock’ is generally overlooked by traditional models, as discussed below. Sixth, the problem of endogeneity of exchange rate in the inflation determination process may cast doubts on the single equation inferences. Seventh, the extent to which exchange rate impulses are transmitted throughout the pricing chain, starting from import prices up to the retail prices, cannot be estimated within the single equation frameworks.

Thus, alternative perspectives are required to address these concerns. At least two approaches are present that can address these issue coherently. First, is the simultaneous equations approach, while second is the Vector Auto Regressive (VAR) models. These approaches can handle the major issues highlighted above while providing richer estimates of the ERPT coefficient. Before the advent of the Vector Auto Regressive methods laid by Sims (1980), the simultaneous equations approach was perhaps the dominant approach to address the above concerns. However, there were certain concerns raised in the use of multivariate simultaneous equations approach. The fundamental apprehension was on the subjective and ad-hoc nature of assumptions regarding the exogeneity of variables in the simultaneous equations structure. The critique of macroeconomic models contained in Tinbergen (1939) and Lucas (1976) provided the opportunity to reflect on the foundations on which the macroeconomic empirical exercises were undertaken. While the theoretical criticisms of large scale macroeconomic models were laid in the works of Lucas (1976), the econometric alternative was provided by Sims (1980) who proposed the VAR approach to macroeconomic empirics.

A fundamental criticism of the simultaneous equations approach made by Sims (1980) was that the classification of variables into endogenous and exogenous was not always founded in sound economic theory (Hashimzade and Thornton, 2013). The VAR approach provided by Sims and developed by a large volume of literature later, allows a more data-centric approach where all the variables of a model are assumed to be a-priori endogenous. This framework permits the examination of dynamic nature of ERPT relationship through incorporating not only contemporaneous but also lagged relationships among the variables into a unified system of equations that are individually estimated using the OLS. Hence, VARs provide a superior alternative to the traditional OLS system by incorporating a much more dynamic, interconnected and complex structure of macroeconomic relationships, while utilizing the strengths of the least squares approach.

The primary challenge in using VAR is identifying structural shocks from the residuals of the modelled equations (Enders, 2014). This issue arises because the estimated VAR will represent the reduced-form equation while the structural shocks in which one is interested are based on the underlying “primitive system” (Enders, 2014, pp. 292). Recovering the information about the primitive system from the observed results is the identification problem in VAR models. Identification is achieved by imposing restrictions on the relationships between the endogenous variables in a manner that structural shocks can be obtained, or worked back, from the reduced-form VAR. Literature has provided different approaches to imposing the restrictions which are generally known as ‘identifying restrictions’. The most frequently employed identifying restriction is the Cholesky method that decomposes residuals of the estimated OLS-based model using either a lower triangular or an upper triangular matrix of contemporaneous relations between the endogenous variables in the system. The Cholesky factorization method is flexible and capable of handling positive definite matrices, where it provides a unique solution, and indefinite matrices where some solutions may exist (Lütkepohl, 2005; Higham, 2009). This approach has been perhaps the most frequently employed method of identifying structural shocks and estimate the impulse responses in the pass-through literature.

Several analysts raised that concern that imposing a Cholesky structure on contemporaneous relations needs to emerge from theory rather than statistical necessities (Hashimzade and Thornton, 2013). In other words, the restrictions imposed by the Cholesky approach should have sound economic logic; otherwise the impulse responses and variance decompositions will be unreliable. Moreover, the Cholesky approach is limited to triangular decomposition and thus does not permit other approaches (Saha and Zang, 2013; Lindfield and Penny, 2019). It is plausible that economic theory might demand other forms of restrictions that do not rely on a triangular formulation of the matrix of contemporaneous coefficients or the variance-covariance matrix. Illustrations of such restrictions may be seen in the cases where sign restrictions are needed, or long-run restrictions are to be imposed such as what is done in the Blanchard-Quah decomposition method contained. Furthermore, the Cholesky method is highly sensitive to the ordering of variables and restricts the role of theory to deciding the ordering of variables (Lütkepohl, 2005; Enders, 2014). Enders (2014, pp. 313) notes that “unless the underlying structural model can be identified from the reduced-form VAR model, the innovations in a Choleski decomposition do not have a direct economic interpretation”. The wedge between the VAR estimates and economic theory may not pose a large danger to the forecaster, but can have serious implications for an analyst interested in explaining macroeconomic processes such as the ERPT mechanism[37].

Hence, other approaches have been proposed in the literature to synthesize economic theory in a richer manner with the empirical finesse of the VAR models. One such approach is provided by the Structural VAR (SVAR) models. This model provides the ability to fully identify the structural shocks such that the identified shocks are directly in consonance with an economic model. If forecasting is the only aim, then the forecast errors of the estimated VAR model, which are observable are useful in themselves and their source may not be important. However, when the interest lies in economic analysis, i.e. when one wants to estimate the impulse responses and variance decompositions, identifying the structural shocks is necessary and forecast errors are not sufficient. SVAR utilizes “economic theory (rather than Choleski decomposition) to recover structural innovations from the residuals” (Enders, 2014, pp. 314) of the observed or the estimated VAR model. However, the restrictions cannot be made haphazardly, but must ensure that the structural shocks are recovered from the forecast errors and the independence of the shocks is maintained (Lütkepohl, 2005; Enders, 2014). In order to locate the structural model from the estimated VAR system, imposition of $(n^2-n)/2$ restrictions are required. Hence, with a VAR having 4 endogenous variables, as adopted in this chapter, at least six restrictions are necessitated to just-identify the structural model. If the number of restrictions are lesser than this, the model will not be identifiable. If it is more than this, the SVAR system will be over-identified. The identification of the structural shocks requires information on the estimated matrix of contemporaneous coefficients as well as the estimated variance-covariance matrix.

An important motivation in employing the VAR framework is to recognize the differences between impacts of shocks versus the changes in exchange rate on domestic prices. An economic shock is different than an economic change. Changes in exchange rate may occur regularly in a defined or an undefined fashion but are a result of the regular trading activities in the international foreign exchange rate market. Such movements are generally predictable or if not predictable, are at least expected by economic agents and hence form a part of the price discovery process. Shocks on the other hand are largely unexpected, sudden and unpredictable. There is no a-priori mechanism to account for shocks and this is what lends such variations the connotation of a shock. Single equation models tend to treat all changes as shocks, while the VAR system identifies them after accounting for the interrelations and feedbacks among the endogenous variables. Moreover, an exchange rate shock needs to be of a sizeable nature to induce relevant economic adjustments in domestic prices. This dimension can be handled by the VAR approach. Particularly, the SVAR model can allow identification of shocks that are theoretically plausible and provide economic information rather than purely statistical information. Unlike traditional VARs, the SVAR is capable of synthesizing economic theory through plausible restrictions on the relationships estimated by an unrestricted VAR[38]. This permits the construction of economic shocks whose time-paths and effects on other variables in the system can be traced to a theoretically sound macroeconomic process[39].

A. Theoretical model

This chapter explores the dynamic relationship between exchange rate, wholesale price inflation, consumer price inflation and real output growth for the period 1991-92 to 2021-22 using quarterly data with key exogenous variables and economic restrictions that help identify the structural shocks from the estimated residuals. An important pre-condition to utilize VAR models is to employ stationary variables. While not all analysts, including Sims himself, agree with the need to use only stationary variables, it is generally expected that stationary variables will be able to better capture the underlying data generating process and their use will help to estimate a stable VAR system. The stability of the VAR system is critical to ensure that the economic inferences are valid and generalizable. The variables employed in the SVAR framework, both the endogenous and exogenous, are used in stationary form[40].

As stated above, four endogenous variables are utilized for the analysis. The first variable is the exchange rate variable, measured by the log difference of the nominal effective index. The second variable is the wholesale price inflation, measured by the log difference of WPI. The third variable is the consumer price inflation measured by the log difference of CPI. The fourth variable is the real output growth rate, measured by the log difference of the real GDP. All the variables are employed in the first difference of logarithmic values, i.e. in the log difference form, to ensure stationarity of the variables. Inclusion of wholesale and consumer inflations into the single VAR system together is to changes in pass-through in the aggregate pricing chain. Literature has generally found that the inflationary impulses of emanating from exchange rate shocks reduce as one moves from import prices to the consumer prices. Ideally, import price variable should also be included, but the data are missing for quarterly and also monthly levels for the entire sample period. Moreover, it is the import price variable that is necessitated rather than import unit value index. Given these constraints, the import price variable is not included[41]. However, studies in the Indian context have more frequently employed the CPI instead of the WPI when estimating the VAR models and have largely found higher pass-through to CPI than when the WPI is used.

The VAR system is conceptualized to allow the exchange rate impulses propagate through the price channel and culminate into real impact ensuring the logical completion of the ERPT process. The use of real output growth as the last variable in the system is different than other studies in Indian context who generally model output gap or real output growth as endogenous variables in the VAR system such as done in Ranadive and Burange (2015), Mendali and Das (2017) or Patra et al. (2018) in recent times. Macroeconomic theory, whether one looks from the Classical or the Keynesian perspectives, theorize price impacts as culminating into real impacts for meaningful economic impact to occur. Pure price relationships, without culmination into quantity impacts, would tend to suggest a mechanism that does not produce any change in actual economic decisions of agents. In other words, without allowing price changes to induce real impacts, the price relationships captured by the ERPT process would not lend themselves useful for economic analysis and policy formulation. The final aim of economic processes is to cause actual behavioral changes, and pure price relationships would not allow for such changes, thereby would not generate information that may be useful for either policy or economic analysis. Motivated by these observations, the real output variable is utilized as the final culmination of the inflationary impulses from exchange rate into the domestic economic structure.

While the endogenous variables shape the core equations of the VAR system and will provide the fundamental relationships which are to be modelled into an interrelated dynamic pass-through process, there are variables that may not be a part of the system itself but may still play a pivotal role in shaping the behavior of the system. Such variables are the exogenous variables that are considered to be ‘outside’ the system of interrelationships captured by the SVAR model, but are nevertheless critical for properly capturing the pass-through mechanism. While several studies in the Indian context have endogenized several of these variables, the choice appears to have either been ad-hoc or undertaken within a lower triangular matrix, thereby broadly treating the initial variables of the system as exogenous. One important variable in this context is the oil price variable, which has been frequently utilized as an endogenous variable in the VAR system such as undertaken in Ranadive and Burange (2015), Mendali and Das (2017), and Patra et al. (2018). However, it is difficult to rationalize the oil price movements as emerging from the pass-through mechanism itself. Oil price formulation is a much more complex phenomenon that is captured by several international and global factors and endogenizing this variable into the pass-through VAR system would perhaps not do justice to the complexities of the oil markets and the price discovery process in these markets[42]. Hence, oil price inflation is treated as the first exogenous variable in the SVAR system.

The second exogenous variable in the structural VAR system is the monetary policy variable, measured by the log difference of the real money supply. The use of real money supply, i.e. nominal M3 deflated by WPI was undertaken to avoid the non-stationarity problem of the nominal money supply variable encountered in this study. The nominal broad money variable remained non-stationary despite first differencing and attempting different transformations such as its year-on-year quarterly growth rate as well as other formulations. Money supply is a critical factor impacting the pass-through mechanism and ignoring it due to econometric issues could not be justified on theoretical basis. Given its conceptual importance in the issue under investigation, the nominal brad money variable was deflated by wholesale price index to obtain the real money supply variable, which represents the purchasing power of given stock of money. This variable is employed as a proxy for monetary policy variable and is stationary in log difference form.

The third and fourth exogenous variables are dummy variables representing the monetary policy regime change in October 2016 when Flexible Inflation Targeting (FIT) was introduced and another dummy variable representing the impact of the pandemic on output and inflation. Following Enders (2014), an intervention analysis approach is adopted and gradual intervention is permitted by specifying the dummy variables with values 0.25, 0.50, 0.75 and thereafter 1.00, up till the end of the sample period, to model their gradual incorporation by agents and the spread of their impact across the economy[43]. The rationale and nature of these two variables have already been elaborated in sections 5.3 and 5.7.1. These two variables have been used to proxy the important policy changes which could have impacted inflation and output behaviour.

Choice of lag length is another critical econometric dimension in the VAR analysis. There is a danger of overfitting a model and running into “degrees of freedom” problem (Khundrakpam and Jain, 2012). In case of underfitting the model, the estimates will be unreliable and the resultant impulse responses and variance decompositions might possess no economic or econometric meaning. Hence, using some forms of criteria to locate the correct lag length so as to avoid the problems of underfitting and overfitting is necessary. The information criteria are employed to “pare down” (Enders, 2014, pp. 290) to the correct lag length and this is accomplished by undertaking the lag length test for up to eight lags. The choice of the correct length is based on using the Akaike Information Criteria (AIC), Schwarz Information Criteria (SIC), and the Hannan-Quinn Information Criteria (HQIC). Among these three, reliance is made on the AIC given that it performs better in small-samples and thus has better small-sample properties compared to other criteria (Lütkepohl, 2005; Enders, 2014). Accordingly, the lag length is selected to be four in the present context.

Thus the VAR model contains four equations, each for the exchange rate, wholesale price inflation, consumer price inflation and real output growth. The reduced-form VAR can be stated as follows:

$$\mathbf{y_t = A_0 + A_1(y_{t-1}) + A_2(y_{t-2}) + A_3(y_{t-3}) + A_4(y_{t-4}) + C(x_t) + e_t} \qquad \textbf{....(12)}$$

Where, y_t is the vector of contemporaneous values of the four endogenous variables, A_0 is the 4-dimensional vector of intercepts, A_1 to A_4 are the 4*4 square matrices, C is the 5*4 matrix of coefficients of exogenous variables while x_t is the vector of exogenous variables, and ε_t is the 4 dimensional vector of current time-series values of the reduced-form innovations, and ε_t depicts a 4 * 1 white noise innovation process with expected value of zero, $E(e_t e_t') = \sum_e$, and $E(e_t e_s') = 0$ for all $t \neq s$. Hence, following is the structure of the VAR model in matrix form:

$$\begin{bmatrix} \Delta InNEER_t \\ \Delta InWPI_t \\ \Delta InCPI_t \\ \Delta InGDP_t \end{bmatrix} = A_0 + A_1 \begin{bmatrix} \Delta InNEER_{t-1} \\ \Delta InWPI_{t-1} \\ \Delta InCPI_{t-1} \\ \Delta InGDP_{t-1} \end{bmatrix} + A_2 \begin{bmatrix} \Delta InNEER_{t-2} \\ \Delta InWPI_{t-2} \\ \Delta InCPI_{t-2} \\ \Delta InGDP_{t-2} \end{bmatrix}$$

$$+ A_3 \begin{bmatrix} \Delta InNEER_{t-3} \\ \Delta InWPI_{t-3} \\ \Delta InCPI_{t-3} \\ \Delta InGDP_{t-3} \end{bmatrix} + A_4 \begin{bmatrix} \Delta InNEER_{t-4} \\ \Delta InWPI_{t-4} \\ \Delta InCPI_{t-4} \\ \Delta InGDP_{t-4} \end{bmatrix} + C^{*}x_t + \varepsilon_t \qquad \textbf{...(13)}$$

B. Nature of restrictions and construction of the SVAR model

Table 5.12: Restrictions imposed on the reduced-form VAR for identifying the SVAR model

Sr. No.	Type of Restriction	Restriction
1	Contemporaneous restrictions (total restrictions = 06)	1. WPI does not have a contemporaneous impact on NEER. 2. CPI does not have a contemporaneous impact on WPI and NEER. 3. Output does not have a contemporaneous impact on CPI, WPI as well as NEER.
2	Short-run restrictions (total restrictions = 01)	4. Output does not impact NEER.
3	Long-run restrictions (total restrictions = 01)	5. NEER does not impact Output
4	Restrictions on Exogenous Variables (total restrictions = 04)	6. Oil prices do not impact the exchange rate but affect inflation (WPI and CPI), and output. 7. Money Supply growth impacts inflation and output but not the exchange rate. 8. The introduction of Flexible Inflation Targeting impacts inflation and output but not the exchange rate. 9. The lockdown impacts output and inflation but not the exchange rate.

Source: Author's specification.

The fundamental relationship through which the identification of the structural innovations is undertaken are contained in the relationship between the structural shocks and errors from the reduced-from estimated VAR. The restrictions utilized for the SVAR estimation including the linear restrictions on exogenous variables are shown in Table 5.12.

The first set of restrictions are on contemporaneous relations between the endogenous variables. A unit lower triangular matrix is obtained through these restrictions. The rationale for not allowing each variable to impact the previous variables in the ordering is to recognize that the inflationary impulses from exchange rate shocks require time to generate feedback effects. Given that the analysis is aggregate in nature, the impact of exchange rate variations on domestic economy via the price channel will cause large number of adjustments in diverse markets that are themselves interconnected in a complex web of relations. Expecting, for instance, wholesale price inflation to immediately cause change in exchange rate will imply that the adjustments in wholesale markets are instantaneous. This seems to be improbable given that aggregate adjustments inherently involve lags and agents require time to absorb the inflationary impulses from exchange rate shocks. Similarly, CPI is not permitted to contemporaneously impact WPI to account for lags in adjustments at the retail level due to inflationary impulses from both the exchange rate and the wholesale markets. Wholesale markets are bulk markets and the agents trading in these markets tend to be more sensitive and reactive to inflationary impulses than are the retail consumers. The consumer market is far larger, wider and complex which implies larger amount of time in adjustments due to exchange rate shocks and the subsequent chain of events. Given that price impact from exchange rate will require time to spread across the large number of retail markets across the geographical spread of the country, it is plausible to expect that CPI inflation will not be able to immediately impact wholesale markets as adjustment is time consuming in the retail markets and price signals will not be generated instantaneously. However, WPI inflation will have immediate repercussions for consumer markets as important inputs, capital goods, essentials like crude oil and a host of other commodities are traded in wholesale markets whose price impulses will rapidly cause behavioral changes from consumers further down the supply chain.

CPI is also not permitted to impact NEER contemporaneously to recognize the fact that adjustments in consumption due to changes in prices from exchange rate variations will take time to accumulate at a level that can cause expenditure switching and thereby cause variations in the exchange rate. Output is also restricted in terms of its immediate impact on prices in the pass-through mechanism. Quantity adjustments require time and are generally slower than price variations which may happen not only due to real but more frequently due to monetary and financial reasons. Exchange rate, for example, may vary sizeably due to changes in net capital inflows, causing an inflationary shock. Such changes are rapid in nature. These changes will tend to pass over into other price variables in the VAR system much more rapidly than would real impulses, such as an output shock. Quantity adjustments require time to unfold and accumulate to an extent that are sizeable enough to induce price reactions. While prices may react faster to each other and output in itself may react instantaneously to price variations, the reaction of prices to output variations will depend on the length of the real adjustment in the economy. Quantity or real adjustments require changes in the factor allocations, capacity utilization and other aspects that are not rapid but require sufficient time to uncover themselves. Hence, it seems much more plausible to conceptualize prices are rapidly reacting to each other and impacting output than theorizing output as inducing immediate price reactions, because the output adjustments are time consuming in the first place. Hence, output is constrained in its instantaneous impact on the prices in the VAR system.

However, in the short-run, quantity adjustments due to the initial exchange rate shock can induce variations in domestic prices. The feedback effects from changes in output growth could induce short-run impact on prices, given that some amount of time is available for quantity adjustments to accumulate and percolate through a large set of markets; though this process will still require time to unravel completely, which can occur only over longer horizons. Consistent with this belief, output is permitted to impact the domestic price variables but is not allowed to impact exchange rate in the shorter horizons. Exchange rate displays considerable volatility in the short-run and is driven by many non-quantity factors such as market sentiments, movements in derivate markets, global shocks and others. Domestic output variations will need to be sufficiently large to cause meaningful reactions from a volatile variable such as the exchange rate. Thus, it seems plausible that exchange rate is not impacted during short horizons by output variations. However, over the longer horizons, output variations may accumulate sufficient size and depth so as to cause changes in demand for imports and supply of exports on the trade side, and possibly causing changes in net capital inflows, which together could alter the exchange rate of the Indian rupee. Hence, in the long-run, output is permitted to impact the prices as well as the exchange rate. However, over longer horizons, exchange rate is not expected to strongly impact output variations, given that in the long-run the neutrality of money would set it, which could prevent temporary exchange rate shocks to cause changes in output. In the long run, output variations are generally considered to be supply determined, and thus meaningful changes in output growth would occur largely by supply side policies and shocks rather than price shocks such as the exchange rate. Moreover, while domestic prices could still have impact on output and vice versa in the long run, the impact of the external channel on domestic output is expected to weaken over time. Long term output movements are more attuned to changes in domestic supply-side macroeconomic fundamentals that may not be strongly shaped by exchange rate variations once sufficient time is permitted for the pass-through effects to work out their full effects.

Lastly, linear restrictions are also introduced into the VAR system by constraining the possible impacts off the exogenous variables on the endogenous variables. The restrictions are driven by the understanding that not all exogenous variables in a VAR system can have meaningful implications for all endogenous variables. Oil prices are allowed to affect inflation and output but not the exchange rate. This is consistent with the literature in the Indian context where oil price is always ordered before exchange rate. As explained earlier, the oil markets are complex and the price discovery process cannot be associated with the exchange rate of a single currency such as the Indian rupee. Oil markets generally use the US Dollar or the currencies of the OPEC members and thus movements in Indian currency are not expected to bring any sizeable implications for the global crude oil price. It is also assumed that money supply does affect exchange rate but impacts inflation and output. Given that the RBI has left the exchange rate to market forces, monetary policy has assumed independence from exchange rate considerations and thus it is expected that monetary management will not be directed towards exchange rate management, consistent with the exchange rate regime adopted in India. The introduction of the FIT regime was geared towards better managing price stability and keeping inflation under tolerable limits. Inflation can generate impact on output, at least in the short-run, but the rationale of the FIT regime did not have exchange rate considerations. Hence, the dummy variable for FIT is assumed to not impact exchange rate. Lastly, the dummy representing the economic implications of the pandemic, primarily due to the series of necessary lockdowns, is not expected to affect exchange rate as it was largely a domestic event.

The set of restrictions contained in Table 5.12, are portrayed in matrix representations 14 to 17.

$$\begin{bmatrix} \varepsilon_t^{\Delta \text{InNeer}} \\ \varepsilon_t^{\Delta \text{InWPI}} \\ \varepsilon_t^{\Delta \text{InCPI}} \\ \varepsilon_t^{\Delta \text{InGDP}} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ a_{2,1} & 1 & 0 & 0 \\ a_{3,1} & a_{3,2} & 1 & 0 \\ a_{4,1} & a_{4,2} & a_{4,3} & 1 \end{bmatrix} * \begin{bmatrix} e_t^{\Delta \text{InNeer}} \\ e_t^{\Delta \text{InWPI}} \\ e_t^{\Delta \text{InCPI}} \\ e_t^{\Delta \text{InGDP}} \end{bmatrix} \quad \text{....(14)}$$

Representation 14 positions the identification of the structural innovation through the errors estimated from the reduced-from VAR system. Similarly, the variance-covariance matrix of the errors from the estimated VAR can be represented as shown in the representation 15. The co-variances are restricted to be zero so as to allow the identification of structural shocks associated with each of the variable under consideration. The consequent variance-covariance matrix is shown in the representation 15 as follows.

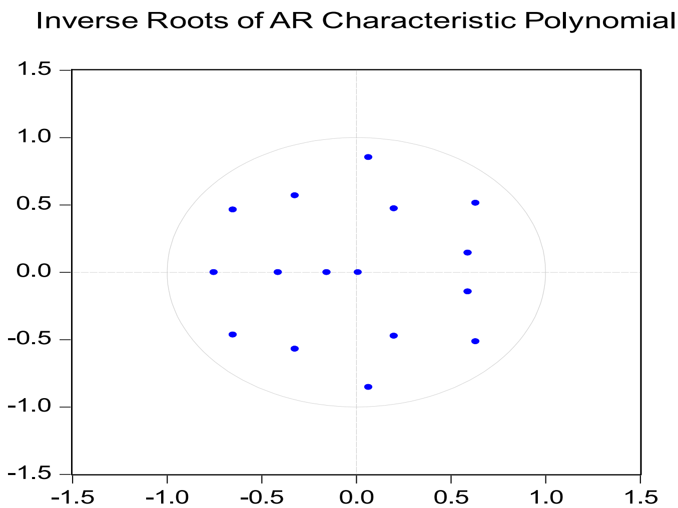
$$\begin{bmatrix} \text{var}(e_{1t}) & 0 & 0 & 0 \\ 0 & \text{var}(e_{2t}) & 0 & 0 \\ 0 & 0 & \text{var}(e_{3t}) & 0 \\ 0 & 0 & 0 & \text{var}(e_{4t}) \end{bmatrix} \quad \text{....(15)}$$

Where, e_{1t} is the error term of the equation for exchange rate variable, e_{2t} is the error term for the equation of WPI, e_{3t} is the error term for the equation of CPI, and e_{1t} is the error term of the equation for real output growth. Similarly, the short-run impulse response matrix is specified so as to restrict the effects of aggregate production on the value of currency to zero, while the long-run impulse response matrix is constrained by assuming the influence of exchange rate on output to be zero.

C. Estimated results

This section presents the impulse response functions and variance decompositions from the estimated SVAR model as examined above. Before undertaking further analysis, ensuring that the estimated VAR system is stable, is warranted for meaningful and econometrically reliable analysis (Lütkepohl, 2005). The inverse of roots of the Auto Regressive (AR) characteristic polynomial shown in Figure 5.2, which signifies whether all the roots have modulus of less than unity, i.e. are within the unit circle, shows that all the unit roots are very well within the unit circle, indicating a stable VAR. There will be n*m roots where n is the number of endogenous variables and m is the number of lags. Hence, there are sixteen roots and all lie within the unit circle. The results from the estimated VAR such as the impulse responses and variance decompositions are thus reliable from an econometric point of view.

Figure 5.2: Stability of the estimated VAR system

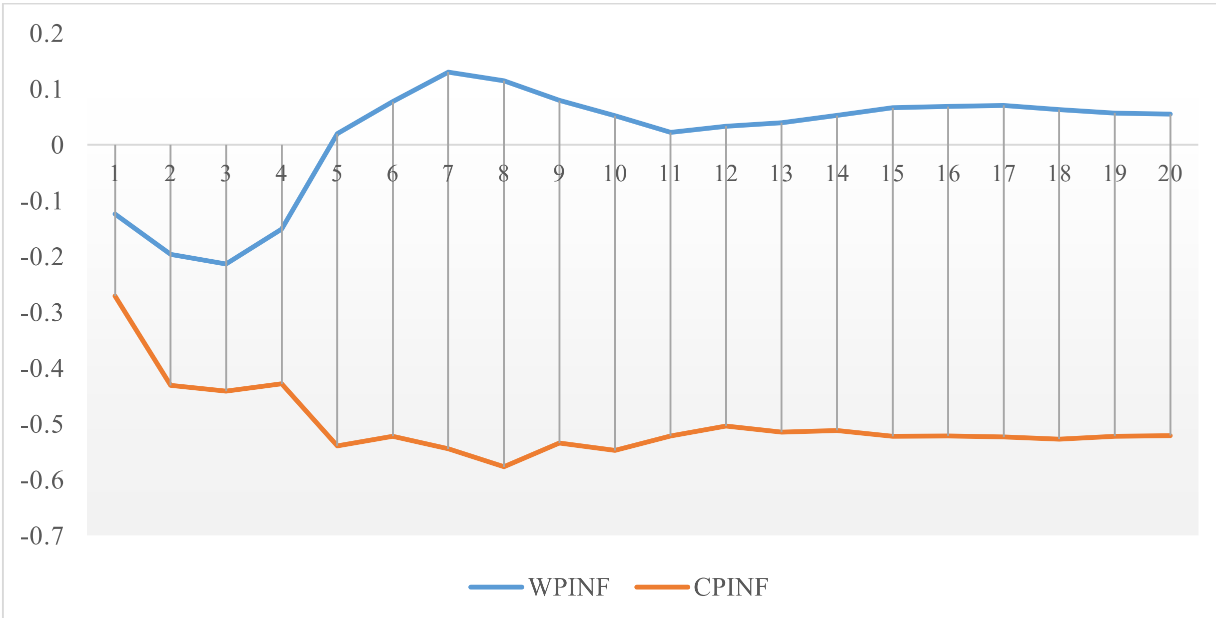


Source: Author’s estimation.

The primary interest in examining the SVAR formulation is to trace the response of inflation to impulses in exchange rate variable and in other possible sources of inflation. Figures 5.3 to 5.7 signify these findings. Figure 5.3 presents the accumulated impulse responses of both the domestic price variables to an initial structural shock in exchange rate. The impulse responses are derived by using the structural decomposition that helps to take into the account the identifying restrictions imposed on the unrestricted VAR. The findings indicate that the pass-through over time is larger for CPI than it is for the WPI, perhaps also implying a larger pass-through from the WPI to CPI. In recent times, Ranadive and Burange (2015) investigated pass-through across the pricing chain ranging from import prices to consumer prices. They found a fall in pass-through across the pricing chain with the lowest pass-through for consumer prices. However, they employed the bilateral exchange rate variable unlike the NEER as used in this chapter[44]. Similarly, Mendali and Das (2017) estimated the extent of pass-through using VAR framework and employed NEER and the WPI variables. They found a very low pass-through to WPI. The findings contained in Figure 5.3 are thus contextualized in the wake of current findings where WPI is used. However, studies such as Patra et al. (2018, 2020), find that pass-through is considerably higher when the

CPI is used. Figure 5.3 shows that the pass-through effects of exchange rate on WPI is lower than the inflationary impact on consumer price inflation.

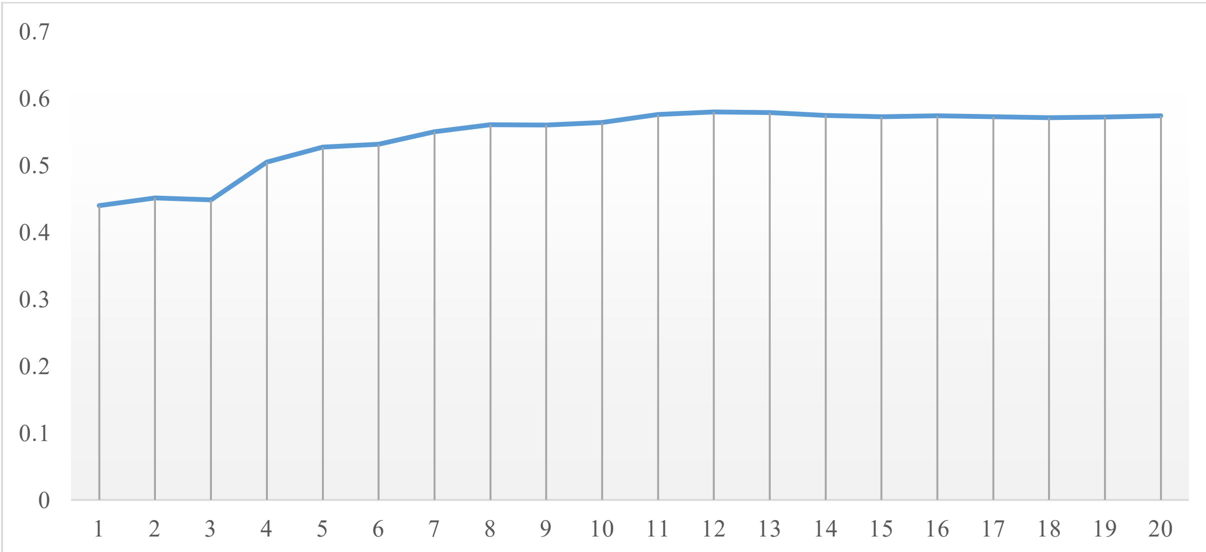
Figure 5.3: Accumulated Impulse Responses of domestic prices to structural innovation in exchange rate



Note: Data are rescaled to represent percentage changes. **Source**: Author's estimation.

Do wholesale markets tend to quickly pass-over the inflationary impulses from exchange rate shocks? Do the firms in wholesale markets rapidly revise the prices further down the pricing chain to avoid excessive absorption of the exchange rate shock and thus maintain their markups? The results contained in Figure 5.4 seem to suggest that this might be the case. Figure 5.4 displays the accumulated impulse response functions from a wholesale price shock to consumer price inflation. It seems that price disturbances in the wholesale markets are in large part being passed into consumer prices. Another reflection of this fact is contained in Table 5.12 which shows the short-run, long-run and dynamic elasticities of pass-over from currency variations to domestic inflation and from wholesale markets to the retail inflation.

Figure 5.4: Accumulated impulse Responses of consumer price inflation to structural innovation in wholesale price inflation



Note: Data are rescaled to represent percentage changes. **Source**: Author's estimation.

The pass-over from currency variations shock to WPI is consistently lower than the pass-through to CPI, indicating that either the price pressures, upwards or downwards, are being pass over in large proportion to the consumer prices, or perhaps there are other channels of transmission from exchange rate to consumer prices which may be pushing the prices at retail level. It can only be speculated at this stage which of these mechanism is actually at work, but if the estimates of table 5.12 are observed then clearly, there is a high transmission of price impulses from WPI to CPI as shown in column three. Pass-through to WPI remains considerably lower even after 12 quarters. The dynamic pass-through estimates in table 5.13 show that the pass-through to WPI and CPI peaks after eight quarters and begins subsiding thereafter, while the pass-through remaining much larger for CPI than WPI even after 12 quarters. Evidently, the extent of pass-through is much more sizeable in the case of consumer inflation and this implies that the exchange rate channel of inflation remains a challenge for the RBI to tackle with. Irrespective of the time period allowed for adjustments, pass-through remains incomplete in both the cases, indicating the absorption of inflationary impulses from the exchange rate shock at different points in the pricing chain.

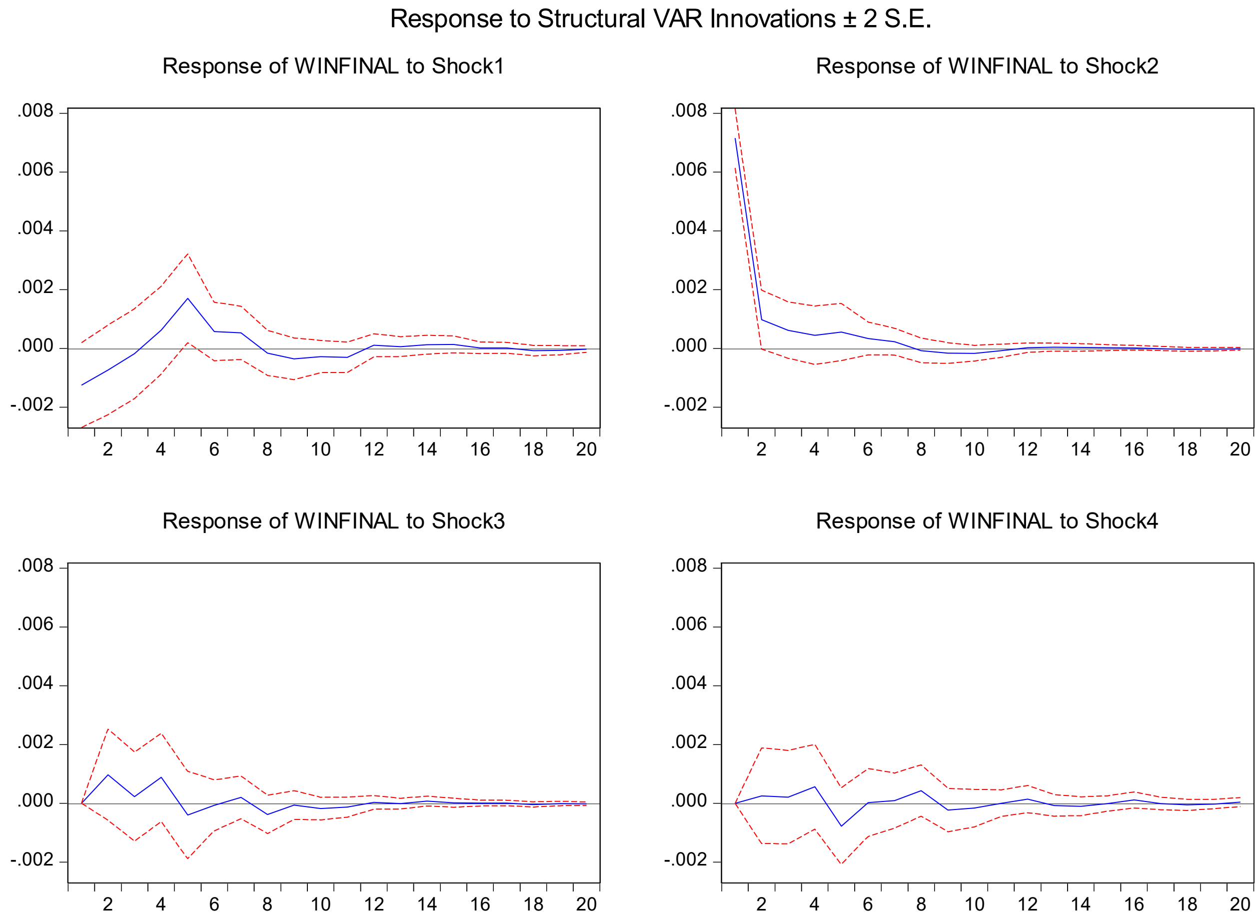
Table 5.13: Short-run pass-through, Long-run pass-through and dynamic ERPT elasticity

Dimension	WPI	CPI	WPI → CPI
	(1)	(2)	(2)
Pass-through after One Quarter	0.12%	0.27%	0.44%
Pass-through after Four Quarters	0.15%	0.43%	0.50%
Pass-through after Eight Quarters	0.11%	0.58%	0.56%
Pass-through after Twelve Quarters	0.03%	0.50%	0.58%
Dynamic pass-through elasticity after Four Quarters	5.70%	16.12%	54.86%$
Dynamic pass-through elasticity after Eight Quarters	7.43%	37.55%	54.63%$
Dynamic pass-through elasticity after Twelve Quarters	1.70%	26.02%	58.56%$

Note: Dynamic elasticity estimates are estimated using methodology in Ito and Sato (2008), and Ranadive and Burange (2015); $ - estimated using the four accumulated impulse response of WPI to structural shock in WPI, instead of exchange rate; Signs are negative indicating the expected direction of relationship between NEER and inflation variables, but the absolute values are reported here. **Source**: Author's estimation.

Figure 5.5 presents a comparative perspective on the sources of wholesale price inflation in India. The impulse responses of WPI to the structural innovations in all the four endogenous variables are presented herewith. The strongest response of WPI is to the structural shock in its own lagged values, implying strong inertia and possibly persistence of inflation. This observation is also testified by Table 5.13 which presents the estimates of variance decomposition of the inflation variables with reference to structural shocks in all the four endogenous variables. The implications of the real shock, as captured by shock 4 in figure 5.5, are weak and fade away after 8 quarters, while consistently remaining low.

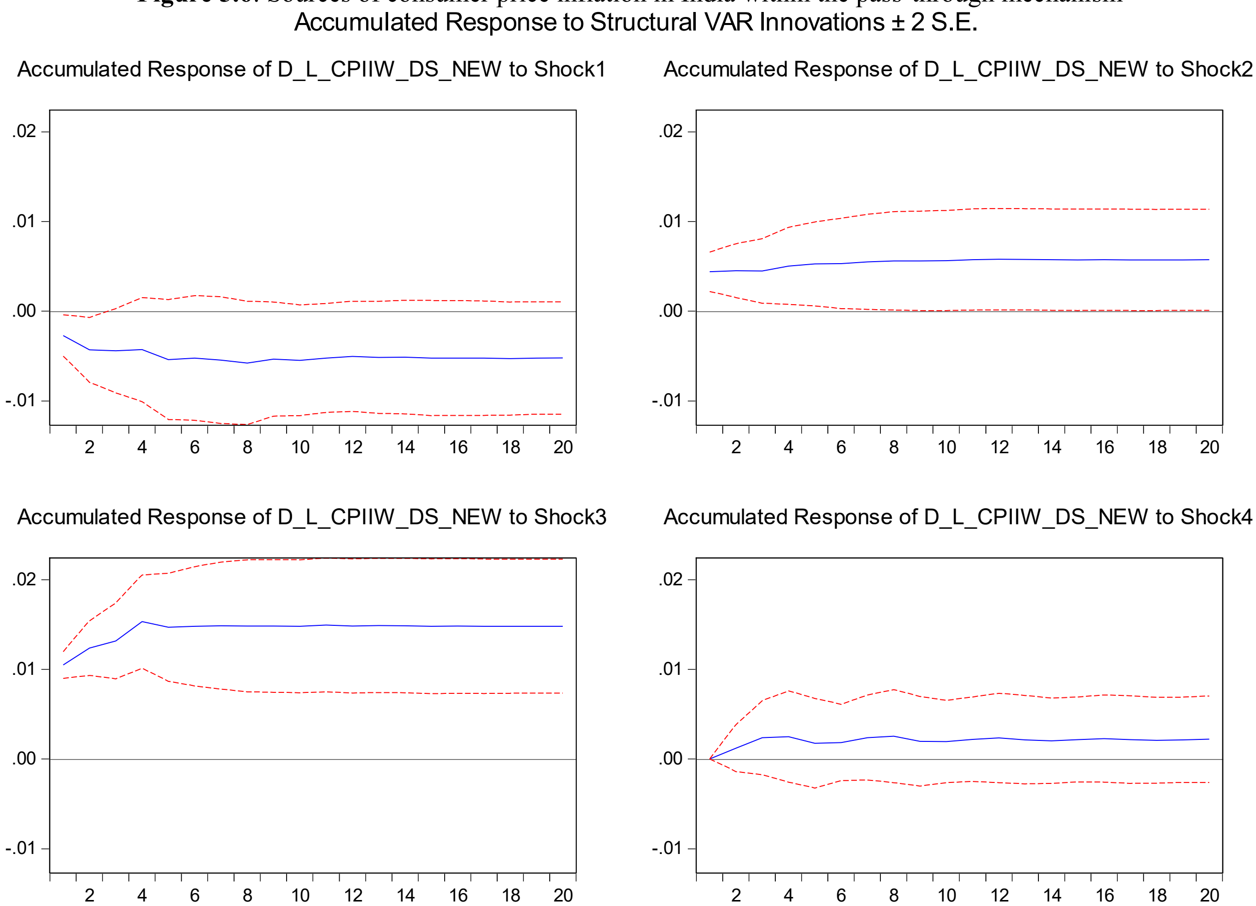
Figure 5.5: Sources of wholesale price inflation in India within the pass-through mechanism



Note: WINFINAL is the WPI variable for All Commodities in log difference form. Data have not been rescaled for representing percentage changes. **Source**: Author's estimation.

Similarly, the sources of inflationary movements at the retail level is captured by the impulse responses in Figure 5.6. Similar to the observations for WPI, the consumer price inflation is strongly driven by its own impulses, indicating persistence and inertia as key sources of inflation in India. Perhaps, the inflation process in India is indeed backwards-looking as suggested by many studies in recent past. The response of CPI to the real shock (shock 4) is slightly larger than the response from WPI indicating that real factors, such as aggregate demand movements, may be playing a more prominent role in pushing inflation in India at the retail level. The CPI is also considerably sensitive to WPI movements, showing that there is transmission of price impulses from wholesale markets to the retail markets.

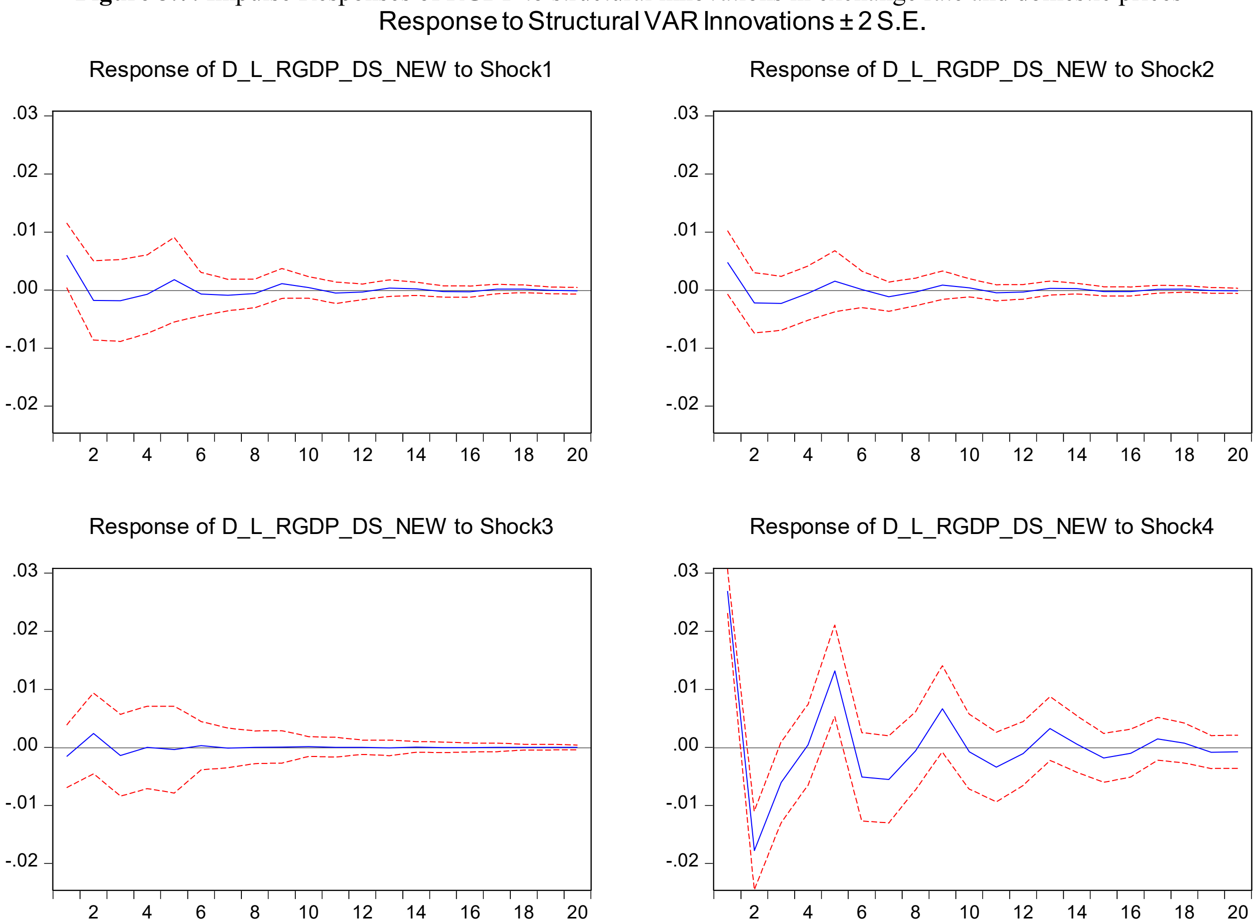
Figure 5.6: Sources of consumer price inflation in India within the pass-through mechanism



Note: D_L_CPIIW_DS_NEW is the CPI variable for Industrial Workers in log difference form. Data have not been rescaled for representing percentage changes. **Source**: Author's estimation.

In a similar vein, figure 5.7 presents the impulse response functions of the real output growth to structural shocks in all the four endogenous variables. Clearly, output growth is driven by its own inertia and considerable degree of a self-adjustment is evident in the behavior of output growth. The assumption that output is largely independent of price impulses in the long run seems relevant given these findings. There are much more complex and richer factors other than price forces that may be driving the behavior of output growth in India.

Figure 5.7: Impulse Responses of RGDP to structural innovations in exchange rate and domestic prices



Note: D_L_CPIIW_DS_NEW is the CPI variable for Industrial Workers in log difference form. Data have not been rescaled for representing percentage changes. **Source**: Author's estimation.

Table 5.14 presents the estimates of Variance Decomposition which examines the contribution of all four structural shocks in explaining the forecast error variance of WPI and CPI. As noted earlier, the initial shock in inflation is able to explain the large majority of forecast error variance of inflation itself, indicating strong need for Central Banks to account for inertia and persistence of inflation in order to influence it meaningfully. Interestingly, the importance of exchange rate increases with time in explaining the behaviour of both the wholesale and consumer price inflations as shown by the increasing values of Shock 1 in table 5.13. This is consistent with the literature surveyed earlier in section 5.3. Furthermore, as found earlier in the previous section, there is active pass-through from wholesale prices to consumer prices as indicated by the increasing importance of WPI shock in explaining the CPI behaviour over time depicted by estimates in table 5.13.

Table 5.14: Variance decomposition estimates for WPI and CPI to all the four structural shocks

Period	Wholesale Price Inflation				Consumer Price Inflation			
	Shock1	*Shock2*	*Shock3*	*Shock4*	*Shock1*	*Shock2*	*Shock3*	*Shock4*
	NEER	WPINF	CPINF	RGDP	NEER	WPINF	CPINF	RGDP
	%	%	%	%	%	%	%	%
1	2.93	97.07	0.00	0.00	5.39	14.14	80.47	0.00
2	3.75	94.40	1.73	0.12	6.88	13.41	78.69	1.03
3	3.77	94.22	1.81	0.20	6.79	13.22	78.05	1.94
4	4.34	91.76	3.13	0.76	6.58	13.00	78.53	1.89
5	8.81	86.33	3.18	1.68	7.29	12.85	77.65	2.22
6	9.28	85.89	3.17	1.67	7.30	12.84	77.63	2.22
7	9.68	85.44	3.21	1.67	7.32	12.83	77.43	2.42
8	9.66	84.95	3.42	1.97	7.38	12.83	77.36	2.44
9	9.82	84.72	3.42	2.04	7.47	12.79	77.10	2.64
10	9.92	84.55	3.46	2.08	7.48	12.78	77.09	2.64

Source: Author's estimation.

5.8. Summary and concluding remarks

This chapter examined the issue of ERPT to domestic inflation by investigating the nature of short-run and long-run pass-through in India at the aggregate level using quarterly and annual data from 1991-92 to 2021-22. Section 5.1 introduced the issue and provided the analytical background on this matter. It delineated the shift in attention from the quantity to price impacts of exchange rate in modern macroeconomic literature and highlighted the fundamental concerns of the literature on the price impacts emanating from exchange rate behaviour. Section 5.2 underlined the primary concerns of this work by specifying the key issues and hypotheses to be investigated. The four major issues tasks undertaken in this chapter were laid bare in this section.

Thereafter, Section 5.3 and 5.4 developed the theoretical model adopted in this chapter. By grounding the analysis in a well-defined theoretical framework, the inferences from this chapter can be better contextualized with extant literature and theoretically reliable inferences can be drawn and compared with a-priori expectations. A backward-looking open economy version of the Phillips curve was developed for the Indian economy to study the ERPT issue. The coefficient of pass-through has been found as considerably sensitive to the control variables employed in the inflation equation, particularly the monetary policy variables. Hence, two baseline models were developed in this section. The rationale, context and consistency of the theoretical framework with the extant wisdom was examined in this section. Section 5.5 explained the variables employed, important issues related to their construction, their sources and other allied matters. Section 5.6 presented the descriptive statistical estimates of the macroeconomic variables employed in this study, while also assessing their key time series properties before preparing them for the empirical analysis.

Section 5.7 presented the empirical perspectives. Sub-section 5.7.1 examined the issue of short-run and long-run extents of pass-through in India within a dynamic partial adjustment framework. The primary findings included a higher long-run pass-through as compared to short-run pass-through, fulfilment of the 'incompleteness hypothesis' in the Indian context, inflation inertia and persistence and monetary policy being the primary drivers of inflation after which ERPT played a pivotal role in shaping the inflationary movements in India. Sub-section 5.7.2 investigated the issue of ERPT to domestic inflation using annual data and found the results to be largely consistent with the findings for quarterly data. Sub-section 5.7.3 looked into the issue of stability of the pass-through coefficient as estimated through the two baseline models and found that pass-through had been largely stable across the study period. This finding was robust to alternative econometric methods of studying the intertemporal stability of pass-through coefficient. The rolling regression approach, a Time-Varying-Coefficient (TVC) approach and a Kernel density based TVC approach were employed. All the approaches yielded the same finding – pass-through to domestic inflation has been stable over time.

Sub-section 5.7.4 studied the pass-through phenomenon by relaxing the ceteris paribus assumption and allowing richer dynamics into the macroeconomic transmission process from exchange rate shocks to domestic prices using a Structural Vector Auto Regression approach. The structural decomposition approach allowed tracing the impulse responses and variance decompositions which formed the primary issues of concern in this approach. Pass-through to WPI inflation was found to be lower than for CPI inflation with higher transmission of price impulses from WPI to CPI. The dynamic elasticity estimates further testified these findings. Consistent with the findings from the single equation models used earlier in the chapter, inflation was found to be largely driven by its inertia and displayed persistence over time. The importance of ERPT channel was found to be increasing over time.

Notes

[1] The idea of the "fear of floating" has been well-articulated in Bianchi and Coulibaly (2023) who propose a model of monetary policy response under the reluctance to shift to flexible exchange rate despite its equilibrating role. The authors show that rather than being an equilibrating tool, a floating regime can "expose the economy to self-fulfilling crises" (pp. 1).

[2] Naturally, during this period, the elasticity school of pass-through, which argued that it is the price elasticity of imports demand and supply that together determined the extent of pass-through, engaged in examining the fulfilment of the Marshall-Lerner conditions and the evidence largely showed that the conditions were rather well behaved in most of the advanced trading countries.

[3] The focus on the price impact of exchange rate was not established by Dornbusch (1987) per se. It was an age old issue and had always remained at the heart of the debates on exchange rate regimes and the relationship of exchange rate with trade balance adjustment mechanism. However, the work by Dornbusch provided a systematic framework that solely focused on pass-through analysis from the perspective of industrial organization literature, with special emphasis on microeconomic foundations which created a lineage of works adopting this approach.

[4] This may not be confused with the Taylor's rule which was propounded by the same author.

[5] One may refer Laflèche (1996) for a detailed structure of the pass-through process wherein both the direct and indirect channels of transmission of exchange rate changes to domestic prices are examined.

[6] It is important to differentiate between the ERPT relationship in terms of levels of prices and exchange rate versus in terms of first differences or growth rate in these variables. The pass-through relationship in first difference, log differences and growth rates is perhaps the most frequently employed form in the empirical relationship. The nature of pass-through is different when looked at from this angle. In this sense, the relationship is expressed in terms of changes in prices rather than the level of prices. The extent of pass-through, i.e. the elasticity coefficient of pass-through, will express how the change in the rate of depreciation or appreciation impacts the rate of inflation, whether on trade or domestic front. The theoretical idea of ERPT is expressed in terms of price levels, though empirically, the conclusions drawn from first differences or growth rates in prices also give qualitatively similar inferences though.

[7] Namely the transactions formulation of Irving Fisher, and the 'cash balance' formulation of the Cambridge school. Please refer Frisch (1984, chp. 7) for a detailed perspective.

[8] It must be noted here that in the very long run, when secular movements of inflation are examined, macroeconomists consider inflation as fundamentally emerging from secular monetary expansion. It is in the domain of short-run and medium-run analysis that the richer models of inflation are adopted.

[9] The LERMS was a dual exchange rate system to prepare the bedrock for transition to market determined rates. It "consisted of an official rate for some government and private transactions and a market determined

rate for the others" (Rajan and Yanamandra, 2015, pp. 32). A brief summary of the evolution of the exchange rate regimes in India is provided in Dua and Rajan (2010) who trace the history of India's tryst with exchange rate regimes since independence.

[10] Invariably, the linkages between exchange rate and domestic inflation emerge from the analysis of inflation within an open economy framework. In single equation models, the inflation function is estimated, generally within a Phillips Curve approach, and it is thus necessary to account for not only the exchange rate variable in the inflation function, but also critical macroeconomic forces determining inflation itself whose exclusion may result in either underestimation or overestimation of the true extent of price impact from currency alterations. Single equation models analyze the pass-through matter within a partial equilibrium framework and it is thus necessary to control for the impact of the major macroeconomic determinants of inflation, including its inertia, so as to derive a purer and refined estimate of ERPT coefficient.

[11] Please refer sections 4.7 and 4.8 of chapter for more a detailed perspective on this issue.

[12] Another important dimension in this regards is that in single equation models, every change in exchange rate will be construed as an exogenous shock. Conceptually, one needs to differentiate between 'change' and 'shock'. This differentiation is necessary because it is not possible to expect symmetrical behavior from domestic prices to changes versus shocks in exchange rate. A shock is generally conceptualized as a sudden and substantial variation in a variable and it is generally not expected in advance. Change, on the other hand, are well-perceived by economic agents and may be forecasted well-in-advance. Reaction of domestic prices under both these situations can be quite different. This concern motivates the use of a SVAR framework in this chapter.

[13] Their theoretical framework was considerably restricted and could not capture the rich complexities of the inflation process. The specification relied upon the law of one price relationship which inherently presumes complete ERPT and hence the structure of the model may be more relevant for large open economies rather than a small open economy like India. The control variables chosen were expected to capture the demand and supply side shocks but the use of US PPI, which is a frequent practice in literature, is problematic when looking at the pass-through within the Indian setting. The sensitivity of domestic inflation in India to movements in the US PPI is not a well-established phenomenon. The authors compensated for this deficit by incorporating the World CPI in another specification which better captures the supply side shocks emanating from external sector. Ideally, the oil price and food inflation variables should be included in pass-through analysis. Ignoring oil price pass-through to inflation may overstate the ERPT itself, and not accounting for food price shocks may result in an under fitted model even though the traditional statistics of goodness of fit may seem high.

[14] Output gap variable has also been frequently employed as a proxy for the unobservable aggregate real marginal costs in estimation of the inflation function. See Patra and Kapur (2012) for more details on this approach to conceptualizing the output gap variable. In this case, the output gap variable can very well be assumed to reflect cost conditions and thus the Phillips curve equation can be considered as an aggregate supply curve.

[15] "In the literature, a partial equilibrium micro-founded mark-up equation… has emerged as the standard empirical specification" (Patra et al., 2018, pp. 7).

[16] There were other important changes too. The concept of natural rate of unemployment was incorporated into the Phillips curve specification. Furthermore, the excess demand variable was now defined as a gap between the natural unemployment rate and actual unemployment. See (Motyovszki, 2013) for more details.

[17] Neutrality of money and the ability of demand side forces to induce real impact continued to remain the key issue of debate across these evolutions of the Phillips curve.

[18] A brief history of the use of Phillips curve in estimation of inflation in India can be located in Kapur (2013).

[19] Indian import basket of crude oil is specifically defined as explained in chapter four. The world crude oil price on the other represents the oil price movements for all crude types together. However, both these variables have very strong positive and statistically significant correlation.

[20] There was largely no sizeable difference in the results between the two approaches as seen later in the empirical estimates.

[21] Several important events have characterized the Indian economy during the study period of 1991-92 to 2021-22. The BoP crisis, economic reforms, Asian Financial crisis, slowdown in world trade during the early 2000s, Global Financial Crisis, various shifts in the monetary policy regimes, and the COVID-19 pandemic, among few others. Incorporating all these factors in the parsimonious framework of this chapter is not feasible.

[22] An alternative specification of this variable which treats it as a short term event was also tested for. In this case, the period from 1st Quarter of 2020-21 to the 4th Quarter of 2020-21 was valued at one, while the remaining periods were treated as having the value of zero. This implied that the impact of the pandemic was short-lived and economy regained its earlier momentum considerably rapidly. It seemed ambitious to treat this event as possessing a short memory. There are very few illustrations in Global history that can parallel with this event. The disaggregated economic distortions created by the pandemic and the subsequent series of lockdowns cannot be expected to resolve themselves without aggressive fiscal and monetary actions. The policy response and the consequent results of these responses need to be allowed

sufficient time to emerge. Hence, the period from 1st Quarter of 2020-21 to the 2nd Quarter of 2022-23 is valued at '1' to allow sufficient time for these adjustments to emerge.

[23] While these two baseline models represent the theoretical model, the estimated models include the variables that significantly explain the behavior of inflation. The results are contained in Tables 5.5 and 5.7.

[24] Both the specifications are examined for checking the empirical robustness of the pass-through coefficient later in the empirical exercises.

[25] The quarterly nature of the data make it plausible to allow a lag of more than one-period and the same are tested later and reported in the relevant section. Largely, the first lag and the fifth lag, implying a broadly on year lag, are found to be meaningful in this context.

[26] Patnaik et al. (2011) finds the CPI-IW as a better measure of inflation than WPI or GDP Deflator. However, this seemed to be more from the perspective of the econometric fit of the variable in the model.

[27] These are estimates as given in Gopinath (2017). They are open to debate with regards to their accuracy and scope. Moreover, the emerging issue of vehicle currency necessitates a re-look at using the bilateral Rupee-US Dollar rate as the main fulcrum of foreign exchange rate movements in pass-through studies in India.

[28] While the NEER has the advantage of comprehensiveness, it must be noted that it is a statistical construction rather than an actual phenomenon and is thus sensitive to the choice of the base year, the weighting pattern, the choice of weights, statistical measurement errors and other such phenomenon.

[29] The decision to not employ the latest 40-currency trade weighted NEER with base 2015-16 was on account of missing backwards data.

[30] This framework has been adopted from OECD (2019).

[31] Other approaches to the estimation of the trend were also tested for. Specifically, simple linear trend regression method, exponential smoothing model, and the Butterworth filter were also employed and the resultant trend was used to define the output gap variable. The use of these alternative methods did not change the direction of the impact of output gap on inflation. However, there were slight variations in the extent of the output gap coefficient in the estimated inflation equation.

[32] This is indeed a speculation at this stage and the statement reflects on the findings of the empirical literature. It is thoroughly recognized that correlation does not imply causation. But the results presented later testify the statement made here.

[33] The theoretical rationale for using log-difference form in the estimation of pass-through were also highlighted in chapter four.

[34] Unlike the specification of the theoretical model contained in equation 5, the estimated equation 9 has dropped the variables D_{FIT} and D_{MOPT} as they were found to be have economically and statistically insignificant impact on inflation within the first specification.

[35] The augmentation occurs on account of incorporating backward-looking adaptive expectations instead of rational expectations in the new Keynesian framework.

[36] Both the output gap and the real GDP growth rate were included in this model, but their coefficients were insignificant when their current-period values were used. However, when their lagged value was taken, it turned out to be significant, though negative. The negative sign of output gap would imply an inverse Phillips Curve, suggesting perhaps that lower unemployment induces higher inflation and vice-versa. Moreover, the interpretation of lagged output gap and lagged real output is different than its interpretation in terms of current period. Due to the theoretically inadmissible sign in when the current period value was used, output gap and real GDP were excluded from the final estimated model. However, in all these cases, the value of the pass-through coefficient largely remained the same.

[37] However, an important feature of the Cholesky decomposition is that it imposes the exact number of restrictions required and thus always produces a 'just-identified' VAR.

[38] However, invertibility between the disturbances and structural shocks is critical in identifying the shocks. Analysts have pointed out that this may not always be the case.

[39] A more survey of the identification issue, different identification strategies proposed in the VAR literature and their relative merits and demerits are contained in Christiano (2012).

[40] All the variables are utilized in log difference form after adjustments for seasonality using X-13 ARIMA approach of the US Census Bureau.

[41] However, a similar VAR was estimated using annual data and including import unit value index. The results were largely the same as reported in this section.

[42] There are several oil markets globally. The market for OPEC-dominated sour grade crude oil, the sweet grade oil of US called the Brent crude are the most active markets. These markets tend to be interconnected from price determination point of view. The nature of oil pricing is thus complicated by such considerations and juxtaposing them as an endogenous to the pass-through mechanism seems difficult to justify.

[43] The traditional alternative to this approach is to specify the dummy variables as having value of 1.00 from the period when the intervention was introduced. Both the dummy variables were adopted in this manner also, and results remained very much the same. However, the coefficients of these two dummy variables were much more significant and slightly larger when used in the 'gradual intervention' approach.

[44] The VAR model in this chapter was also estimated with the bilateral exchange rate with other specifications remaining the same. Pass-through behaved fairly similar to what the current findings suggest, indicating that the current results are robust to alternative definitions of the exchange rate.