Identifying Terms of Trade Shocks in a Developing Country using a Sign Restrictions Approach

Kagiso Mangadi¹, Jeffrey Sheen

Department of Economics, Macquarie University, North Ryde, NSW 2109, Australia

Abstract

Using data for Botswana from 1960 to 2012, we examine the responses of macroeconomic variables to four generalized positive terms of trade shocks—global demand, globalizing, sector-specific and global supply. A sign restricted structural vector autoregression model with a penalty function is estimated to identify the four shocks. While positive global demand and globalization shocks are both expansionary, they have opposite effects on inflation. A positive commodity market specific shock dampens real GDP growth and is inflationary, suggesting a possible Dutch disease response. A negative global supply shock suppresses both output growth and inflation. All but the last shock lead to a significant declining interest rate probably reflecting improved credit risk. Monetary policy contraction is recommended for the first shock, and expansion for the others.

Keywords: Terms of Trade Shocks, SVAR models, Sign Restrictions, Monetary Policy

JEL Classification: C32, E52, F41

1. Introduction

The terms of trade play a prominent role in the macroeconomic performance of many economies, and is one of the most important relative prices for small open economies (Cashin et al, 2004), especially developing economies. Many shocks to the terms of trade occur, but they are not all the same since they arise in a variety of global contexts. Our contributions in this paper are to identify the impacts of these various shocks on a developing country, using a sign restrictions approach on impulse responses, and to consider the appropriate policy responses.

Terms of trade shocks tend to have persistent and volatile effects on macroeconomic variables such as output growth, exchange rates, inflation, real income and savings, (see

Email addresses: kagiso.mangadi@mq.edu.au (Kagiso Mangadi), jeffrey.sheen@mq.edu.au (Jeffrey Sheen)

September 12, 2016
Mendoza 1995; Kose and Riezman 2001; Broda, 2004; Cashin et al, 2004 and Andrews and Rees 2009). Such variability not only causes business cycle uncertainties, but can also have important implications for economic performance and growth (Loayza and Raddatz, 2007). The identification of the context of these terms of trade shocks and hence their effects on macroeconomic variability is necessary to inform the appropriate policy response. Since these shocks can have different macroeconomic implications, the necessary policy responses are also bound to differ.

The global context in which an international relative price shock occurs must be distinguished. It has been argued in the literature that the response of macroeconomic variables to external shocks will largely depend on the characteristics of the underlying shock. For example, Melolimna (2012), Peersman and Van Robays (2009) and Kilian (2009) showed that the consequences of oil shocks on the US and Euro economies were dependent on the features of the shocks. Kilian (2009) argued that there is a fundamental flaw in an approach that analyzes the response of macroeconomic variables to variations in the price of oil alone, while holding all other external variables constant. The same argument can be extended to the analysis of terms of trade shocks. It would be incorrect to analyze the consequences of terms of trade shocks on an economy by allowing only the terms of trade to change while holding all other variables constant. This is because, though the terms of trade may be exogenous to a small domestic economy, it is endogenous in the world economy. Failure to recognise this endogeneity between world variables and the terms of trade can lead to confusion, false conclusions and inappropriate policy responses. Export and import prices are typically influenced by different external shocks, each of which may affect the domestic economy differently depending on what happens to world demand (Karagedikli and Price, 2012). Therefore, to be able to understand the effect of terms of trade shocks on the domestic economy, it is crucial to determine the external drivers of the actual export and import price shocks.

The effects of terms of trade shocks tend to be more pronounced in developing countries than in the developed world. This is because most developing countries depend heavily on commodity exports. The structure of their economies is such that exports tend to be concentrated in one or just a few primary commodities and account for a sizeable proportion of GDP and government revenues (Kose and Riezman, 2001 and Hove, 2015) while imports typically comprise mainly intermediate inputs, food items, oil and manufactures. In addition, developing countries have little influence over the prices of their exports, which are also usually characterized by high volatility. In this way, developing countries are highly vulnerable to terms of trade shocks. Because of this vulnerability, the appropriate policy response will likely depend on the global context of the identified shock. While there is an extensive literature on the effects of terms of trade shocks on
African economies (for example see Kose and Riezman, 2001, Cashin et al, 2004, Hove et al, 2015 and Cashin and Pattillo, 2006), none of the literature on developing economies, to our knowledge, has disentangled the global context of terms of trade shocks. Thus this paper considers a significant problem faced by most developing countries, which has not yet been properly addressed.

We estimate a sign restricted structural vector autoregression (SVAR) model with a penalty function to identify the underlying determinants of a set of likely terms of trade shocks that have impacted Botswana in the last fifty years. Botswana is chosen because it is a quintessential small commodity-dependent developing country that has a history of sound macroeconomic policies and well-managed resource revenues while being vulnerable to terms of trade shocks. This makes it a good benchmark case for many other developing countries in understanding the implications of external shocks, because we can investigate the effects of external shocks without being concerned about the distortions created by the pitfalls associated with a large natural resource endowment leading to huge infusions of foreign exchange into the domestic economy. We use annual data for the period 1960 to 2012, and investigate the effects of the likely set of external shocks on the country’s key macroeconomic variables.

Four generalized external shocks are identified from the data using sign restrictions on impulse responses. The first is a positive global demand shock that is assumed to raise both export and import prices as well as global output. The second is a positive globalizing shock representing the experience of emerging economies into the global economy—especially China—that is assumed to raise export prices, reduce import prices, and improve global GDP. The third is a positive sector-specific shock, representing a booming commodity sector that could give rise to the ‘Dutch disease’. In this case, the export price alone is assumed to surge, and is not associated with a boom in the global economy. Finally, the fourth shock allows for a negative global supply shock, such as in energy markets, which is assumed to reduce import prices and is accompanied by a decline in global output.

The first three shocks identified in this study are in line with the work of Jääskelä and Smith (2013) and Karagedikli and Price (2012), who identified similar shocks for Australia and New Zealand respectively. Our study introduces a fourth global supply-side shock to the model, which was not included in the aforementioned studies. This shock likely represents what essentially happened in the immediate aftermath of the financial crisis of 2008. In addition to this, our work focuses on a developing economy with unique features such as Botswana, while they focused on developed economies. Since the structure of the Botswana economy is significantly different from that of the Australian and New Zealand
economies, the results of the analysis are better suited for informing appropriate policy in commodity exporting developing countries. Another point of difference is that our analysis is extended to include a penalty function in the identification process. This is a vital difference since it has been shown that the alternative use of the median response from multiple models is likely to be flawed (for example, see Uhlig (2005)).

We find that our results support the argument that the direction and magnitude of the response of macroeconomic variables to external shocks largely depend on the characteristics of the underlying shock. The identified world demand shock is found to be expansionary and inflationary, while the globalization shock is expansionary but drives inflation down as a result of falling import prices. A positive commodity market specific shock has opposite effects to the globalization shock. Unlike the globalization shock, the positive specific commodity market shock marginally dampens real GDP growth, and is instead inflationary due to rising import prices. The real effective exchange rate strengthens temporarily, causing other sectors to decline and counteracting the output effect of the booming sector. This is weakly consistent with a Dutch disease effect. Lastly, an identified negative global supply shock is found to suppress both output growth and inflation. All four shocks are actually ‘positive’ terms of trade shocks that lead to a decline in the market (lending) interest rate, which may be indicative of a declining credit risk premium. The appropriate monetary policy responses qualitatively differ for the first shock, and will quantitatively differ for all four shocks.

The remainder of this paper is structured as follows. Section 2 is a review of both the empirical and theoretical literature on the topic, with particular emphasis placed on existing literature pertaining to Africa and the developing world, as well as on the identification of external shocks. Section 3 provides a discussion of the methodology, including an outline of the SVAR model with sign restrictions adopted for the study, while sections 4 and 5 discuss the results and provide concluding remarks.

2. Review of the Literature on Terms of Trade Shocks

Shocks to the terms of trade and their effects on macroeconomic variables have been studied at length and using different methodologies. This section discusses some of the literature on terms of trade shocks, as well as on the different techniques of disentangling these shocks, which is a crucial part of our study.
Developing economies, are characterized by a high level of volatility that tends to negatively impact economic performance and growth. It is therefore important to investigate the sources of this high volatility to ensure policies can be designed to maximise their growth performance. A large portion of variations in developing country macroeconomic fundamentals such as domestic output and exchange rates is attributed to terms of trade fluctuations (see Broda and Tille, 2003; Kose, 2002; Kose and Riezman, 2001). In addition to this, understanding the patterns of persistence of external shocks is crucial for formulating appropriate policy responses.\(^1\)

Past empirical work on the impact of various shocks to developed countries assert the importance of understanding the sources of the shocks in order to fully ascertain their effect on macroeconomic variables. The shocks are disentangled and identified using different identification schemes, each with its own advantages and disadvantages. One popular technique in this area is the SVAR method, which has been utilized widely in the literature to identify different types of shocks. Killian (2009) estimates an SVAR model to decompose oil price shocks into an aggregate demand shock, a precautionary demand shock and an oil supply shock. Similarly, Peersman and Van Robays (2009) use a sign restrictions approach to examine the different types of oil shocks affecting the economy of the Euro area, distinguishing between three types of oil shocks. In related work, Melolinna (2012) uses a penalty function method to identify oil shocks and other macroeconomic shocks for the US economy. Dungey and Fry (2009) propose a method for decomposing shocks that involved combining three different identification techniques, namely, the traditional short run restrictions, the sign restrictions methodology and using cointegrating relationships to identify monetary policy shocks, fiscal policy shocks and other economic shocks.

As mentioned above, Karagedikli and Price (2012) identify how the terms of trade propagate through the New Zealand economy using the sign restrictions methodology. This study closely followed similar work by Jääskelä and Smith (2013) for the Australian economy. These papers applied a similar methodology by estimating sign restricted VARs with common variables, namely the growth of world GDP, import price inflation, export price inflation, the growth of domestic output, domestic CPI inflation, the interest rate and the exchange rate. The two studies differed in their measurement of variables and in the terms of trade shocks they sought to identify. Both studies identified a global demand shock. Karagedikli and Price (2012) also identified an import price shock, which they

---

\(^1\)Interestingly, while clearly bothersome, terms of trade shocks tend to be relatively short-lived for some developing countries (Cashin et al, 2004), and longer-lived for others.
defined as a shock that leads to an increase in import prices and a decrease in world output. They also identified an export price shock, which was restricted to have a negative effect of world GDP and import prices. In addition to the global demand shock, Jääskelä and Smith (2013) also identified a commodity market specific shock that was constrained to have a positive effect on export prices, a negative impact on world GDP and no effect on import prices. This study concluded that while a rising terms of trade tends to be expansionary, it is not always inflationary with the effect largely dependent on the nature of the shock as well as the response of policy. Even though the current study closely follows Karagedikli and Price (2012) and Jääskelä and Smith (2013) in some aspects, these studies estimated sign-restricted SVARs for developed economies, whose features and structures are fundamentally different from developing country economies. By focusing on a benchmark developing economy—Botswana, this study contributes to the literature on understanding the impact of external shocks that are relevant to most developing economies.

2.2. Policy Options for Dealing with Terms of Trade Shocks

There is much evidence showing that the response of economies to macroeconomic shocks is influenced by the policy framework in place (for example, see Aizenman and Riera-Crichton, 2008, Aizenman et al., 2012). The Friedman hypothesis recommends a flexible exchange rate as a buffer against real shocks. The argument is that, in the presence of price stickiness, the speed at which relative prices adjust is mainly determined by the exchange rate regime. A flexible exchange rate is better since it allows for a more rapid adjustment of relative prices than a fixed exchange rate. The Friedman hypothesis has since been examined and supported (see Broda, 2004; Chia and Alba, 2006; Broda and Tille, 2003), leading to the conclusion that flexible exchange rates are better suited for insulating the economy against terms of trade shocks. The strength of this support is likely to depend on the prevalent sources of the terms of trade shocks.

The effectiveness of macroeconomic policies other than exchange rate policy has also been evaluated. For instance, Andrews and Rees (2009) found that along with a flexible exchange rate, well developed financial markets and a monetary policy that focuses on low inflation are also important for neutralizing the volatile effects of the terms of trade on an economy. Hove et al (2015) assert that CPI inflation targeting, when compared with non-traded inflation targeting and exchange rate targeting, is a better policy option for economies that are more vulnerable to commodity terms of trade shocks—this policy response can also reduce macroeconomic fluctuations and welfare losses. Once again, such conclusions should depend on the identified source of the external shocks, and we discuss below the policy implications for each of the identified terms of trade shocks to
Botswana.

Two main conclusions emerge from this brief literature review. The first is that it is crucial to identify which external shocks to the terms of trade matter for developing economies, and the appropriate policy responses to each. The other is that the SVAR methodology is an important tool for disentangling the shocks. However, the studies discussed above have not applied the sign restrictions methodology to understanding shocks to the terms of trade in a developing country context.

3. Methodology

VAR models are often used for investigating interdependencies between variables. In such models, each variable is expressed as a function of its own lags as well as the lags of other variables in the system. The VAR model yields impulse response functions, variance error decompositions and historical decompositions which contain important information for informing policy. However, in order to give these meaningful economic interpretations, a structural vector autoregression (SVAR) model has to be estimated. The structural error terms represent fundamental economic shocks, and it is through these that meaningful macroeconomic analysis can be carried out.

3.1. Identifying Structural Shocks

Recall that the usefulness of SVAR models mainly depends on the identification of structural errors and that restrictions have to be imposed in order to identify these shocks. These restrictions can either be parametric and/or sign restrictions, with different conclusions drawn depending on the type of restrictions imposed.

Parametric restrictions involve constraining the parameters of the model. These solve the identification problem “by reducing the number of parameters to be estimated so that suitable instruments are made available for estimation” (Fry and Pagan, 2011).

There are different types of parametric restrictions. These include short run and long run restrictions. Short run restrictions are usually zero contemporaneous restrictions imposed on the short run parameters of the model. The Cholesky decomposition is a popular example of such restrictions. This technique identifies structural shocks by ordering the variables in the system such that the most exogenous variable appears first. They are short run restrictions because the response of variables is constrained in the period immediately following the shock.
Long run restrictions involve constraining the impulse responses in the long run to have values that are motivated by economic theory. Imposing long run restrictions recognizes that some shocks may have a permanent effect on the variables. Here, “the cumulative response of the variable over the entire period of analysis is zero.”

The last class of parametric restrictions involve using a combination of short run and long run restrictions.

The identification methods outlined above however, are not without flaws. Zero short run restrictions have been criticized for being too stringent as well as for the fact that they are typically not based on economic theory. Even though long run restrictions are more consistent with economic theory, they have been found to have considerable distortions due to small sample biases and measurement errors (Peersman, 2005).

The sign restrictions methodology overcomes some of the shortfalls of conventional identification techniques. This procedure requires no parametric constraints to be placed on the short run or the long run effects of a shock. Furthermore, the sign conditions are usually theoretically oriented in that they are based on models (such as DSGE). The sign restrictions approach involves “placing restrictions on the direction that variables will move over a given horizon, in response to different types of shocks”, (Jääskelä and Smith, 2013). This technique assumes that all shocks are uncorrelated. Here, restrictions are placed on the signs of the accumulated impulse responses. This identification procedure is especially important in situations where variables are simultaneously determined, thus making it difficult to justify any parametric restrictions (Fry and Pagan, 2011). A brief discussion of the procedure to generate candidate shocks can be found in Appendix A of this paper.

3.2. Model Specification

A sign restricted VAR is estimated using data for the Botswana economy. Botswana is a small open economy for which it is highly unlikely that domestic variables will have an impact on foreign variables. Therefore, a block recursive structure is imposed on the model, i.e. the model is partitioned into a domestic block of variables and a ‘rest of the world’ or foreign block. This allows for no feedback from variables in the domestic block to those in the world block. To achieve this, one has to ensure that there are no contemporaneous or lagged domestic variables appearing in the set of equations which describe the world variables.
The following model is estimated:

\[
\begin{bmatrix}
w_t \\
d_t
\end{bmatrix} = \alpha x_t + \sum_{i=1}^{p} A_i \begin{bmatrix}
w_{t-i} \\
d_{t-i}
\end{bmatrix} + B \begin{bmatrix}
\varepsilon_{w, t} \\
\varepsilon_{d, t}
\end{bmatrix}
\]

(1)

where \(w_t\) and \(d_t\) are vectors of foreign and domestic variables respectively, \(x_t\) is a vector of exogenous variables, \(B\) is the matrix of contemporaneous impact of the vectors of mutually uncorrelated foreign and domestic innovations \((\varepsilon_{w, t}^-\) and \(\varepsilon_{d, t}^-\)). The estimation precision of impulse responses is influenced by the accuracy of model parameter estimates, therefore it is crucial to employ appropriate procedures to determine the optimal VAR order. We therefore utilize the Akaike Information Criterion (AIC) to achieve this. This test has been found to outperform the more popular Schwarz Information and Final Prediction Error criteria in selecting the optimal order for small samples. The AIC selected an optimal lag length of 1, which was verified using the Bayesian Information Criterion (BIC).

To impose the small open economy assumption, the \(A_i\) matrix is defined to be lower triangular, ensuring that lags of the domestic variables have no influence on the world block.

The variables which appear in the foreign block are the growth of world output \((\Delta y^w_t)\); export price inflation \((\pi^x_t)\) and import price inflation \((\pi^m_t)\).

\[
w_t = (\Delta y^w_t, \pi^x_t, \pi^m_t)'
\]

(2)

The domestic block contains key variables that describe conditions in the Botswana economy—these are domestic output growth \((\Delta y^d_t)\), CPI inflation \((\pi^d_t)\), the short term lending interest rate \((i^d_t)\) and the change in the real effective exchange rate \((\Delta q_t)\).

\[
d_t = (\Delta y^d_t, \pi^d_t, i^d_t, \Delta q_t)'
\]

(3)

3.3. Identification

The sign restrictions methodology is used to identify the shocks of interest. This is in line with past studies where sign restrictions were used to identify monetary policy shocks, fiscal policy shocks, technology shocks, oil shocks and so on (see Uhlig, 2005; Peersman and Van Robays, 2009; Liu, 2008; Dungey and Fry, 2009 and Karagedikli and Price, 2012).

Table 1 below shows the restrictions imposed on the world variables in order to identify the shocks of interest. A positive sign (+) means that the impulse response of the variable
is constrained to be positive, while a negative sign (-) implies that the impulse response of the variable is restricted to be negative. A ‘u’ means that no restrictions are imposed on the variable in question.

Table 1: VAR Sign Restrictions

<table>
<thead>
<tr>
<th>Global Demand Shock</th>
<th>Export Prices</th>
<th>Import Prices</th>
<th>World GDP</th>
<th>Domestic Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>+</td>
<td>+</td>
<td>$u$</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Globalization Shock</th>
<th>Export Prices</th>
<th>Import Prices</th>
<th>World GDP</th>
<th>Domestic Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>-</td>
<td>+</td>
<td>$u$</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Commodity Market Specific Shock</th>
<th>Export Prices</th>
<th>Import Prices</th>
<th>World GDP</th>
<th>Domestic Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>$u$</td>
<td>-</td>
<td>$u$</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Global Supply Shock</th>
<th>Export Prices</th>
<th>Import Prices</th>
<th>World GDP</th>
<th>Domestic Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>$u$</td>
<td>-</td>
<td>-</td>
<td>$u$</td>
<td></td>
</tr>
</tbody>
</table>

Four types of terms of trade shocks are identified by restricting the impulse responses of the variables in the foreign block. Since the interest is on the response of domestic variables, these are left unrestricted.

A global demand shock is essentially a shock to incomes. A positive global demand shock is one that stimulates overall global economic activity and increases the prices of all products i.e. both import and export products. The global demand shock is identified by restricting the responses of world output, export prices and import prices to be positive. This is because a global economic boom is expected to increase world GDP as well as the prices of all products, whether exported or imported.

Recall that a positive globalization shock is one that captures the increasing participation and importance of emerging economies such as China and India in world markets. It should increase export prices due to the increase in global demand for raw materials, and at the same time import prices should fall as a result of the decline in the price of manufactured goods coming out of these emerging economies. This shock is thus one that is restricted to an increase in global economic activity and export prices, but a reduction in import prices.

Like Jääskelä and Smith (2013), we define a positive commodity-market specific shock as a shock that accounts for increases in export prices not caused by a rise in global economic activity—to be sure, a fall is the restriction applied. This shock is therefore identified by restricting the responses of export prices and world output to be positive and negative respectively, while the response of import prices is left unconstrained. This identification allows for a test of the Dutch disease phenomenon, whereby a booming export sector crowds out other sectors.
The final positive terms of trade shock occurs through a fall in import prices accompanied by a decline in global activity. This is essentially a global supply-side shock, which can be thought of as a fall in price of energy price inputs. This is a contemporary shock driven by global excess supply for oil, which is influenced by the global business cycle. Introducing this shock is justified in that falls in oil prices since the financial crisis of 2008 were driven by global excess supply in oil markets. This terms of trade shock is identified by restricting the responses of import prices and world GDP to both be negative.

Based on table 1 above and the discussion in the preceding section, the following sign restricted model is estimated:

\[
\begin{bmatrix}
\epsilon_{t}^{\pi x} \\
\epsilon_{t}^{\pi m} \\
\epsilon_{t}^{yw} \\
\epsilon_{t}^{yd} \\
\epsilon_{t}^{\Delta q} \\
\epsilon_{t}^{i}
\end{bmatrix} = \begin{bmatrix}
+ & + & + & u & 0 & 0 & 0 \\
+ & - & u & - & 0 & 0 & 0 \\
+ & + & - & - & 0 & 0 & 0 \\
u & u & u & u & u & u & u \\
u & u & u & u & u & u & u \\
u & u & u & u & u & u & u
\end{bmatrix} \times \begin{bmatrix}
\epsilon^{\text{demand}} \\
\epsilon^{\text{global}} \\
\epsilon^{\text{comm.mkt}} \\
\epsilon^{\text{supply}} \\
\epsilon^{\pi} \\
\epsilon^{q} \\
\epsilon^{i}
\end{bmatrix}
\]

A positive sign (+) means that the impulse response of the variable is constrained to be positive, a negative sign (-) is the reverse, while a ‘u’ means that no restrictions are imposed on the variable in question.

Equation 4 summarizes the sign restrictions discussed in the preceding section. For instance, the fourth column of the impact matrix in equation (4) above shows that the global supply shock is identified by constraining the responses of import prices and global output to be negative, while leaving export prices unrestricted. In the same way, the upper left positive sign (+) shows that in order to identify a positive global demand shock, the response of export price inflation is constrained to be positive. The 3×4 upper left block represents the four external shocks of interest. Since we are not identifying any domestic shocks, the last three columns of the impact matrix contain a series of zeros and ‘u’s. The 3×3 upper right block illustrates the fact that shocks to domestic variables cannot influence any of the world variables.

3.4. Sign Restrictions with a Penalty Function Approach

Once the restrictions have been imposed, the model is estimated and simulated. There will be many VAR representations which agree with the postulated signs—so we can consider all the impulse response functions that are feasible and report the median response at each horizon for each variable (Liu, 2008). The problem with this however is that the
orthogonality condition may be violated since the median response is calculated with impulse responses from multiple models.

It is for this reason that sign restrictions have been criticized. They generate impulse responses from multiple models rather than from a single model, which means that there can be many impulses responses that are consistent with the sign constraints. This problem is exacerbated by the fact that many of the uses of the information, such as the construction of variance decompositions, require that impulse responses be uncorrelated. The pure sign restrictions method thus fails to address the multiple models problem, which can result in excess uncertainty about the model’s estimates and consequently may lead to incorrect policy inference (Fry and Pagan, 2007 and Liu and Theodoridis, 2012).

One way of dealing with the problem discussed above is to complement the sign restrictions method with the penalty function approach. This approach has been used in the literature to find a unique solution from the set of impulse responses that produce the correct signs (see Uhlig, 2005; Mountford and Uhlig, 2009 and Melollina, 2012). The penalty function method produces a unique set of structural innovations by minimizing some criterion function. The shocks of interest are identified by finding the impulse response which comes as close as possible to satisfying the sign restrictions. This is achieved by minimizing a penalty for the impulse responses that violate the sign restrictions, and rewarding responses that satisfy the constraints. This helps to exactly identify the best impulse response out of all those that satisfy the sign conditions, thus reducing the uncertainty of the identification procedure (Liu and Theodoridis, 2012). Imposing a penalty function thus helps us to exactly identify the best impulse response out of all those that satisfy the sign conditions.

From Uhlig (2005), a penalty function can be defined as follows:

\[
    f(w) = \begin{cases} 
    w & \text{if } w \leq 0 \\
    100 \times w & \text{if } w \geq 0 
    \end{cases}
\]

where \( w \) is the impulse response. The penalty function above is asymmetric in that when imposing sign restrictions, wrong responses are penalized more times than correct responses are rewarded.

Let \( r_{j,a}(k) \) be the impulse response of variable \( j \) at horizon \( k \) to an impulse vector \( a \), where \( k = 0, \ldots, K \). Here \( K \) is the last period at which impulse responses are restricted. \( \sigma_j \) is the standard deviation of variable \( j \), such that the impulse responses are re-scaled. This makes it possible to compare deviations across the various impulse responses. Let
$l_+ \text{ be the set of variables for which the impulse response is constrained to be positive, while } l_− \text{ represents the set of variables for shock identification for which the impulse responses are restricted to be negative (Mountford and Uhlig, 2009; Uhlig, 2005).}

The criterion function to be minimized can thus be given by:

$$
\Psi(a) = \sum_{j \in l_+} \sum_{k=0}^{K} f\left(-\frac{r_{j,a}(k)}{\sigma_j}\right) + \sum_{j \in l_-} \sum_{k=0}^{K} f\left(\frac{r_{j,a}(k)}{\sigma_j}\right)
$$

In our case, a global demand shock impulse vector is one that minimizes the criterion function $\Psi(a)$, which penalizes negative impulse responses of world output, export and import prices. The globalization shock minimizes $\Psi(a)$ which penalizes negative impulse responses of world output and export prices, and positive responses of import prices. The commodity market specific shock minimizes the criterion function which penalizes positive responses of world GDP and negative responses of export prices. Finally the global supply-side shock impulse vector is one that minimizes the criterion function which penalizes positive responses of import prices and world output.

4. Data

The data set for this analysis comprises 7 key variables relevant to Botswana—these are export price inflation, import price inflation, world output growth, domestic output growth, domestic inflation, the real effective exchange rate and the domestic interest rate. The choice of variables is guided by past empirical work in this area as well as their relevance to the Botswana economy. We use annual data for the period 1960 to 2012, the frequency is largely dictated by the availability of data.

Export and import price inflation are calculated using export and import price indices obtained from the Federal Reserve Economic Data (FRED), while all other data was obtained from the World Development Indicators of the World Bank. World output growth is calculated as the trade-weighted real GDP of Botswana’s major trading partner countries.

Domestic output is Botswana’s real GDP. The inflation rate is the headline inflation for Botswana, calculated from the consumer price index, while the interest rate used here is the prime lending rate, which is the lowest interest rate at which funds can be loaned out by commercial banks. It is thus a market-determined rate, which is largely influenced by credit risk premia as well as monetary policy decisions.

2Botswana’s major trading partners include China, the European Union, Israel, Norway, South Africa, the United Kingdom and the United States.
The real effective exchange rate (REER)\(^3\) is the trade weighted average of bilateral real exchange rates between Botswana and its major trading partners.

Preliminary analysis of the data series was carried out and Table B.1 in Appendix B shows the descriptive statistics of the data series.

5. Results

This section reports the result of the impulse response analysis undertaken in the study. Taking into consideration the shortcomings of the sign restrictions methodology already discussed in the preceding section, we report the results of the sign restrictions approach with a penalty function. We then explain briefly what would happen without the penalty function.

5.1. Impulse Response Analysis: Sign Restrictions with a Penalty Function Approach

The sign restrictions with a penalty function methodology imposes more restrictions, along with the sign constraints, to resolve the identification problem that arises due to weak information, and to narrow down the range of acceptable responses that carry the correct sign.\(^4\) In this way, the multiple models problem is avoided and a unique solution obtained.

Furthermore, since it has become common practice to impose contemporaneous restrictions as opposed to constraining longer lags, the sign restrictions are imposed for the first period only. The results of the experiments are discussed in the following subsection.

5.1.1. Responses to a Global Demand Shock

Figure 1 below shows the responses of the variables of interest following a positive global demand shock. To reiterate, this type of shock is one that stimulates overall global economic activity and increases prices of all commodities. A positive global demand shock is therefore identified by restricting the impulse responses of world output, import prices and export prices to be positive.

\[^3\text{REER}_t = \text{NEER}_t \times \frac{\text{CPI}_t}{\text{CPI}^*_t},\] where \(\text{REER}_t\) is the real effective exchange rate in time \(t\), \(\text{NEER}_t\) is the nominal effective exchange rate in time \(t\), calculated as the weighted average of Botswana’s nominal bilateral exchange rates. \(\text{CPI}_t\) and \(\text{CPI}^*_t\) are domestic and foreign consumer price indices respectively, where \(\text{CPI}^*_t\) is the weighted average of consumer price index of trading partner countries.

\[^4\text{The analysis is based on 2000 successful draws from the posterior of the VAR and from the unit sphere. These are used to show the median target, 16th and 84th percentiles of the impulse responses.}\]
As expected, the positive shock leads to a positive contemporaneous response of world output that declines over time but appears to remain above trend growth for up to 3 periods before normalizing. Both import and export prices increase on impact, but with the rise in export prices being slightly higher than that of import prices, thus signifying an improvement in the terms of trade.

With the exception of the interest rate, the responses of the rest of the domestic variables are insignificant, however their median responses will still be discussed. The global demand shock results in a positive response of domestic output growth. The positive effect declines over time but appears to be long-lasting, which may be attributed to the positive growth of world output and the eventual real depreciation of the exchange rate. The contemporaneous response of the inflation rate strengthens over time and remains positive, reinforced by the high prices of imports. Interestingly, the negative effect on the interest rate suggests the decline in credit risk premia in the booming economy outweighs any possible countercyclical response by the central bank.

In summary, a positive global demand shock leads to an improvement in the terms of trade. The shock also stimulates domestic output and induces upward inflationary pressures on the economy. With interest rates lower, the central bank should be in a position to tighten monetary policy to moderate inflation.
5.1.2. **Responses to a Globalization Shock**

A globalization shock essentially captures the impact of the increasing dominance of emerging economies such as China and India into world product markets. This type of shock is expected to increase export prices as the global demand for raw materials rises, at the same time import prices fall due to influx of cheap manufactures coming out of these economies. A positive globalization shock is thus identified by restricting the responses of world GDP and exports prices to be positive, while the import prices are constrained to be negative.

The responses of the variables in the model to a globalization shock are shown in figure 2 below.

![Figure 2: Responses to a Positive Globalization Shock](image)

The black line represents the median impulse response function of a positive one standard deviation shock, the blue lines represent the 16th and 84th percentiles.

In keeping with *a priori* expectations, the shock contemporaneously increases both world output and export prices, while decreasing import prices, once again signalling an improvement in the terms of trade. The effect of the shock on export prices declines over time but remains positive indefinitely. The response of world output growth also declines and normalizes by the end of the third year.

Even though domestic real GDP is slightly negative on impact, the improvement in the terms of trade and the increase in output of trading partner countries stimulate output growth, which quickly becomes positive and remains above trend growth for 5 periods.
The contemporaneous response of inflation is negative due to falling prices of imports. The positive shock also leads to a slight depreciation of the exchange rate which lasts for less than half a year. Once again, the negative effect on the interest rate suggests that a credit risk premia effect outweighs any countercyclical monetary policy response by the central bank.

To summarize, a positive globalization shock is expansionary but not inflationary, in that not only does it stimulate the growth of domestic output over time, the fall in import prices exerts downward pressure on the inflation rate. With inflation abating more than the nominal interest rate, the real rate of interest will be higher, and the central bank may choose to lower the interest rate further. However it should take into account the booming GDP, and be aware that this positive terms of trade shock will correct itself over time.

5.1.3. Responses to a Commodity Market Specific Shock

A positive commodity market specific shock relevant to Botswana is one that accounts for an increase in export prices not caused by a rise in global economic activity. It is therefore identified by restricting the impulse responses of world output growth and export prices to be negative and positive respectively. Figure 3 below shows the response of both foreign and domestic variables to a positive commodity market specific shock.

![Figure 3: Responses to a Positive Commodity Market Specific Shock](image)

The black line represents the median impulse response function of a positive one standard deviation shock, the blue lines represent the 16th and 84th percentiles.

The contemporaneous responses of world output and export prices are as expected. In
identifying this shock, the response of import prices was left unrestricted, so the response reported here is the unrestricted response. From figure 3, the positive shock leads to a contemporaneous increase in import prices, this is in line with the result Jääskelä and Smith (2013) obtained for Australia. While both import and export prices increase, the increase in prices of exports is slightly higher, therefore this particular shock results in a small improvement of the terms of trade.

The responses of the domestic variables are relatively insignificant, except for the interest rate, however their median patterns will still be discussed.

The growth of domestic output is negative on impact. This may be largely explained by the negative response of world GDP growth to the shock. The response of inflation is a little sluggish on impact, but quickly becomes positive within a year where it stays for up to 5 periods. The central bank responds to falling output levels by adopting an easy monetary policy stance indefinitely. The exchange rate appreciates briefly on impact, however a combination of high import prices and low interest rates contribute to a real depreciation of the exchange rate within a few months of the shock. As explained earlier, this result may be interpreted as (weak) evidence of a Dutch disease effect—a booming sector leading to a terms of trade increase strengthens the real exchange rate temporarily, and compromises the competitiveness of other sectors. Overall GDP growth may thus decline in the short term.

Overall, the commodity market specific shock may dampen the growth of output and initially appreciate the real exchange rate. The central bank may respond by lowering the interest rate further, which will moderate the real appreciation and ease the short term Dutch disease.

5.1.4. **Responses to a Global Supply Shock**

A negative global supply shock is one associated with a fall in import prices and a slowdown of global economic activity. This shock is therefore identified by restricting the responses of import prices and world output growth to be negative.
The negative global supply shock in Figure 4 leads to a negative response of prices of all commodities (and particularly energy prices) and world GDP growth. Consequently, domestic output and inflation also respond negatively on impact, but with output growth recovering over time while the response of inflation is long lasting. The response of the nominal interest rate, while initially sluggish on impact, becomes strong and negative, as the monetary authorities respond to stimulate output growth and to reduce the risk of deflation. Falling export prices, coupled with the low interest rate lead to a real appreciation of the exchange rate which lasts for up to 3 periods.

In summary, a negative global supply side shock suppresses both GDP growth and inflation, and raises the real interest rate. This suggests the central bank ought to undertake a significant monetary expansion to stimulate output growth and guard against possible deflation.

5.2. Impulse Response Analysis: Comparison of Results with a Pure Sign Restrictions Approach

The model is run again using Uhlig (2005)’s pure sign restrictions approach (i.e. without the penalty function) and the results obtained are largely insignificant, with the exception of the responses of the variables in the foreign block for which restrictions are imposed.
This may be explained by the multiple shocks and multiple models problems, where other shocks can be identified with the same set of restrictions and assumptions imposed, and also because there are many impulse responses which agree with the set restrictions, obtained from many models. It is for this reason that the analysis is paired with a penalty function, which successfully reduces the responses obtained by focusing on a single model that is closest to the median response in each period.

However, even though the responses are insignificant, it is worth noting that for the most part, they appear to follow similar patterns as the responses under the penalty function approach. These responses can be viewed in Appendix C.

6. Conclusions

This study sought to identify the underlying external determinants of terms of trade shocks within a developing country context, as well as to determine the effects of these shocks on developing country macroeconomic variables.

Our main finding reinforces the empirical argument that the response of macroeconomic variables to external shocks, is largely dictated by the underlying characteristics of the shock. Therefore, the monetary policy implications of the study findings will also depend on the nature of the shock.

In the case of a positive global demand shock, the central bank has room to raise interest rates in order to curb rising inflationary pressures. This can be achieved without counteracting the full effect of the positive shock on real GDP. This is because the rising global output growth, together with a real depreciation of the exchange rate and the improvement in the terms of trade may still act to sufficiently stimulate domestic GDP growth.

The central bank’s policy option in response to the effects of the globalization shock is to decrease the nominal interest rate further. This would encourage investment spending, increasing domestic output growth even more. The low interest rate, along with high foreign output and the exchange rate depreciation further amplify the positive effect of the globalization shock on real output growth.

The commodity market specific shock suppresses domestic output growth due to a (weak) form of the Dutch disease. While Dutch disease effects are typically more complex to address, the central bank could lower interest rates, simultaneously addressing the exchange rate misalignment and stimulating overall domestic output growth.
In dealing with the negative effects of a global supply shock, the central bank can decrease interest rates even further. This has the potential to improve investment spending, increase net exports and thus domestic output growth.

These conclusions are based on an SVAR model with sign restrictions to identify the key terms of trade shocks. As a next step in this research line, it would be informative to develop and estimate a structural DSGE model for a better and deeper understanding of the effects of these shocks on a developing country’s economy.

7. References


Appendix A. Sign Restrictions Approach to Shock Identification

This appendix indicates how to generate candidate shocks using the sign restrictions approach (see Fry and Pagan (2011)).

Consider the following VAR(1) model:

\[ y_t = A_1 y_{t-1} + e_t \]  \hspace{1cm} (A.1)

where \( y_t \) is an \( nx1 \) vector of endogenous variables, \( A_1 \) is a matrix of coefficients and \( e_t \) are reduced form errors. The reduced form errors can be correlated, and so these residuals therefore have limited economic meaning.

The SVAR representation of equation (1) will be:

\[ B_0 y_t = B_1 y_{t-1} + \varepsilon_t \]  \hspace{1cm} (A.2)

The reduced form VAR and the SVAR can be distinguished by the following features: the matrix, \( B_0 \), which captures the contemporaneous relations between the variables; and the matrix \( B_1 \), which is an \( nxn \) matrix of coefficients capturing the model dynamics. \( B_1 \) is defined so that \( A_1 = B_0^{-1} \times B_1 \); finally, the reduced form errors are replaced by \( \varepsilon_t \), which is an \( nx1 \) vector of structural shocks with zero mean and variance-covariance matrix \( V \).

The fact that the covariances of \( \varepsilon_t \) are zero implies that each shock is independent and hence \( \varepsilon_t \) has a structural interpretation. These shocks are unobservable.\(^5\)

Rewriting equation (1) as \((I - AL)y_t = e_t\), where \( L \) is the lag operator leads to the moving average (MA) representation of the VAR model:

\[ y_t = D_0 e_t + D_1 e_{t-1} + D_2 e_{t-2} + \ldots = D(L)e_t \]  \hspace{1cm} (A.3)

where \( D(L) = I_n + D_1 L + D_2 L^2 + \ldots \)

\( D_j \) is the impulse response of \( y_{t+j} \) to a one unit change in \( e_t \).

\(^5\)This implies that \( \varepsilon_t = B_0 e_t \). If \( P = B_0^{-1} \) so that, \( e_t = P \varepsilon_t \), then \( V = PE(\varepsilon \varepsilon' )P' = P \Sigma P' \). This is the identification problem for the SVAR methodology.
The corresponding MA representation of the corresponding SVAR is therefore:

$$y_t = C_0 \varepsilon_t + C_1 \varepsilon_{t-1} + C_2 \varepsilon_{t-2} + ... = C(L)\varepsilon_t$$  \hspace{1cm} (A.4)$$

here, $C(L) = C_0 + C_1 L + C_2 L^2 + ...$ with $C_j$ being the $j^{th}$ period impulse response of $y_{t+j}$ to a one unit change in $\varepsilon_t$.

The estimated shocks from the VAR model are combined to produce orthogonal candidate structural shocks. We only retain combinations of the estimated shocks that yield impulse response functions for the corresponding structural innovations that carry the correct signs, otherwise they are discarded.

Suppose that after estimation we have:

$$\hat{\varepsilon}_t = \hat{B}_0^{-1}\hat{\varepsilon}$$  \hspace{1cm} (A.5)$$

The next step is to re-scale the structural shocks, by dividing each by its standard deviation. This ensures that they have unit variance.

Suppose that $\hat{S}$ is the matrix of estimated standard deviations of $\hat{\varepsilon}_t$ on the diagonal and zeros elsewhere. Then,

$$\hat{\varepsilon}_t = \hat{B}_0^{-1}\hat{S}\hat{S}^{-1}\hat{\varepsilon}_t$$  \hspace{1cm} (A.6)$$

If we let $\hat{S}^{-1}\hat{\varepsilon}_t = \hat{\eta}_t$ and $\hat{B}_0^{-1}\hat{S} = \hat{T}$, then $\hat{\varepsilon}_t = \hat{T}\hat{\eta}_t$.

Here, $\hat{\eta}_t$ represents the new structural shocks with unit variances. Since these new standardized shocks are simply the new re-scaled version of $\hat{\varepsilon}_t$, they have the same characteristics. These shocks are also uncorrelated.

Next, an orthogonal square matrix, $Q$ is introduced such that $Q'Q = QQ' = I_n$. The $Q$ matrix is used to form combinations of $\hat{\eta}_t$ so that: $\hat{\eta}_t^* = Q\hat{\eta}_t$. These are the candidate structural shocks.

If this is the case, it means that:

$$\hat{\varepsilon}_t = \hat{T}Q'\hat{Q}\hat{\eta}_t = \hat{T}^*\hat{\eta}_t^*$$  \hspace{1cm} (A.7)$$

The new set of structural shocks, $\hat{\eta}_t^*$ have the same covariance matrix as the standardized structural shocks, $\hat{\eta}_t$ however they will have a different impact $\hat{T}^*$ on $\varepsilon_t$ and hence on the variables $y_t$. In other words, the new shocks produce varying impulse responses, which is the basis for the sign restrictions methodology. In a nutshell, by restricting the signs of the impulse responses, we are selecting a matrix $Q$ so that the structural shocks are
Appendix B. Descriptive Statistics and Unit Root Tests

Table B.1 below shows the results of the descriptive statistics of the data series used.

Table B.1: Descriptive Statistics

<table>
<thead>
<tr>
<th>Series</th>
<th>Mean</th>
<th>SE</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Export Price Inflation</td>
<td>0.0461</td>
<td>0.1240</td>
<td>-0.1667</td>
<td>0.3846</td>
</tr>
<tr>
<td>Import Price Inflation</td>
<td>0.0457</td>
<td>0.1189</td>
<td>-0.2619</td>
<td>0.3871</td>
</tr>
<tr>
<td>World Output Growth</td>
<td>2.8019</td>
<td>1.9672</td>
<td>-3.1226</td>
<td>8.2848</td>
</tr>
<tr>
<td>Domestic Output Growth</td>
<td>0.0000</td>
<td>4.7327</td>
<td>-21.5888</td>
<td>12.6142</td>
</tr>
<tr>
<td>Domestic Inflation</td>
<td>10.1030</td>
<td>2.5315</td>
<td>6.5590</td>
<td>16.4280</td>
</tr>
<tr>
<td>Real Effective Exchange Rate</td>
<td>0.0811</td>
<td>0.2423</td>
<td>-0.7068</td>
<td>0.9440</td>
</tr>
<tr>
<td>Lending Interest rate</td>
<td>13.3718</td>
<td>3.3668</td>
<td>7.6667</td>
<td>24.2083</td>
</tr>
</tbody>
</table>

Table B.2 below shows the results of the Augmented Dickey-Fuller test for a unit root. The null hypothesis for the test is that the series contains a unit root. Since the results show that the null hypothesis is rejected for all the variables, we conclude that the variables are stationary in levels or do not contain a unit root.

Table B.2: Unit Root Tests

<table>
<thead>
<tr>
<th>Variable</th>
<th>Test Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Export Price Inflation</td>
<td>-4.172**</td>
</tr>
<tr>
<td>Import Price Inflation</td>
<td>-4.687**</td>
</tr>
<tr>
<td>World Output Growth</td>
<td>-5.012**</td>
</tr>
<tr>
<td>Domestic Output Growth</td>
<td>-3.115***</td>
</tr>
<tr>
<td>Domestic Inflation</td>
<td>-3.381***</td>
</tr>
<tr>
<td>Real Effective Exchange Rate</td>
<td>-7.328**</td>
</tr>
<tr>
<td>Lending Interest rate</td>
<td>-3.521***</td>
</tr>
</tbody>
</table>

Note: **,**,*** represent significance at 1 percent, 5 percent and 10 percent levels of significance.
Appendix C. Results of the Pure Sign Restrictions Approach

Appendix C.0.1. Responses to a Global Demand Shock

Figure B5 below shows the responses of the variables following a positive global demand shock. The same restrictions as before are applied to identify the shock.

The black line represents the median impulse response function of a positive one standard deviation shock, the blue lines represent the 16th and 84th percentiles.

Appendix C.0.2. Responses to a Globalization Shock

Figure B6 below shows the responses of the variables to a positive globalization shock.
Figure C.6: Responses to a Positive Globalization Shock—Pure Sign Restrictions

The black line represents the median impulse response function of a positive one standard deviation shock, the blue lines represent the 16th and 84th percentiles.

Appendix C.0.3. Responses to a Commodity-Market Specific Shock

Figure B7 below shows the response of the variables in the model to a positive commodity-market specific shock.
Figure C.7: Responses to a Positive Commodity-Market Specific Shock—Pure Sign Restrictions

The black line represents the median impulse response function of a positive one standard deviation shock, the blue lines represent the 16th and 84th percentiles.

Appendix C.0.4. Responses to a Global Supply Shock

Figure B8 below shows the responses to a negative oil price shock.

Figure C.8: Responses to a Negative Global Supply Shock—Pure Sign Restrictions

The black line represents the median impulse response function of a positive one standard deviation shock, the blue lines represent the 16th and 84th percentiles.