WP/18/134

IMF Working Paper

Short Term Inflation Determinants in Barbados

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INTERNATIONAL MONETARY FUND

 WP/18/134

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WHD

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June 2018

Abstract

Inflation in Barbados is mainly imported. But how are external shocks transmitted to the domestic economy? Shouldn't there be also a domestic component, albeit very small, given the presence of capital controls? We focus on short term dynamics and contribute to the existing literature in three ways: (i) we identify the process with which inflation expectations are likely to be formed in Barbados; (ii) we add forward looking inflation expectations as one of the main channels through which external monetary shocks are transmitted to the economy; and (iii) we measure the importance of domestic shocks. We find that due to the peg, forward-looking inflation expectations in the reserve currency country are an important component of the inflation expectation process in Barbados and that they are a key channel in the international monetary transmission mechanism. Domestic factors, mainly monetary shocks, also matter given the limited degree of monetary autonomy provided by capital controls.

JEL Classification Numbers: E31, E58, F30, F41.

Keywords: Barbados, inflation, monetary transmission, pegged exchange rate, capital controls.

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† This paper benefitted from comments received during a presentation to the WHD department. I am particularly grateful to Leo Bonato, Jack Chen, Manuk Ghazanchyan, Antonio Spilimbergo, and Bert van Selm for detailed comments on earlier drafts. The usual caveat applies: all remaining errors are mine only.

I. INTRODUCTION

1. Inflation in very small open economies with pegged exchange rate is mostly imported. Barbados is highly dependent on imported goods for production and consumption for which it is a price taker. In addition, it pegs its exchange rate to the US, its largest trading partner. Hence, we expect domestic inflation to follow US inflation in the long run, with possible only small idiosyncratic deviations (mainly thorough external shocks) from this steady state. In this set up, domestic shocks are deemed not to affect domestic inflation by the literature.

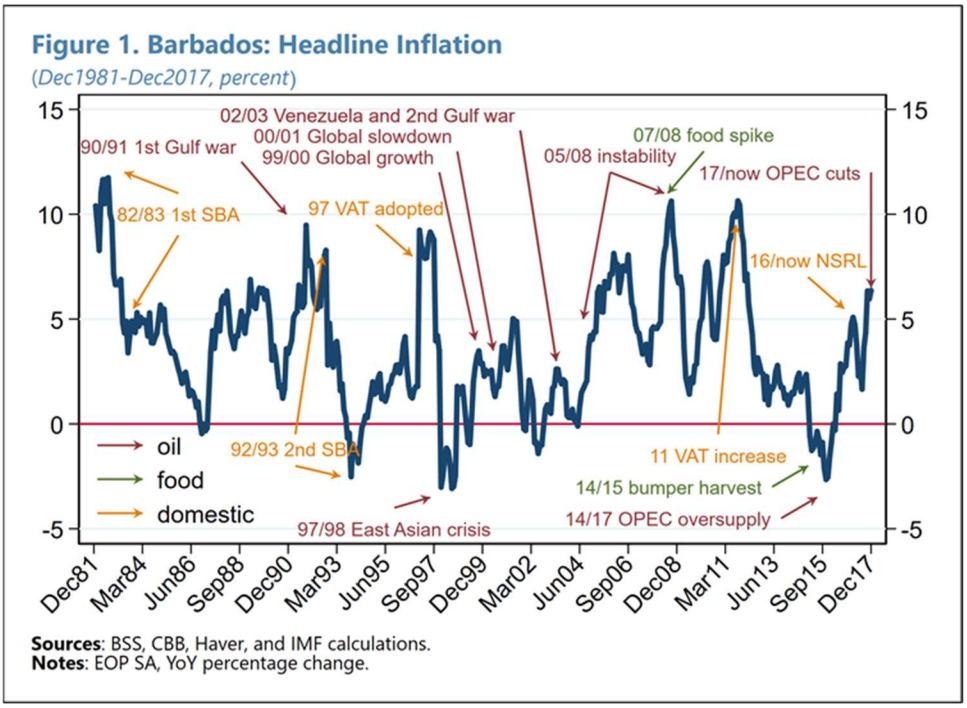
2. The contribution of this paper is to investigate the role of expectations and domestic factors for inflation dynamics in Barbados. In line with past literature we find external factors to dominate price dynamics in Barbados. We contribute to the existing literature in three ways: (i) we identify the mechanism with which inflation expectations are formed in Barbados; (ii) we add forward looking inflation expectations as one of the main channels through which external monetary shocks are transmitted to the economy; and (iii) we measure the importance of domestic shocks, especially monetary shocks. We do not know of existing literature that estimates the process with which inflation expectations are formed for the case of Barbados or that estimates the relative importance of domestic shocks.

3. The remainder of the paper is organized as follows: Section II reviews inflation dynamics in Barbados in light of known external and domestic shocks. Section III presents the analytical framework that allows us to disentangle external from domestic shocks, as well as defining the process with which inflation expectations are formed. Section IV presents the empirical strategy and results. Conclusions follow in section V.

II. RECENT TRENDS IN HEADLINE INFLATION

4. Inflation in Barbados is highly volatile mainly due to external but also domestic factors. Figure 1 reports inflation dynamics for the last 36 years in Barbados. Over the period, inflation has averaged around 3.6 percent and it has been highly volatile between 12 and -4 percent YoY. Inflation appears to follow a first order autocorrelation process but not to have either a deterministic or a stochastic trend.[1] The same picture reports known external and domestic shocks associated with changes in headline inflation.

[1] We formally test these hypotheses (not reported). The correlogram and partial correlogram (as well as the portmanteau (Q) statistics) clearly indicate the presence of an ARMA(1,1) process. The augmented Dickey-Fuller test confirms Downes *et al*. (2017) results that the CPI index is I(1) but headline inflation is I(0).



5. Oil prices are an important external determinant of headline inflation. The Barbados economy is highly susceptible to fluctuations in international energy as fuel imports alone represent 17 percent of total imports. Barbados no longer imports non-refined oil. Most refined oil is imported from Trinidad and Tobago but some is also imported from Suriname and Puerto Rico. Several major distinct oil related shocks can be identified (Hamilton 2011 and Downes *et al*., 2017).

- **The 1990-91 first Gulf war**. Iraq invaded Kuwait in August 1990 and the price of oil doubled in the following two months. The spike was short-lived as Saudi Arabia restored oil production by the end of the year.

- **The 1997-98 East Asian crisis**. In the summer of 1997, Thailand and South Korea experienced severe BoP crisis and international investors started doubting the East Asian Tiger miracle growth model plunging the region in recession. The oil price collapsed below US$12 per barrel by the end of 1998.

- **1999-01 resumed growth and US recession**. By the end of 1990, oil prices were back to the 1997 levels and the price of West Texas Intermediate increased by an additional 38 percent by November 2000. The oil price fell soon afterwards in the face of global slowdown and in March 2001, the US entered in recession.

- **2003 Venezuela unrest and second Gulf war**. Oil production in Venezuela dropped between the end of 2002 and the beginning of 2003 due to strikes. Iraqi production was disrupted during the second Gulf War. Oil prices and Barbados' inflation increased moderately during that period.

- **2005-08 geopolitical instability and speculative investment**. Over this period, unrest in the Middle East, Iraq, and Nigeria, declining production from Saudi Arabia, rapid global expansion, and speculative positions of hedge funds caused the oil price to increase from US$55 to US$142 per barrel.

- **2014-17 downturn**. The price of the West Texas Intermediate decreased from US$100 to US$30 between July 2014 and January 2016. During this period, declining oil prices have been attributed to the strong US$, OPEC oversupply, shale drilling, declining demand, and the Iran nuclear deal.

- **2017-now**. During the last two years, geopolitical unrest and higher global growth have pushed oil prices from as low as US$30 to US$70 per barrel.

6. Food prices are also an important external determinants of headline inflation. Barbados' second largest import item is food, representing 13 percent of total imports and therefore, its economy is highly exposed to fluctuations in international food prices. Again, few food price shocks can be identified:

- **2007-08 food price volatility**. International food prices drastically increased in 2007/08. The causes of such food price spike include supply side elements (poor harvests especially of wheat, lower grain stocks, and rise in oil prices), demand side elements (widespread inflation resulting from rapid growth in the world economy), policy elements (export bans and restrictions, restocking in tight markets and reduced import tariffs) and financial elements (depreciation of the US$). The spike was short-lived and commodity prices, including food, rapidly decreased starting in the summer of 2008.

- **2014-15 food price drop**. International food prices decreased by 14 percent between August 2014 and May 2015, dropping to a five-year low, according to the Word Bank. Good harvest and cheap oil contributed to abundant global supplies of food in 2014. This, together with prospects of a bumper crop for wheat, maize and rice in 2015, contributed to lower food prices.

7. More generally, inflation and exchange rate dynamics in trading partners are expected to passthrough to domestic prices through the NEER. Table 1 reports Barbados' largest import partners. The United states is the largest trading partner with a share of 40 percent of total imports. Because of this and the pegged exchange rate, it is safe to assume that Barbados and US inflations are closely related, at least in the steady state. Trinidad and Tobago is the second largest exporter to Barbados, mainly of refined oil and other fuels. The UK, Japan and Canada, as well as other smaller regional exporters have gradually lost their market shares in Barbados' imports at the advantage of some European countries and definitely China. Finally, import sources have become less concentrated as the share represented by the largest 11 exporters decreased from 80 to 70 percent in the last 25 years.

Table 1. Barbados: Largest Import Partners

(1990-2016, percent of total imports)

	1990	1995	2000	2005	2010	2016
USA	33.8	40.7	41.6	35.9	43.9	39.1
Trinidad	10.8	10.8	16.4	21.2	7.2	13.4
China				2.9	4.8	7.3
UK	11.1	9.8	8.1	5.4	5.4	4.8
Japan	5.3	6.7	5.2	7.6	3.6	2.7
Canada	5.7	5.0	4.1	3.4	4.4	2.3
Germany	2.1	2.3				2.0
Antigua	5.3					
France					2.1	
Jamaica	2.4	2.2				
Venezuela	4.0	4.0				
Total	**80.5**	**81.5**	**75.4**	**76.4**	**71.4**	**71.6**

Sources: Comtrade and IMF calculations.

8. Finally, domestic factors have also been important determinants of headline inflation. In 1982 and 1992, Barbados entered into two SBAs with the IMF and the fiscal adjustment that ensued caused inflation to decrease from 10 to 5 percent in the 12 months after September 1982 and from 8 to -0.5 percent in the 12 months after September 1992.[2] In 1997, the introduction of a 15 percent VAT generated a sharp increase in inflation. VAT rates were increased to 17.5 percent in 2011, again fueling inflation. In late 2016, the National Social Responsibility Levy (NSRL) was introduced with a 2 percent rate. This consumption tax aimed at rebalancing the economy and help address external imbalances caused by excessive and deteriorating structural fiscal deficits. The NSRL rate was increased in 2017 to 10 percent, further impacting inflation.

III. THE ANALYTICAL FRAMEWORK

9. The literature on external determinants of inflation is vast. Several papers have aimed at understanding the main drivers of consumer price inflation (see, for example, Galí and Gertler, 1999). Some studies have focused on external factors like food and oil prices (Blanchard and Galí, 2008 and Downes *et al*., 2017). Other explored the importance of exchange rate changes (Burstein and Gopinath, 2014). Other focused more explicitly on the impact of monetary policy on real aggregates in economies of imperfect competition and price rigidities (Galí and Monacelli, 2005). In general, the literature derives some modified versions of the Philips curve suited to explain the issue at hand, which it then proceeds to estimate.

[2] Both of these arrangements featured a strong fiscal adjustment to defend the exchange rate and contain inflation and compress domestic absorption. This in turn, would contribute to increasing the depleted foreign exchange reserves.

(continued…)

10. The New-Keynesian models seem particularly suited to study international transmission channels of monetary policy and to disentangle domestic from external factors, including expectations. The framework[3] complements the traditional neoclassical channels of investment (impacted by the direct real interest rate, user cost of capital and the closely related Tobin's q channel), consumption (impacted by the wealth and intertemporal substitution effects) and the trade channel (impacted by the real effective exchange rate). The New-Keynesian framework tries to overcome the limitations of the neoclassical framework[4] and puts more emphasis on inflation expectations (that in general amplify the effect of traditional channels) and on optimal monetary policy rules that trade-off stabilization of domestic factors (traditionally the output gap and inflation) and external factors (traditionally the terms of trade). For instance, Obstfeld and Rogoff (2000) claim how international trade costs and frictions play a central role in the international monetary transmission channels. Corsetti and Pesenti (2001) show how noncompetitive behavior of international trading firms cause negative feedback loops that offset the impact of expansionary policies through a deterioration of the terms of trade. In other words, the framework allows for the use of a richer set of assumptions (than the neoclassical framework) linking external shocks to domestic inflation and for potential endogeneity between domestic and external factors.

11. In the same spirit, we also use a modified Philips curve to separate domestic and external determinants of headline inflation. We use Galí and Monacelli (2005) small economy model and modify the price setting of firms to derive a modified Phillips curve that figures fluctuations in import prices (terms of trade) as an additional inflation driver. The sketched model in the next two sections enables us to compare the role of domestic and external factors in determining CPI inflation dynamics in the empirical section that follows.

A. Firms' price setting

12. Some firms are assumed to set new prices at any given time by discounting their future expected marginal costs above a constant mark-up:

$$\overline{p}_t = \mu + (1-\beta\theta)\sum_{k=0}^{\infty}(\beta\theta)^k E_t\{mc^n_{t+k}\} \quad (1)$$

Where $\overline{p}_t$ denotes the log of newly set domestic prices, μ is the log of the constant markup, β is the discount rate, $(1-\theta)$ is the random fraction of firms updating prices at time t, $E_t\{\cdot\}$

[3] Woodford (2003) and Galí (2008) are traditional references.

[4] For instance, (Obstfeld and Rogoff, 2000) the assumption that only the exchange rate affects the international trade channel is not supported by the empirical literature that finds a weak relationship with domestic inflation (the purchasing power parity puzzle) and other macroeconomic aggregates (the exchange rate disconnect puzzle)

(continued…)

is the expectation operator, and mc_t^n is log deviation of the nominal marginal cost from its steady state. Equation (1) can be re-written[5] as:

$$\overline{p}_t = p_{t-1} + \beta\theta E_t\{\overline{p}_{t+1} - p_t\} + \pi_t + \nu + (1-\beta\theta)mc_t \tag{2}$$

Where π_t is denotes domestic inflation, $\nu = (1-\beta\theta)\mu$, and $mc_t = mc_t^n - p_t$ is the log of the real marginal cost (deviation from the steady state).

13. The CPI index is a weighted average of changed and unchanged prices. Using a CES aggregator to weigh the two prices, the CPI index can be written as:

$$P_t = \left[\theta P_t^{1-\varepsilon} + (1-\theta)\overline{P}_t^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}} \tag{3}$$

Which simplifies in its log-linearized form to:

$$\begin{aligned} p_t &= \frac{1}{1-\varepsilon}\ln\left[\theta P_t^{1-\varepsilon} + (1-\theta)\overline{P}_t^{1-\varepsilon}\right] \\ &\simeq \frac{1}{1-\varepsilon}\left[\theta(1-\varepsilon)p_{t-1} + (1-\theta)(1-\varepsilon)\overline{p}_t\right] \\ &= \theta p_{t-1} + (1-\theta)\overline{p}_t \end{aligned} \tag{4}$$

Hence, inflation is simply the log differences in prices weighted by the share of firms that have changed prices. I.e.:

$$\pi_t = (1-\theta)(\overline{p}_t - p_{t-1}) \tag{5}$$

14. The New-Keynesian Phillips curve of these types of models is then a function of forward looking inflation expectations and firms' marginal costs. By substituting equation (5) into equation (2) and re-arranging:

$$\pi_t = \xi + \beta E_t\{\pi_{t+1}\} + \lambda mc_t \tag{6}$$

Where $\xi = \lambda\mu$ and $\lambda = \frac{(1-\theta)(1-\beta\theta)}{\theta}$.

15. Firms use a Cobb Douglas technology functions with domestic and imported inputs. Hence, their marginal costs are a weighted average of the domestic and imported marginal costs with weights being the shares of the domestic and imported inputs in the production function. If we assume that firms are price takers in the tradable market and noting that domestic marginal costs are proportional to the output gap (Galí and Monacelli, 2005), we can re-write equation (6) as:

[5] See appendix B of Galí and Monacelli (2005).

$$\pi_t = \xi + \beta E_t\{\pi_{t+1}\} + \kappa x_t + \lambda\alpha\pi_t^f \quad (7)$$

Where x_t is the output gap, α is the share of foreign inputs in the firms' production function and therefore, it measures the degree of openness of the economy, π_t^f is the component of imported inflation in domestic inflation. The last term essentially captures the impact of changes in the terms of trade on domestic inflation. When terms of trade improve ($\pi_t^f > 0$), consumers can buy more imports per unit of exports. This would stimulate expenditure switching to foreign goods and the higher demand for imports would generate upward pressure on domestic inflation.[6],[7] This pressure, is stronger the higher is the degree of openness of the economy.[8]

B. The monetary authority

16. The Barbadian dollar is pegged to the US dollar and the monetary authority can in principle only target foreign reserves. With a pegged exchange rate, a permanent increase in the money supply will be accompanied in the short run by higher output and lower interest rate to restore equilibrium in the goods and money markets. However, the lower domestic interest rate generates excess demand for FX assets and capital outflows. The monetary authority can sterilize this balance of payments effect until reserves run out. If not, capital outflows reverse the impact of the monetary impulse and the domestic interest rate increases until the FX market is again in equilibrium. The volume of base money remains unaffected but the increase in net domestic assets is accompanied by a decrease in net foreign assets. Hence, it is plausible to assume that with capital mobility, the CBB targets a level of reserves to avoid fears of devaluation that might generate speculative attacks on the currency.

17. Capital controls confer some degree of monetary independence to the CBB. Capital controls[9] greatly reduce the elasticity of net capital inflows to changes in the domestic interest rate. In this way, the monetary authority can affect output (and inflation) in the short term while maintaining temporary disequilibrium in the FX market. Incidentally, capital

[6] Alternatively, the relative increase in export prices could have the same impact on domestic cost-push inflation.

[7] Here we assume a linear relationship between terms of trade and domestic inflation. Hence, inflation increases, whenever terms of trade improve. For a model of nonlinear relationship, see Gruen and Dwyer (1996).

[8] The impact is also higher, the lower is the elasticicty of demand to import prices.

[9] These take the name of "exchange controls" in Barbados and are a mean to regulate the consumption of foreign reserves. The exchange control authority in Barbados is the Minister of Finance. the Minister of Finance delegates much of his authority to the CBB, which sees that the provisions of the Exchnage Control Act, CAP 71 for larger transactions are carried out. The CBB, in turn, delegates some of its authority to Authorised Dealers and Authorised Depositaries for smaller transactions.

(continued…)

controls reduce the need to sterilize the balance of payments effect on the monetary supply. Since capital controls do not fully insulate the effect on the asset market of a change in foreign reserves, eventually, domestic interest rate (and inflation) converge to the respective country risk adjusted rates in the US.

18. Hence, we can assume that the monetary authority minimizes in the short term a traditional loss function.

$$L = \alpha x_t^2 + \beta\left(\pi_t - \overline{\pi}\right)^2$$

Where short term deviations of the money base from a steady state trend consistent in the long run with the FX market equilibrium allow the monetary authority to minimize the output gap x_t. This, in turns, indirectly minimizes deviations from a target inflation.[10]

IV. EMPIRICAL STRATEGY AND RESULTS

19. We disentangle domestic and external determinants of inflation in Barbados using a variant of the Neo-Keynesian Phillips curve previously derived. We first estimate a variant of (7) using OLS. Our baseline equation is given by:

$$\pi_t = \alpha_1 + \underbrace{\left[\alpha_2\pi_{t-1} + \alpha_3\pi_{t-1}^{US,e}\right]}_{\text{inflation expectations}} + \underbrace{\left[\alpha_4 idef_t + \alpha_5 oil_t + \alpha_6\pi_t^{US}\right]}_{\text{external determinants}} + \underbrace{\left[\alpha_7 ogap_t + \alpha_8 mst_t\right]}_{\text{domestic determinants}} + u_t$$

Where:[11]

- **Inflation expectations** are formed on all available information at time t and are proxied[12] by a weighted average of backward and forward-looking expectations. Backward looking agents form expectations based on past inflation (π_{t-1}) while forward looking agents form expectations based on expected inflation in the US $(\pi_{t-1}^{US,e})$. Lagged inflation enters the equation because of the results reported in footnote 1. US inflation expectations enter the equation as, with a pegged exchange rate, Barbados inflation is anchored in the long term to the US inflation.[13] Given the presence (also) of lagged

[10] It is beyond of the scope of this paper to estimate the monetary rule of the CBB which may have changed over time. For instance, in recent times, the CBB has dramatically expanded base money with the obective of filling the financing gap and, by lowering interest rates through financial repression, reduce governments borrowing costs. What matters here is that capital controls restablish a link between base money, ouput, and inflation in the short term; link we try to measure in this paper.

[11] See Appendix A for a formal definition of the variables used in this paper.

[12] Barbados does not publish inflation expectations.

[13] This is the key point also made in Downes *et al*. (2017) who find a long term cointegrating relationship (in levels) between Barbados and US prices.

inflation, inflation expectations contain both external and domestic determinants. We expect inflation expectation terms to be positively related to inflation.

- **External factors**. With a pegged exchange rate and limited financial flows external shocks affect domestic inflation mainly through trade channels (changes in the terms of trade or NEER). Here we proxy changes in the terms of trade or NEER using annual changes of in the import deflator $(idef_t)$ and its key components: the annual change in oil prices (oil_t) and US inflation (π_t^{US}). We expect external determinants to be positively related to inflation.

- **Domestic factors**. We proxy domestic factors with the output-gap $(ogap_t)$ as suggested in (7) and by the monetary stance (mst_t) defined as deviation in the volume of base money from the steady state trend consistent with the equilibrium in the FX market. We expect domestic determinants to be positively related to inflation.

This empirical setup is appealing because it is consistent with a large class of linear rational expectation structural models and can accommodate various assumptions about the information set available to the agents; thing we obviously exploit here.

20. Results of our baseline equation are reported in the first column of Table 2. A 1 percent increase in lagged inflation generates a 0.87 pp increase in current inflation. Oil prices have a very small (0.004 pp) but highly significant impact on current inflation. Import prices have a relatively larger (0.044 pp) and highly significant impact on current inflation. A 1 percent increase in the output gap generates a 0.048 pp increase in current inflation. All other variables have an impact that is not statistically different from zero. These results produce three key takeaways: (i) past inflation is the main determinant of current inflation (a recurring empirical fact in the literature); (ii) external factors have low explanatory power; and (iii) domestic factors are irrelevant. We will return on these points in the remainder of the paper as, it turns out, this type of inference is partially incorrect.

Table 2. Barbados: Estimation Results

(Sample: Apr-1984 / Dec-2017) 1/

	M01 - OLS		M02 - SUR		M03 - CSUR	
π_{t-1}	0.870	***	0.871	***	0.870	***
	0.000		*0.000*		*0.000*	
$\pi_{t-1}^{US,e}$	0.047		0.109		0.130	***
	0.666		*0.243*		*0.000*	
oil_t	0.004	***	0.007	***	0.006	***
	0.004		*0.000*		*0.000*	
$idef_t$	0.041	***				
	0.000					
π_t^{US}	0.066					
	0.209					
$ogap_t$	0.048	*	0.048	*	0.046	*
	0.089		*0.089*		*0.088*	
mst_t	0.006		0.009	*	0.009	*
	0.225		*0.086*		*0.088*	
$\widehat{idef}_t^{res}$			0.038	***	0.038	***
			0.000		*0.000*	
$\hat{\pi}_t^{US,res}$			0.102	**	0.103	**
			0.049		*0.047*	
$const.$	0.000		0.001		0.001	
	0.904		*0.687*		*0.271*	
Obs	429		426		426	
Root MSE	0.010		0.010		0.010	

Sources: IMF calculations.
1/ p-values in italic underneath estimated coeffcients. ***, **, * indicate significance at 1, 5, and 10 percent level.

21. Variables in the baseline regression are likely collinear and/or endogenous. External variables are potentially collinear as they all proxy the same thing: import prices and therefore, terms of trade. Domestic variables are endogenous and, therefore, correlated with the dependent variable. So, our estimates are likely to be inefficient but more problematic, inconsistent.

22. We address potential collinearity by extracting orthogonal factors in external variables. In order to address potential collinearity among external variables we notice that oil prices and inflation expectations affect both US inflation and import prices while US inflation, in turn, affects import prices. Hence, we estimate the following two regressions outside the model:

$$\pi_t^{US} = \beta_1 + \beta_2 oil_t + \beta_3 \pi_{t-1}^{US,e} + v_t$$
$$idef_t = \gamma_1 + \gamma_2 \hat{\pi}_t^{US,res} + \gamma_3 oil_t + w_t$$

And take the fitted residuals from both regressions and define them as $\hat{\pi}_t^{US,res}$ and $\widehat{idef}_t^{res}$, respectively. The first indicates the portion of US inflation not explained by expectations and oil prices. The second, indicates the portion of Barbados import prices not explained by US inflation (and therefore, US inflation expectations, and oil prices).

23. We address endogeneity by using a system estimation. In order to account for endogeneity among domestic variables[14] we estimate the following seemingly related regression (SUR) system.

$$\begin{cases} \pi_t = \alpha_1 + \alpha_2 \pi_{t-1} + \alpha_3 \pi_{t-1}^{US,e} + \alpha_4 \widehat{idef}_t^{res} + \alpha_5 oil_t + \alpha_6 \hat{\pi}_t^{US,res} + \alpha_7 ogap_t + \alpha_8 mst_t + u_{1t} \\ ogap_t = \beta_1 + \sum_{i=1}^{3} \beta_{1+i} ogap_{t-i} + \sum_{i=0}^{3} \beta_{5+i} \pi_{t-i} + \sum_{i=0}^{3} \beta_{9+i} mst_{t-i} + u_{2t} \\ mst_t = \gamma_1 + \sum_{i=1}^{3} \gamma_{1+i} mst_{t-i} + \sum_{i=0}^{3} \gamma_{5+i} \pi_{t-i} + \sum_{i=0}^{3} \gamma_{9+i} ogap_{t-i} + u_{3t} \end{cases} \quad (8)$$

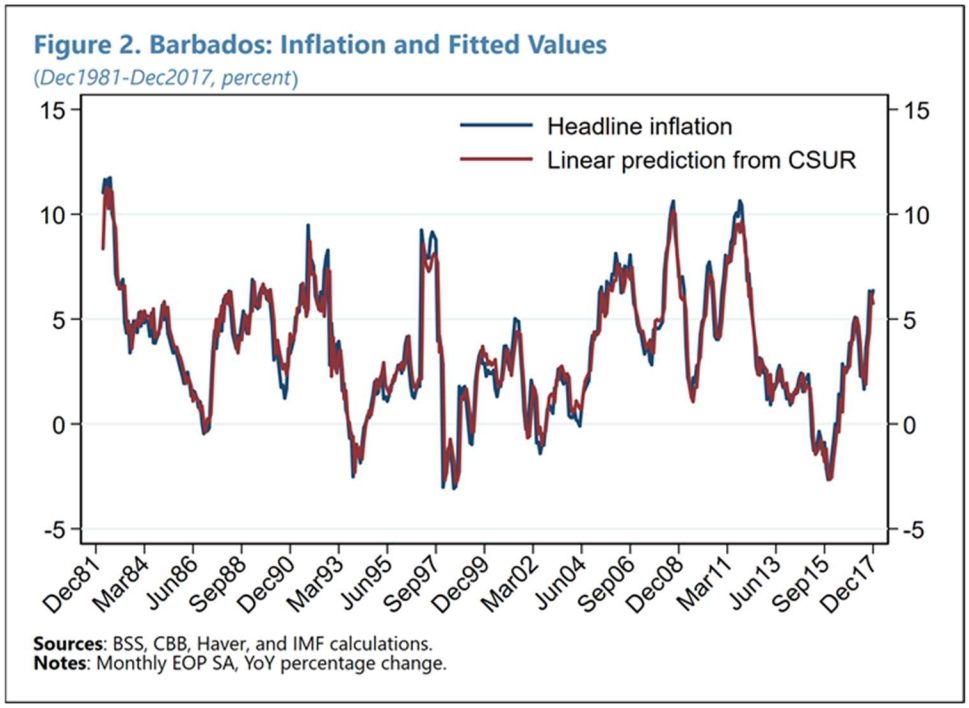
24. Unconstrained SUR results are reported in the second column of Table 2. After accounting for endogeneity and potential collinearity, US inflation expectations have a much larger impact (0.11 pp) on current inflation but only significantly different from zero at 10.9 percent level. Oil prices have now a higher impact (0.007 pp). The set of import prices not affected by US inflation and oil prices has a lower impact (0.04 pp) on current inflation but still highly significant. Us inflation not affected by expectations or oil prices has a 0.1 pp impact on current inflation and it is now significant at 5 percent level. Domestic determinants have similar parameters but the monetary stance has now a much smaller standard errors. In other words, endogeneity and collinearity in M01 were the source of inefficiency that led us to believe that domestic factors (the monetary stance) were irrelevant. With better standard errors, the explanatory power of domestic factors remains low as expected in a small open economy like Barbados but it is now statistically different from zero.

25. Constrained SUR (CSUR) results are reported in the third column of Table 2. So far, we ignored the shares of backward and forward-looking agents in inflation expectations. However, given the estimated parameters and standard errors in M02, it is clear we cannot reject the null that their sum adds up to one at any meaningful significance level.[15] When we

[14] Notice, that since we assume that firms have a constant mark up over marginal costs, there are no negative feedback loops from domestic policies to external factors (import prices or terms of trade). Their eventual presence is of course an empirical matter that does not affect the quality of our results.

[15] The formal test for the linear restriction that $\hat{\alpha}_2 + \hat{\alpha}_3 = 1$ has a $\chi(1)$ distribution with a p-value of 0.827.

restrict the shares of backward and forward-looking agents to add up to one, both parameters take the same standard errors and now, also the forward-looking inflation expectations are statistically different from zero. Figure 2 reports actual and fitted values from the first equation in CSUR.



26. A historical decomposition of inflation gives us a more accurate estimate of the impact of domestic and external factors. M03 continues to have the problem that external factors appear to have a low explanatory power, contrary to expectations that in small open economies, most of the inflation is imported. However, the estimated parameters in M03 give us only the impact of domestic and external factors in excess of what is already explained by lagged inflation. It is necessary to extract the external and domestic components from past inflation if we want to have a better sense of the relative contributions of the two sets of factors. We do this by solving through forward iteration the inflation difference equation in our CSUR system stemming from (8). Headline inflation can be expressed as a function of its initial value plus all external and domestic shocks as follows:[16]

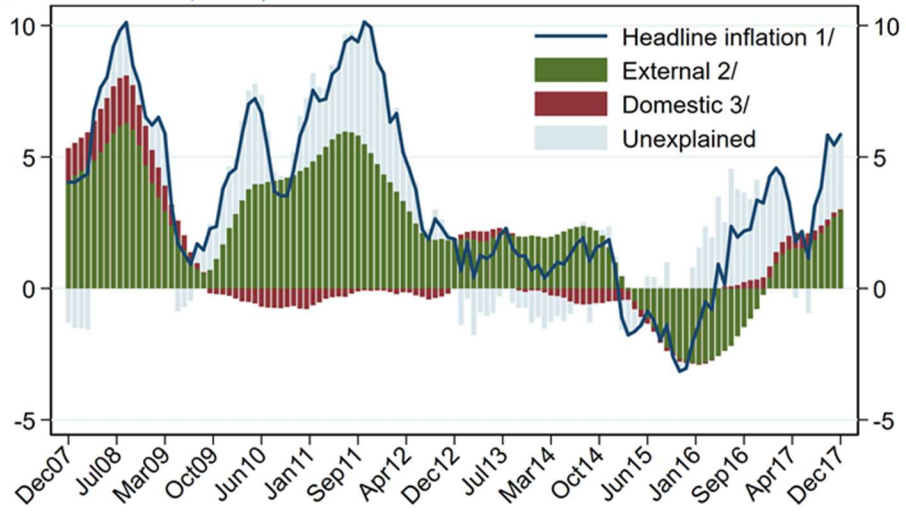
[16] See Appendix B for derivation. The superscript "^" indicates actual estimates from the inflation equation of the CSUR system stemming from (8).

$$\underbrace{\pi_t - \hat{\alpha}_1 \sum_{j=0}^{t-1} \hat{\alpha}_2^j}_{\text{demeaned inflation}} = \underbrace{(1-\hat{\alpha}_2)\sum_{j=0}^{t-1} \hat{\alpha}_2^j \pi_{t-1-j}^{US,e} + \hat{\alpha}_4 \sum_{j=0}^{t-1} \hat{\alpha}_2^j \widehat{idef}_{t-j}^{res} + \hat{\alpha}_5 \sum_{j=0}^{t-1} \hat{\alpha}_2^j oil_{t-j} + \hat{\alpha}_6 \sum_{j=0}^{t-1} \hat{\alpha}_2^j \hat{\pi}_{t-j}^{US,res}}_{\text{external factors}} +$$

$$\underbrace{+\hat{\alpha}_2^t \pi_0 + \hat{\alpha}_7 \sum_{j=0}^{t-1} \hat{\alpha}_2^j ogap_{t-j} + \hat{\alpha}_8 \sum_{j=0}^{t-1} \hat{\alpha}_2^j mst_{t-j}}_{\text{domestic factors}} + \underbrace{\sum_{j=0}^{t-1} \hat{\alpha}_2^j \hat{u}_{1t-j}}_{\text{unexplained residual}} \quad (9)$$

27. On average, external factors are the key determinants of headline inflation but their contribution varies over time (Figure 3 and Table 3). For instance, in the run up to the crisis, persistent increases in food and oil prices, as well as rapidly expanding external demand, were largely responsible for inflation reaching 10.6 percent in September 2008. Over the 2007-10 period, average inflation was 5.6 percent with external and domestic factors contributing 3.8 and 0.5 pp, respectively. During the same period, the contribution of domestic factors gradually decreased, suggesting that external factors were the only factors responsible for the steep downward trend in inflation after the crisis. During the 2011-14 period, inflation averaged 4.2 percent and external and domestic factors accounted for 3.2 and 0.1 pp, respectively. During the 2015-17 period, inflation averaged 1.5 percent and external and domestic factors accounted for -0.5 and 1.0 pp, respectively. The on average larger contribution of domestic factors (as well as their very small standard errors) over this period, is likely due to two factors: (i) the lose fiscal stance and the CBB policy of financing budget deficits; and (ii) the fact that external factors, due to oil price dynamics, had a large negative contribution to inflation in 2015-16 but a large positive contribution to inflation in 2016-17.

Figure 3. Barbados: Contribution of External and Domestic Factors
(Dec2007-Dec2017, percent)



Sources: CBB, Haver, IMF, Comtrade.
Notes: Monthly EOP SA, YoY percentage change. 1/ Demeaned. 2/ Oil prices, US inflation, forward expectations, and import prices. 3/ Output gap and monetary stance.

Table 3. Barbados: Average Contribution of External and Domestic Factors

	1984-17	2007-17	2007-10	2011-14	2015-17
π_t	3.138	3.464	5.272	3.843	1.148
H0 = 0	22.113	11.567	12.682	8.225	2.566
p-value	0.000	0.000	0.000	0.000	0.015
external	3.076	2.283	3.707	3.163	-0.313
H0 = 0	30.464	10.528	13.166	15.311	-1.001
p-value	0.000	0.000	0.000	0.000	0.324
domestic	0.105	0.079	0.571	-0.330	0.134
H0 = 0	2.013	1.324	3.884	-10.079	2.171
p-value	0.045	0.188	0.000	0.000	0.037
residual	-0.043	1.101	0.995	1.010	1.328
H0 = 0	-0.432	7.339	4.394	3.736	4.995
p-value	0.666	0.000	0.000	0.001	0.000
Obs	426	120	36	48	36

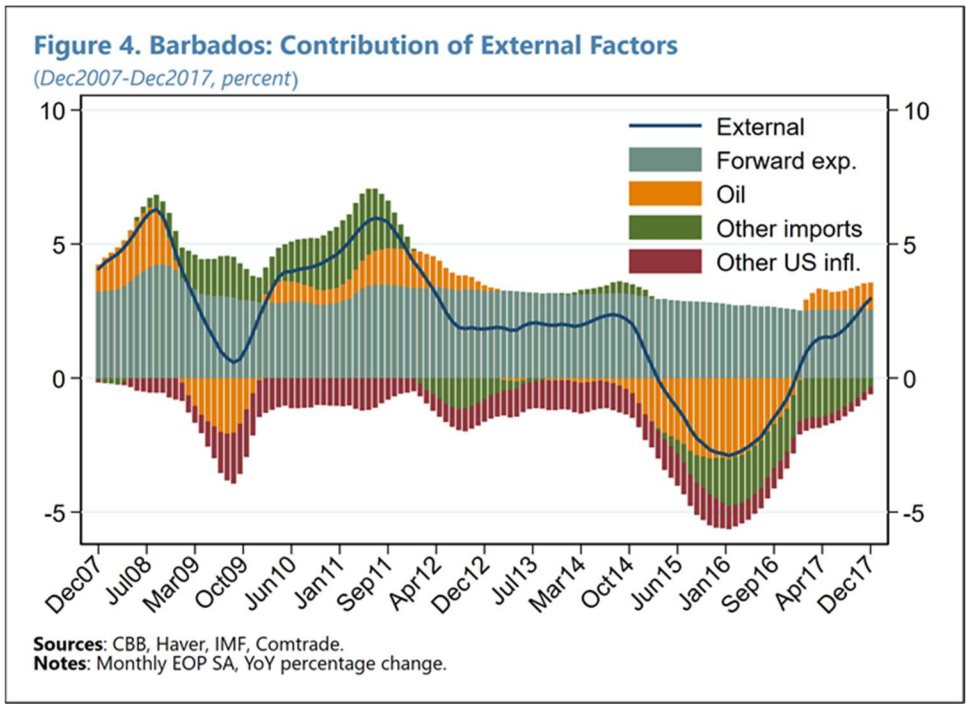
28. The model underestimates inflation in three distinct periods. In the run up to the financial crisis, up to 4 percentage points of inflation remain unexplained. This (as well as for all the other periods) could be attributed to missing variables proxying external demand.[17] The model underestimates inflation again in the 2010-12 period. Some of the unexplained residual then could be attributed to domestic factors: during that period VAT rates were increased and growth decelerated below potential. But also, terms of trade deteriorated rapidly over that period in a manner that our import deflator may fail to capture. Finally, in recent years, inflation underestimation could be due to the introduction of the NSRL and other tax increases aimed at financing increasing structural government expenditures.

29. Among external factors, inflation expectations have the largest contributions to inflation followed by import prices (Figure 4 and Table 4). Forward looking expectations have the single largest and almost constant (positive) contribution to inflation over the full sample with the exception of the period 2015-17. This was expected given Barbados' pegged exchange rate to the US$: the Barbados' inflation tends to converge to US inflation in the steady state with idiosyncratic deviations in the short term. Outside the steady state, oil prices explain much of the short-term volatility: the sharp oil price swings in the 2007-09 and 2014-17 periods, for instance, have an almost a one to one correspondence with imported inflation. Other import prices not affected by US inflation and oil prices have also a large impact on short term dynamics, especially in the last part of our sample. We expect these short term idiosyncratic deviations from the steady state US inflation to be large as the weights of the Barbados CPI are very different from the weights of the US CPI. Finally, the component of US inflation not affected by expectations or oil prices has always a negative contribution to imported inflation. On average, this subtracts about 0.7 pp to inflation and dynamics appear

[17] We tried to add the weighted average of US and UK real GDP growth as a proxy for external demand. We decided not to use it in our system as we found its impact not statistically different from zero and because the low frequency would unduly restrict our sample size.

(continued…)

to reflect the changes in the US monetary stance in the last ten years. Rapid monetary expansion in the US after the global crisis explains the progressively larger negative contribution to domestic inflation (reaching -0.77 pp in the period 2011-14) while gradual tightening in the US starting in 2016 explains the progressively smaller negative contribution (-0.65 pp in the period 2015-17).[18]



[18] Between September 2007 and December 2008, the Fed Funds Rate fell from 5.25 to a range of 0.00–0.25 percent, where it remained until December 2015. Since then, the stance has been gradually tightened.

Table 4. Barbados: Average Contribution of External Factors

	1984-17	2007-17	2007-10	2011-14	2015-17
external	3.076	2.283	3.707	3.163	-0.313
H0 = 0	30.464	10.528	13.166	15.311	-1.001
p-value	0.000	0.000	0.000	0.000	0.324
$\pi_{t-1}^{US,e}$	3.038	3.079	3.244	3.234	2.709
H0 = 0	149.691	88.213	39.629	148.931	104.537
p-value	0.000	0.000	0.000	0.000	0.000
oil_t	0.064	-0.147	0.292	0.424	-1.346
H0 = 0	1.057	-1.107	1.257	4.444	-5.085
p-value	0.291	0.271	0.217	0.000	0.000
$\widehat{idef}_t^{res}$	-0.015	0.087	0.940	0.279	-1.023
H0 = 0	-0.257	0.867	9.287	1.933	-11.317
p-value	0.797	0.388	0.000	0.059	0.000
$\hat{\pi}_t^{US,res}$	-0.012	-0.736	-0.770	-0.773	-0.652
H0 = 0	-0.423	-26.136	-10.205	-30.498	-15.147
p-value	0.672	0.000	0.000	0.000	0.000
Obs	426	120	36	48	36

30. Among domestic factors, the monetary stance has the largest contribution to inflation (Figure 5 and Table 5). Among domestic factors, the monetary stance is by far the largest contributor to domestic inflation[19] but a much smaller contributor than external shocks (in particular, oil price shocks) as found by Downes *et al*. (2017)[20] For instance, in the last ten years, the monetary stance contributed the full average domestic component of inflation while the contribution of the output gap was on average not different from zero. In the run up to the crisis in 2007, and again in 2012, the monetary base grew very rapidly as the CBB was accumulating NFAs to defend the peg on the back of increasing capital inflows and shrinking current account. Conversely, the rapid decline in 2009-10 was the result of a combination of widening current account deficit, capital flow reversals, and contracting credit growth. Since 2015, the CBB engaged in massive deficit financing. This was tapered in 2016 and reduced in 2017 when the CBB forced banks to purchase government debt through financial repression. However, the monetary base continued to have a positive impact on headline inflation. Over the same period, Barbados experienced a sharp contraction in capital inflows, in excess of the ongoing current account deficit improvements. This led to an equally rapid

[19] Notice that domestic factors include also the inflation initial condition. However, this does not amount to overestimation. Since $\hat{\alpha}_2 < 0$, the weight of the initial condition in domestic factors tends rapidly to zero (asymptotically) for $j \to \infty$.

[20] Downes *et al*. (2017) find that "… a one standard deviation in interest rates […] persists in an analogous fashion to shocks from oil prices, [suggesting] that the weighted average interest rate can potentially viewed as a cost-push factor in [the] price formation process of the economy". We ascribe the difference in results to either the different data sample or to the different empirical strategy followed. Indeed, the impulse response functions approach is not suited to account for past shocks in lagged inflation.

(continued…)

loss of reserves that partially offset the expansion of the monetary base in 2015-16 and definitely contributed to the much lower growth rate of the monetary base in 2017.

31. The output gap appears to be relevant only in select periods. For instance, just before the crisis, actual GDP was 2 pp above trend, dropping to 2 pp below trend by 2010; swing also mirrored in headline inflation. But since then, the economy has practically grown at trend[21] with negligible impact on inflation.

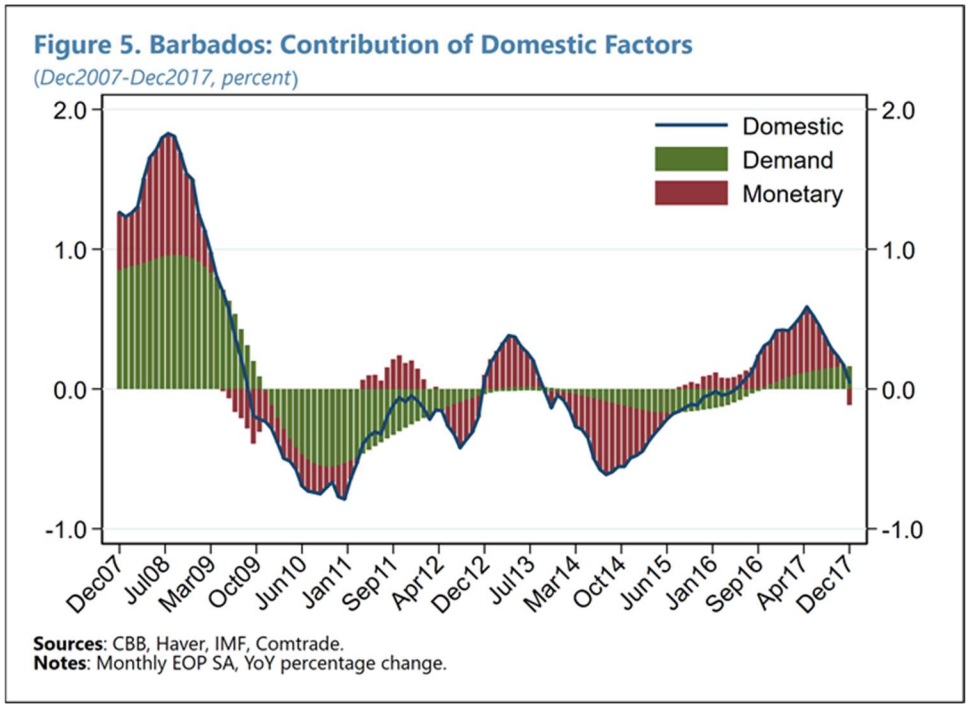


Table 5. Barbados: Average Contribution of Domestic Factors

	1984-17	2007-17	2007-10	2011-14	2015-17
domestic	0.105	0.079	0.571	-0.330	0.134
H0 = 0	2.013	1.324	3.884	-10.079	2.171
p-value	0.045	0.188	0.000	0.000	0.037
$ogap_t$	-0.061	0.031	0.309	-0.135	-0.027
H0 = 0	-2.227	0.919	3.390	-6.457	-1.384
p-value	0.026	0.360	0.002	0.000	0.175
mst_t	0.001	0.048	0.261	-0.195	0.160
H0 = 0	0.060	1.496	4.304	-5.673	3.470
p-value	0.952	0.137	0.000	0.000	0.001
Obs	426	120	36	48	36

[21] Given how inherently difficult it is to estimate potential output (particularly in Barbados), we consider irrelevant deviations from trend smaller than 1 pp.

V. CONCLUSIONS

32. In this paper, we decompose inflation determinants in Barbados between external and domestic factors. We estimate a New-Keynesian Phillips curve using a SUR system to allow for endogeneity among domestic factors and that minimizes potential collinearity among external factors. We then decompose headline inflation and estimate the individual historical contributions of each of the domestic and external factors.

33. The key findings and contributions of this paper are as follows:

- **In line with earlier results, we find that external factors are the largest determinants of inflation in Barbados**. As expected, and in line with previous literature, we find a large impact of external factors on domestic inflation. Over the full 1984-17 sample, external factors contribute on average 3 pp of the 3.5 percent average inflation. External shocks are transmitted to the local economy through the trade channel with potential feedback between domestic and terms of trade. This is captured in our estimation by changes in import prices through forward looking expectations (based on US inflation expectations), oil price shocks and other import prices, including US inflation. The effective exchange rate channel, traditional in neoclassical models, is captured by our import deflator. The credit and risk-taking channels, typical of models with financial frictions, are considered irrelevant in the case of Barbados as banks do not fund themselves abroad and the non-financial sector has negligible liabilities with non-residents (i.e., balance sheet effects are considered negligible).

- **Our first contribution is to estimate the process with which inflation expectations are formed in Barbados**. We are not aware of previous work estimating the inflation expectation process for the case of Barbados. Inflation expectations are a weighted average of backward and forward-looking expectations with weights 0.87 and 0.13, respectively. The external forward-looking component in expectation is justified on at least two grounds: the CBB does not publish inflation expectations numbers and the local economy is highly dependent on imported goods from the US and price fluctuations in that market.

- **Our second contribution is to identify expectations as another important channel through which monetary shocks from the base country are transmitted to Barbados**. The cumulative impact of forward looking expectations in the domestic inflation historical decomposition is large: on average, expectations contribute an almost constant 3 pp to inflation over the full sample. Barbados' inflation tends to converge to US inflation in the steady state with idiosyncratic deviations in the short term. Other import prices represent idiosyncratic shocks around this constant. Oil prices, for instance, explain much of the short-term inflation volatility in the 2007-09 and 2014-17 period. Other import prices not affected by US inflation and oil prices have also a large impact on short term dynamics, especially in the last part of our sample.

- **Our third contribution is that domestic factors matter, albeit as expected, much less than external shocks**. Contrary to what typically assumed for very small open economies, domestic factors, do seem to affect inflation. Over the full 1984-17 sample, external factors contribute on average 10 bps of the 3.1 percent average inflation. But this contribution varies over time. For instance, in the run up to the crisis, domestic factors were contributing up to 190 bps of demeaned inflation.

- **Among domestic factors, monetary shocks have the largest impact on inflation**, albeit much smaller than external shocks. The relevance of monetary shocks stems from the presence of capital controls and their small impact is likely due to the fact that capital controls do not typically deliver full monetary policy independence.[22] In addition, the ability of the CBB to affect real interest rates in the short term is limited due to other institutional features. For instance, any expansion of the money supply does not necessarily translate in more credit to the private sector as, for a given demand for loans and limited investment projects, any excess liquidity flows back in the CBB in the form of banks' reserves. The ability of the CBB to reduce banks' funding costs is also limited as with an oligopolistic structure, limited demand for loans and excess liquidity, the banking sector has little incentives to expand its aggregate balance sheet. We find that monetary shocks contributed up to 90 bps in the run up to the crisis and up to 60 bps in more recent times of deficit financing.

- **Demand shocks have a very small impact on inflation**. The relevance of demand shocks is related to the share (albeit small) of non-tradable goods in the CPI consumption basket and supply constraints (likely in the labor market). However, their impact is very small. This is in line with priors that most demand shocks would affect the current account balance rather than the price index of a basket mainly composed of tradable goods. The inherent difficulty in estimating the output gap, especially in Barbados could also account for this small impact.

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Appendix A. Data description

1. **We build a dataset of monthly observations over the 1984m5-2017m12 interval**. This includes domestic and external factors affecting headline inflation like the forward-looking component of inflation expectations, oil prices, US inflation, import prices, estimates of the output gap and the monetary stance.

π_t **Headline inflation**. Headline inflation is calculated as the 12month difference in the log of the seasonally adjusted monthly CPI index. The CPI series is the product of a splicing process of three differently rebased series separately published by the Central Bank of Barbados. The series is seasonally adjusted using a time invariant additive linear factor model.

$\pi_t^{US,e}$ **Forward looking inflation expectations**. University of Michigan one year US inflation expectations. Data comes from Haver.

oil_t **Oil price inflation**. Oil price inflation is calculated as the 12-month difference in the log of the seasonally adjusted monthly average FOB cost of US imports from Venezuela. The series is seasonally adjusted using a time invariant additive linear factor model. Data comes from Haver. The oil price inflation series has a 95.8 correlation with the inflation calculated with the Western Texas Intermediate (WTI), in turn used in Downes *et al*. (2017) to estimate the passthrough effect of energy prices. While (WTI) is a better proxy for Barbados energy imports, the monthly average FOB cost of US imports from Venezuela is a longer series, allowing us to increase the estimation sample by 3 years.

$idef_t$ **Import deflator**. We build an import deflator[23] defined as:

$$mp_t = \prod_j^{S_t} \left(p_{jt} e_{jt} \right)^{q_{jt}} \tag{A1}$$

rebased to 100 in 2016m5 and where:

- q_{jt} is the import share from country j at time t. Data comes from the UN comtrade database https://comtrade.un.org and linearly interpolated to produce monthly observations.

- p_{jt} is either the monthly export deflator (when available) or the CPI index (as substitute) of country j at time t. Data comes from IFS and Haver and rebased to 100 in 2016m5.

[23] The BSS publishes quarterly import and export price indices but they are not available for the full sample of our dataset.

- e_{jt} is the US$/LCU average monthly exchange rate of country j at time t. Data comes from IFS and Haver.

- S_t is the time varying number of exporting countries to Barbados according to the UN comtrade database https://comtrade.un.org.

π_t^{US} **US inflation**. US inflation is calculated as the 12-month difference in the log of the seasonally adjusted monthly CPI index. Data comes from IFS and Haver.

$ogap_t$ **Output gap**. We estimate a monthly output gap following these steps:

- We convert the annual GDP deflator to a monthly series using Denton (1971) and with CPI index as the higher frequency indicator series.

- We convert the annual nominal GDP to a monthly series using Denton (1971) and with the monthly GDP deflator as the higher frequency indicator series. We use the "stock" options of the technique so that monthly observations correspond to annual GDP estimates.

- We generate a monthly real GDP as the ratio of the monthly nominal GDP and monthly GDP deflator.

- We calculate the output gap as the log difference between the seasonally adjusted real and trend GDP estimated with HP filter. The series is seasonally adjusted using a time invariant additive linear factor model.

Data come comes from IFS and Haver as published by the Barbados Statistical Service.

mst_t **Monetary stance**. Monetary stance is calculated as the log difference between the seasonally adjusted base money and its trend estimated with the HP filter. The series is seasonally adjusted using a time invariant additive linear factor model. Data comes from the Central Bank of Barbados.

Appendix B. Derivation of the Historical Decomposition

1. **A linear, first order autonomous difference equation has the general form**:

$$y_t = ay_{t-1} + b \text{, for } t = 0,1,... \tag{B.1}$$

Where *a* and *b* are known constants. (B.1) can be solved forward by iteration if we know the initial condition y_0. The solution for $a \neq 1$ is:

$$\begin{aligned}
y_1 &= ay_0 + b \\
y_2 &= a\left(ay_0 + b\right) + b \\
y_3 &= a\left[a\left(ay_0 + b\right) + b\right] + b \\
&... \\
y_t &= a^t y_0 + \sum_{j=0}^{t-1} a^j b \\
y_t &= a^t y_0 + b\left(\frac{1-a^t}{1-a}\right) \\
&= a^t\left(y_0 - \frac{b}{1-a}\right) + \frac{b}{1-a}
\end{aligned} \tag{B.2}$$

Where $\frac{b}{1-a}$ is the steady state value of *y*.

2. A **linear, first order non-autonomous difference equation has the general form**:

$$y_t = a_t y_{t-1} + b_t \text{, for } t = 0,1,... \tag{B.3}$$

The solution via forward iteration is given by:

$$y_t = \prod_{i=1}^{t} a_i y_0 + \sum_{j=1}^{t}\left(\prod_{i=j+1}^{t} a_i\right) b_j \tag{B4}$$

3. **The first equation of our CSUR model stemming from (8) is a "partially" non-autonomous difference equation**. It has a constant coefficient but variable intercept. Hence, the solution can be derived from (B4) as follows:

$$\begin{aligned}
y_t &= \prod_{i=1}^{t} a_i y_0 + \sum_{j=1}^{t}\left(\prod_{i=j+1}^{t-1} a_i\right) b_j \\
&\overset{a_i = a\ \forall i}{=} a^t y_0 + \sum_{j=0}^{t-1} a^j b_{t-j}
\end{aligned} \tag{B5}$$

By substituting the relevant items in (B5) from the first equation of the CSUR system stemming from (8):

$$\begin{aligned}\pi_t &= \hat{\alpha}_2^t \pi_0 + \sum_{j=0}^{t-1} \hat{\alpha}_2^j b_{t-j} \\ &= \hat{\alpha}_2^t \pi_0 + \sum_{j=0}^{t-1} \hat{\alpha}_2^j \begin{pmatrix} \hat{\alpha}_1 + (1-\hat{\alpha}_2)\pi_{t-1-j}^{US,e} + \hat{\alpha}_4 \widehat{idef}_{t-j}^{res} + \hat{\alpha}_5 oil_{t-j} + \\ + \hat{\alpha}_6 \hat{\pi}_{t-j}^{US,res} + \hat{\alpha}_7 ogap_{t-j} + \hat{\alpha}_8 mst_{t-j} + \hat{u}_{1t-j} \end{pmatrix}\end{aligned} \tag{B6}$$

And rearranging:

$$\begin{aligned}\underbrace{\pi_t - \hat{\alpha}_1 \sum_{j=0}^{t-1} \hat{\alpha}_2^j}_{\text{demeaned inflation}} = &\underbrace{(1-\hat{\alpha}_2)\sum_{j=0}^{t-1} \hat{\alpha}_2^j \pi_{t-1-j}^{US,e} + \hat{\alpha}_4 \sum_{j=0}^{t-1} \hat{\alpha}_2^j \widehat{idef}_{t-j}^{res} + \hat{\alpha}_5 \sum_{j=0}^{t-1} \hat{\alpha}_2^j oil_{t-j} + \hat{\alpha}_6 \sum_{j=0}^{t-1} \hat{\alpha}_2^j \hat{\pi}_{t-j}^{US,res}}_{\text{external factors}} + \\ &+ \underbrace{\hat{\alpha}_2^t \pi_0 + \hat{\alpha}_7 \sum_{j=0}^{t-1} \hat{\alpha}_2^j ogap_{t-j} + \hat{\alpha}_8 \sum_{j=0}^{t-1} \hat{\alpha}_2^j mst_{t-j}}_{\text{domestic factors}} + \underbrace{\sum_{j=0}^{t-1} \hat{\alpha}_2^j \hat{u}_{1t-j}}_{\text{unexplained residual}}\end{aligned} \tag{B7}$$