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ORIGINAL ARTICLE

The relevance of domestic and foreign factors in driving Ghana's business cycle

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Abstract
It is commonly assumed that external shocks dominate economic fluctuations in least-developed countries (LDCs), particularly commodity-exporting LDCs. Nonetheless, the magnitude and extent of the impact of such shocks compared to other domestic drivers of the business cycle in these countries remain unclear. This study employs a business cycle accounting model to empirically explore the relative contributions of domestic and external factors to Ghana's post-independence business cycle. Contrary to widely held beliefs, our results suggest that external factors do not exert a predominant influence on Ghana's business cycle. Instead, Ghana's business cycle is driven largely by productivity shocks (or efficiency wedges), with the 1980s recession being an exception (which was largely driven by investment wedges). Furthermore, we also show that it is better to capture Ghana's 2011 oil boom as a productivity shock rather than a government spending or an external shock (as some have done) when building a model of economic fluctuations for Ghana's economy for that episode of the business cycle. These results have important implications for building models of economic fluctuations for Ghana's economy.

Keywords Ghana · Business cycle · External shocks · Commodity-dependent economy

JEL Classification E32 · N17

Introduction

Most macroeconomists have always viewed changes in world commodity prices and external shocks as an important source of business cycle fluctuations, particularly in least-developed and emerging economies. Two main reasons underlie this

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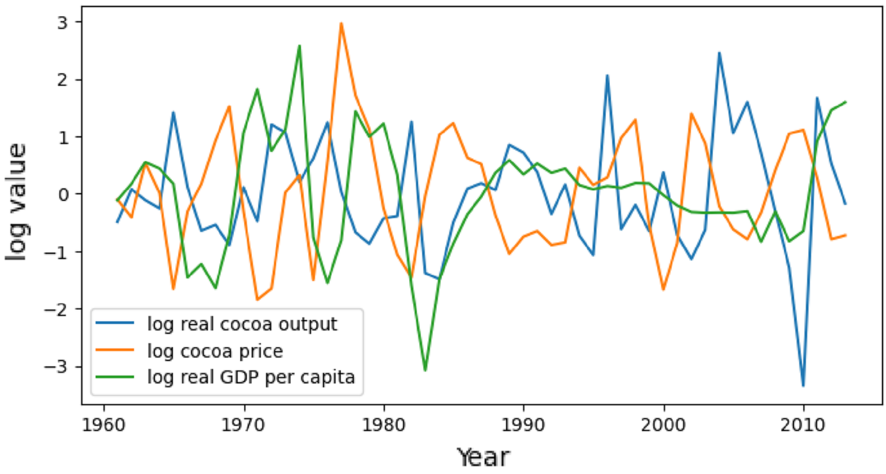
perception. First, many least-developed economies tend to rely heavily on commodity exports. And second, world commodity prices are also highly volatile. According to the open macroeconomics literature, these two factors allegedly make least-developed countries (LDCs) and emerging economies more vulnerable to commodity price shocks. In the literature, some studies have found empirical evidence supporting this narrative for different episodes of the business cycle for different economies (see, for example, Kose 2002). However, are there any exceptions? Or more importantly, to what extent do commodity price shocks really matter for business cycle fluctuations, especially in the 'so-called' commodity-dependent LDCs relative to other domestic drivers of the business cycle?

For economies like Ghana, the events of the past six decades since its independence, for example, calls into question the role of commodity price shocks as the dominant driving factors of Ghana's business cycle relative to other domestic factors. For example, since the mid-1980s, there have been several collapses and booms in gold prices (1985–1989, 1992–1997, 2000–2011) and cocoa prices (1992–1999, 2001–2003, 2008–2011); however, Ghana's business cycle from 1985 to 2011 remained very stable until about 2011 when Ghana began crude oil production in large commercial quantities. While there was a large increase in Ghana's GDP growth rate in 2011, this was largely due to the boom in domestic crude oil production rather than shocks to world oil prices per se. So while commodity prices may contribute to Ghana's business cycle fluctuations, other domestic factors seem even more important. In Fig. 1 below, we plot the HP-filtered cyclical components of Ghana's real GDP per capita (y), real cocoa and

gold prices (cp and gp, respectively), and Ghana's real cocoa and gold output (co and go, respectively). Tables 1 and 2 show the contemporaneous correlations between these variables. As shown, we can observe a weak contemporaneous correlation between Ghana's real GDP per capita and the four commodity variables (thus, real cocoa price and output and real gold price and output).

In this paper, our goal is to shed some light on the dominant role of domestic factors in driving Ghana's business cycle fluctuations relative to commodity price shocks (or more broadly, external shocks hitting Ghana's external sector). Certainly, identifying the key sources of business cycle fluctuations for a given economy is critical for several reasons, and at the top of these reasons, arguably, is the necessity to develop appropriate policy responses to mitigate the negative impact of such shocks on the economy. From the perspective of policymakers, understanding the primary sources of business cycle fluctuations is of utmost importance in developing effective policy responses to enhance household welfare in the aftermath of economic shocks.

For many LDCs like Ghana, an important hypothesis is whether external factors are more relevant in explaining fluctuations in the business cycle than domestic factors, or vice versa. Thus, which factor is more relevant? To evaluate such a hypothesis, one may need to isolate the various business cycle drivers into their domestic and external components and examine their individual contributions to the business cycle. In the literature, one plausible way to do so is to employ a VAR or an SVAR model and examine the responses of output to the various external and domestic shocks in the model. On the other hand, an alternative method is to utilize a business



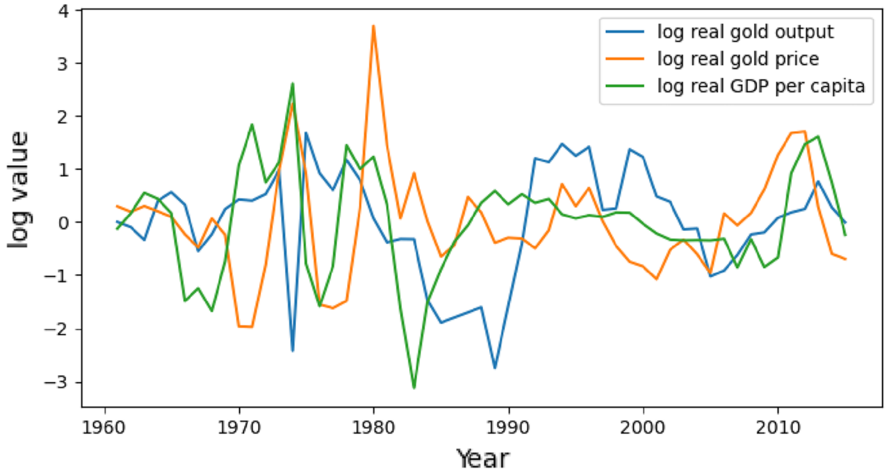


Fig. 1 Cyclical components for real GDP per capita, real cocoa and gold price, and real cocoa and gold output

Table 1 Correlation matrix for real cocoa output (co), real cocoa price (cp), and real GDP per capita (y)

	co	cp	y
co	1.000000	−0.429228	0.164550
cp	−0.429228	1.000000	−0.212392
y	0.164550	−0.212392	1.000000

Table 2 Correlation matrix for real gold output (go), real gold price (cp), and real GDP per capita (y)

	go	gp	y
go	1.000000	−0.116287	0.075447
gp	−0.116287	1.000000	0.163080
y	0.075447	0.163080	1.000000

cycle accounting model, such as the one proposed by Chari et al. (2007) (hereafter also referred to as CKM)[1]. In this study, we adopt the latter approach based on a more structured framework and purposely built for decomposing the business cycle of a given economy into several components. These components can then be further linked to domestic or foreign factors, and their relevance can be determined. We explain this in detail later in our methodology section.

Two main conclusions emerge from our results. First, contrary to popular belief or perception, commodity price shocks or external shocks, in general, are not the main sources of economic fluctuations in Ghana (at least contemporaneously at an annual frequency). Thus, adverse and favorable shocks to world cocoa, gold, and oil prices do not necessarily cause expansions and booms in Ghana's business cycle. Second, among domestic sources of business cycle fluctuations considered in our model, we find that the efficiency wedge (which can be interpreted as domestic productivity shocks) explains about 78.80% of the fluctuations in Ghana's business cycle. Thus, our results point to a much larger effect of productivity shocks on Ghana's output fluctuations than external shocks. These findings are in sharp contrast to Otrok et al. (2015), which emphasizes the importance of the primary goods sector (mainly gold) in driving Ghana's business cycle fluctuations relative to domestic productivity shocks (using an SVAR model).

Our results suggest that while Ghana is a commodity exporter and can be classified as a commodity-dependent economy, domestic shocks (rather than external shocks) remain the dominant source of Ghana's business cycle fluctuations. Hence, developing appropriate policy tools to mitigate the effect of such shocks on the economy should not be neglected by Ghanaian policymakers. Ghana's monetary authorities, for example, should not neglect productivity or supply shocks in its policy design geared towards stabilizing output and maximizing household welfare. Indeed, our results suggest that productivity shocks should be the most important shocks in any optimal monetary policy design for Ghana's economy that seeks to stabilize output fluctuations. Beyond Ghana's economy, these results have important implications for the open macroeconomics literature, in that all small-open economies are not the same, and some countries do not fit the typical narrative of being vulnerable to external shocks in the short run. We elaborate on this later in the study.

To support the insights revealed by our business cycle accounting model, we plot Ghana's real exports and imports (per capita) in Fig. 2 (top panel). The bottom panel plots the cyclical components of these two variables. As shown, fluctuations in Ghana exports (comprising mainly commodity exports) have a strong correlation with imports. The correlation coefficient between the cyclical components of these two variables is about 0.9. To summarize, Fig. 2 suggests that the effect of export shocks due to commodity price shocks, for example, are almost fully offset by fluctuations in imports as these two variables strongly move together in the short run (as well as in the long run). As a result, the impact of external shocks on Ghana's business cycle is less significant. Indeed, from 1960 to 2017, we estimate a −0.04 correlation coefficient between the cyclical components of Ghana's real GDP per

[1] CKM's model has been specifically designed for researchers interested in developing quantitative models of economic fluctuations for specific economies.

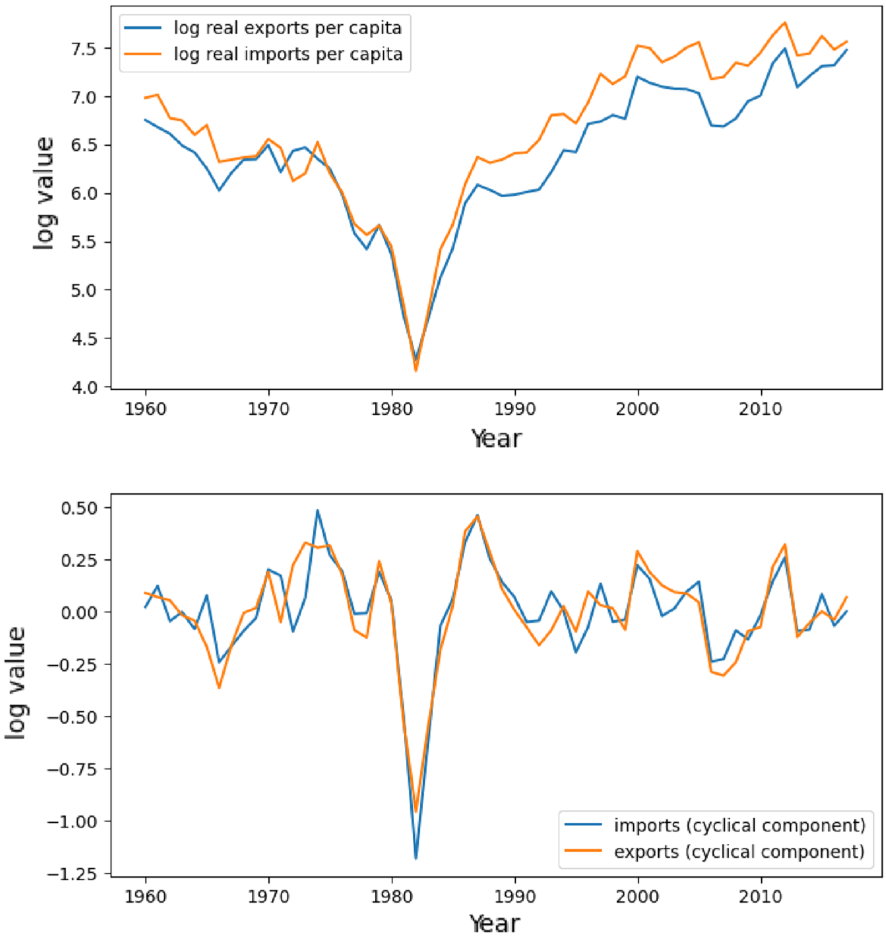


Fig. 2 Ghana's real exports and imports per capita (top panel), and their associated cyclical components (bottom panel). The correlation coefficient between the cyclical components is about 0.90

capita and real net exports per capita. This weak correlation calls into question the commonly held belief that commodity shocks or external shocks, in general, are the dominant driving force of Ghana's business cycle. Instead, Fig. 2 supports our findings (in a more formal setting) that domestic sources rather than external sources are the dominant driving force of Ghana's business cycle. In our view, Ghana's economy resembles a closed economy rather than an open economy concerning output fluctuations in the short run.

It should be noted that we are not seeking to assert that commodity shocks or external shocks have no impact on Ghana's export or import sectors. Indeed, the export sector may be strongly impacted by external shocks. In aggregate, however, these effects are almost completely offset by the reaction of the import sector. There may be some validity to this phenomenon as an automatic stabilizer for Ghana's output fluctuations, but not in the same way as formal fiscal or monetary automatic stabilizers[2].

The strong correlation between the cyclical components of real imports and exports (in per capita terms), as shown in Fig. 2 may be due to several factors. From the global economic perspective, it suggests that global shocks affect Ghana's import and export sectors similarly—in terms of both direction and magnitude. One plausible explanation that may underlie this phenomenon is that a commodity price boom, for example, increases exports, which then causes an increase in aggregate income. The higher income in turn then causes an increase in imports by a similar magnitude as the increase in exports, thus leaving output fairly unchanged. Undoubtedly, other explanations may be underlying this phenomenon. However, whatever that may be, our view is that it will always involve a strong link between Ghana's export and import sectors.

In summarizing the above, the contributions of this paper (or value-added to the literature) are twofold. First, we demonstrate that domestic shocks rather than external shocks are more relevant in explaining Ghana's post-independence business cycles, contrary to prior beliefs and assumptions of the open macroeconomics literature. Second, we also show that productivity shocks are the most relevant domestic sources of Ghana's business cycle fluctuations relative to other domestic factors. Our results have important implications for both policymakers and academics interested in Ghana's economy and the open macroeconomics literature in general. For policymakers, our results suggest that productivity shocks and their role in driving Ghana's output fluctuations should not be diminished, contrary to suggestion made by Otrok et al. (2015). For academics, our results hold relevance in building a detailed quantitative model of economic fluctuations for Ghana's economy. Our paper makes no contributions in terms of methodology.

The remainder of the paper is organized as follows. Section 2 provides a brief overview of how our paper fits the literature. Section 3 presents some structural characteristics of Ghana's economy. In Sect. 4, we present the analytical framework used in this study, our estimation strategy, and a discussion of the calibrated parameters used in the model. Section 5 presents the results of our estimation and an analysis of the results, Sect. 6 discusses some robustness checks and sensitivity analysis, and Sect. 7 concludes.

Relation to the literature

This study is related to various areas of research. Primarily, it is linked to the open-economy macroeconomics literature, which emphasizes the importance of international trade, finance, and external borrowing and lending for short-term economic fluctuations of small-open economies. One of the significant contributions in this area of research is credited to Corden and Neary (1982), who initially proposed a formal economic model that explains the well-known Dutch

[2] Formal fiscal and monetary automatic stabilizers are intentionally built-in stabilization features of the economy.

disease—a phenomenon where a sudden windfall of natural resource revenues, such as oil, gas, gold, cocoa, etc., negatively affects the non-resource sectors of a commodity-exporting economy and may subsequently lead to short-run fluctuations in the business cycle (see Suescún et al. 1997).

The short-run economic impact of a commodity boom, within the framework of the Dutch diseases, however, is theoretically ambiguous and largely contingent on the responses of the commodity sector vis-à-vis the other non-commodity sectors of the economy. As posited by the Dutch disease theory, the occurrence of a commodity boom, arising from a positive commodity price or output shock, may trigger an appreciation of the exchange rate, which in turn renders the other non-commodity sectors of the economy less competitive in the global market, ultimately leading to a contraction in their output levels. Consequently, the commodity sector experiences an upswing, whereas the non-commodity sector experiences a decline. Hence, the net short-run impact of a commodity boom on the economy's aggregate output hinges on the respective reactions of these two sectors of the economy—i.e., the commodity sector and the non-commodity sector.

The aforementioned ambiguity, however, could be mitigated or could vanish through the implementation of additional policy interventions. In certain emerging economies such as Brazil, Colombia, Chile, Peru, and South Africa, Shousha (2016) asserts that a surge in commodity prices triggers an expansion of the business cycle of these economies. According to his empirical analysis, in response to the appreciation of the exchange rate resulting from a commodity boom, the central banks in these economies tend to reduce the interest rate to curtail foreign borrowing by domestic banks. This reduction in the interest rate, in turn, then leads to an expansion of other sectors within the economy. As a result of this exacerbation of a commodity boom via the financial sector, Shousha (2016) argues that business cycle expansions—due to a commodity boom—are generally larger in the above-listed emerging economies than in developed economies. On the contrary, in countries like Nigeria, Oladunni (2020) argues that the Nigerian central bank tends to reduce the interest rate following an oil price boom to curtain inflation and inflation expectations. Among the BRICS economies (and Turkey), Caporale et al. (2022) argue that oil prices have a positive and significant impact on the energy sector in all countries except India, with the chemicals sector being the most affected by oil price fluctuations[3].

Like many African economies, Ghana also heavily relies on commodity exports, mainly cocoa, gold, and crude oil (since 2011), which together account for about 80% of its exports (Asante-Poku and Van Huellen 2021). Consequently, commodity price shocks are potentially relevant to Ghana's business cycle fluctuations. However, to what extent do they matter? For example, how strong are the effects of cocoa, gold, and oil price shocks on Ghana's output fluctuations, and are these effects significant? While answering these questions may seem easier based on the widely held belief that external shocks matter for small-open economies, a critical

[3] Indeed, numerous empirical studies in the literature have identified foreign shocks, such as commodity price shocks, as significant drivers of economic fluctuations for various economies. Our goal here is not to provide an exhaustive list of these studies but rather to show a few examples of these studies.

assessment of this claim from different perspectives is crucial for both policy purposes and academic research.

Using an ARDL model and annual data from 1980 to 2011, Ofori-Abebrese et al. (2017), found that commodity prices had no short-run effect on Ghana's economic growth. Between February 01, 2006, and March 01, 2021, Boateng et al. (2022) also found a less substantial effect of cocoa prices on the Bank of Ghana's Composite Index of Economic Activity (BOGCIEA), using several wavelet techniques. Examining gold price shocks, Otrok et al. (2015) found a positive effect on Ghana's short-run economic growth from 1985:Q1 to 2010:Q3 but no significant effect from 2002:Q1 to 2010:Q3. Additionally, Adu et al. (2015) found no significant impact of gold price shocks on Ghana's real GDP, using quarterly data from 1980 to 2012. Our paper is related to this empirical literature on commodity price shocks (or, more broadly, external shocks) and their effect on Ghana's output fluctuations. Unlike the above papers, however, we adopt a non-reduced-form macroeconomic model for our analysis and investigations. The advantages of our modeling choice are elaborated on later in the study.

A second strand of research related to this paper is the research on the importance of domestic productivity shocks in driving output fluctuations in the short run, where productivity shocks are defined as sudden changes in the efficiency with which an economy utilizes its resources. These shocks have been identified as one of the key drivers of economic fluctuations in some economies, and many economists have recognized their importance for decades. The study of an economy's level of productivity can be traced back to the work of Nobel laureate Robert Solow in the 1950s, who showed that productivity growth was the main driver of long-run economic growth. Subsequent research by other economists such as Edward Prescott and Finn Kydland in the early 1980s, further showed that productivity shocks could also explain short-run fluctuations in output and other macroeconomic variables. For some emerging economies, authors like Aguiar and Gopinath (2007) and Kydland and Zarazaga (2002) have argued that productivity shocks drive the business cycle. In this paper, we investigate the importance of productivity shocks in driving Ghana's business cycle relative to other factors like external shocks within a single macroeconomic model. To the best of our knowledge, we do not know of any such studies focusing on sub-Saharan African (SSA) economies or Ghana's economy. Thus, to what extent do productivity shocks matter in driving Ghana's output fluctuations relative to other potential drivers of Ghana's business cycle?

In the structural VAR (SVAR) literature, we know of one paper that examines the importance of domestic productivity shocks relative to other external shocks in driving Ghana's output fluctuations (see Otrok et al. 2015). Based on their results, the authors emphasized the importance of the primary goods sector in developing a DSGE model of economic fluctuations for Ghana's economy, while diminishing the role of domestic productivity shocks. Our paper, however, argues otherwise. One limitation of the approach used in Otrok et al. (2015) is the fact that the authors used different SVAR models (containing different sets of variables) to estimate the effect of productivity and other external shocks on Ghana's output, which certainly hinders the effective comparison of which factors or shocks are the most relevant in driving Ghana's business cycle.

In terms of motivation, we indeed have a similar motivation as Otrok et al. (2015). Thus, "...to investigate the type of shocks and model features that one should consider in building a structural dynamic stochastic general equilibrium (DSGE) model [for Ghana's economy]". While an SVAR model may be used for such a task, an alternative methodology that is even more appropriate—in our view—is the business cycle accounting (BCA) methodology proposed by Chari et al. (2007). The BCA model is better structured than the SVAR model as it is based on the standard neoclassical growth model which already has a similar structure as the DSGE model. As Chari et al. (2007) mentioned in their paper, the primary goal of the BCA methodology is to 'guide researchers in developing quantitative models of economic fluctuations' for specific economies. This is the last strand of research related to our study.

Since its proposal by Chari et al. (2007), a number of papers[4] have applied the BCA methodology to assess which specific wedges—among efficiency wedge, labor wedge, investment wedge, and government consumption wedge—are more relevant in explaining the business cycle of a given economy for a given episode of the business cycle. During the 1982 recession, for example, Brinca et al. (2016) found that the efficiency wedge played the most important role in the recession for ten countries in their sample. The labor wedge played the most important role for three countries, and the investment wedge played the most important role for seven countries. These findings imply that countries exhibit idiosyncratic characteristics, thus precluding the blind generalization of business cycle accounting (BCA) results from one economy to another, even if the fluctuations in the business cycle are driven by a common global shock, such as the 2007–2008 global financial crisis.

In the BCA model (as we would explain in detail later), the labor wedge distorts the household's optimal intratemporal decisions. The investment wedge distorts the optimal intertemporal decisions of the household. The efficiency wedge distorts the firm's production decisions, and the government consumption wedge (comprising both government consumption and net exports) distorts the model economy's resource constraint. Given these definitions of the wedges, external shocks (hitting both the current and capital accounts of a given economy) would manifest as government consumption wedges in the prototype BCA model (as demonstrated in Chari et al. (2007)). In this paper, we hypothesize that if external shocks (including commodity price shocks, foreign interest rate shocks, and foreign credit shocks) are important drivers of Ghana's business cycle, then the government consumption wedge should be a relevant source of economic fluctuations in our estimated BCA model (tailored to Ghana's economy). A similar hypothesis also applies to the other three remaining wedges.

4 In the literature, CKM's BCA model and its various extensions have been applied to many economies, including Japan (Cunha 2006), China and India (Ljungwall et al. 2009), Argentina (Cavalcanti 2007), UK (Kersting 2008), Japan (Saijo 2008), France (Bridji 2013), Portugal (Iskrev et al. 2013), Italy (Orsi and Turino 2014), Chile (Simonovska and Soderling 2008), Ireland (Ahearne et al. 2006), Brazil (Graminho et al. 2006), Japan (Kobayashi and Inaba 2006), Spain (López and García 2016), Mexico (Sarabia 2008), Portugal (Cavalcanti et al. 2008), Japan (Chakraborty 2009), Korea (Sarabia 2007), UK (Chadha and Warren 2013), among others.

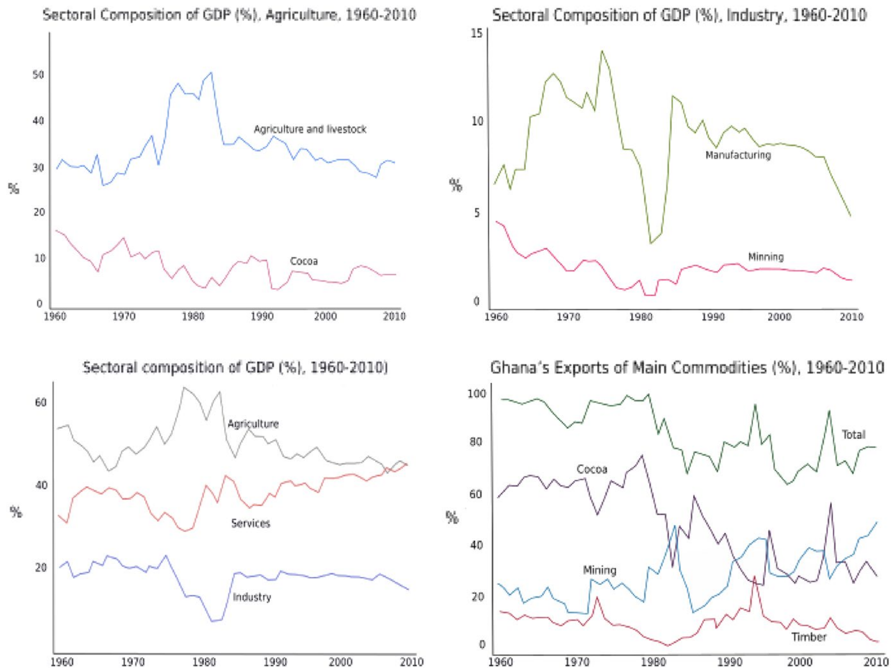


Fig. 3 Structural characteristics of Ghana's economy. Source: Jedwab and Osei (2012)

Our goal is to investigate which of the four wedges dominate in explaining Ghana's business cycle, and to what extent. In this sense, we use the BCA model as an empirical model in the same spirit as one would use other empirical models like the SVAR model.

Structural characteristics of Ghana's economy

As an LDC, Ghana's industrial sector has historically made comparatively smaller contributions to Ghana's gross domestic product (GDP), accounting for less than 20%—on average—of Ghana's GDP from 1960 to 2010, as reported by Jedwab and Osei (2012). Within the industrial sector, Jedwab and Osei (2012) found that Ghana's mining sector contributed approximately 2.4% of Ghana's GDP between 1960 and 2010, using the producer prices for the various extractives, as shown in the top right panel of Fig. 3. Using the international prices of these extractives, however, they suggest that the share of mining in Ghana's GDP may be about 6.3% from 1960 to 2010.

Within the agricultural sector, they report that Ghana's cocoa sector contributed less than 10% to Ghana's GDP from 1960 to 2010, based on the domestic producer price of cocoa (as shown in the top left panel of Fig. 3). Their report,

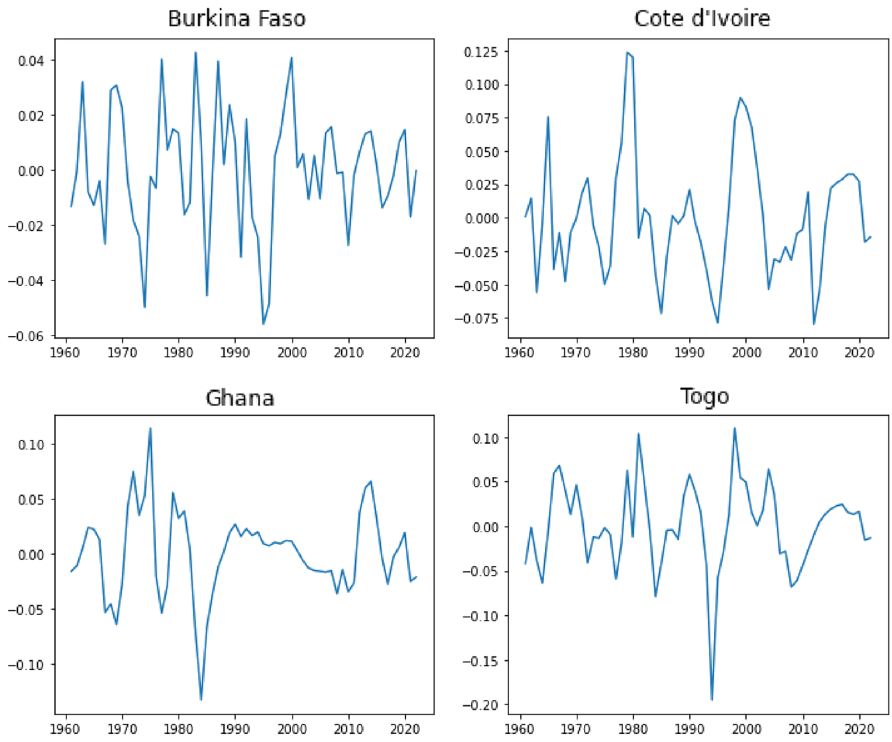


Fig. 4 Cyclicality of real GDP per capita for Ghana, Burkina Faso, Togo, and Ivory Coast. Source: Ameyaw (2023)

however, notes that this value is slightly higher, at approximately 10%, when the international price for cocoa is used instead of the domestic cocoa producer price. Based on these values (as reported by Jedwab and Osei (2012)) Ghana's cocoa and gold sectors contributed between 8 and 16% of Ghana's GDP from 1960 to 2010, depending on whether international prices or domestic producer prices were used in calculating these sector shares in GDP. The right-bottom panel of Fig. 3 confirms that commodity exports, specifically cocoa, mining (mainly gold), and timber, accounted for over 75% of Ghana's total exports from 1960 to 2010.

How does Ghana's economy compare to other economies in the sub-Saharan Africa (SSA) region? In terms of short-run output fluctuations, available data indicate low synchronicity between Ghana's business cycle and that of the sub-Saharan African (SSA) region, as documented by Ameyaw (2023). This low synchronicity points to a minimal spill-over effect of shocks emanating from other SSA economies on Ghana's business cycle, suggesting a business cycle largely driven by domestic factors rather than external events. This is evidently seen in the data, for example, in the mid-1980s, when Ghana's business cycle significantly moderated until about 2010, while the business cycle of its neighbors continued to exhibit significant fluctuations. Between 1960 and 2021, there seems

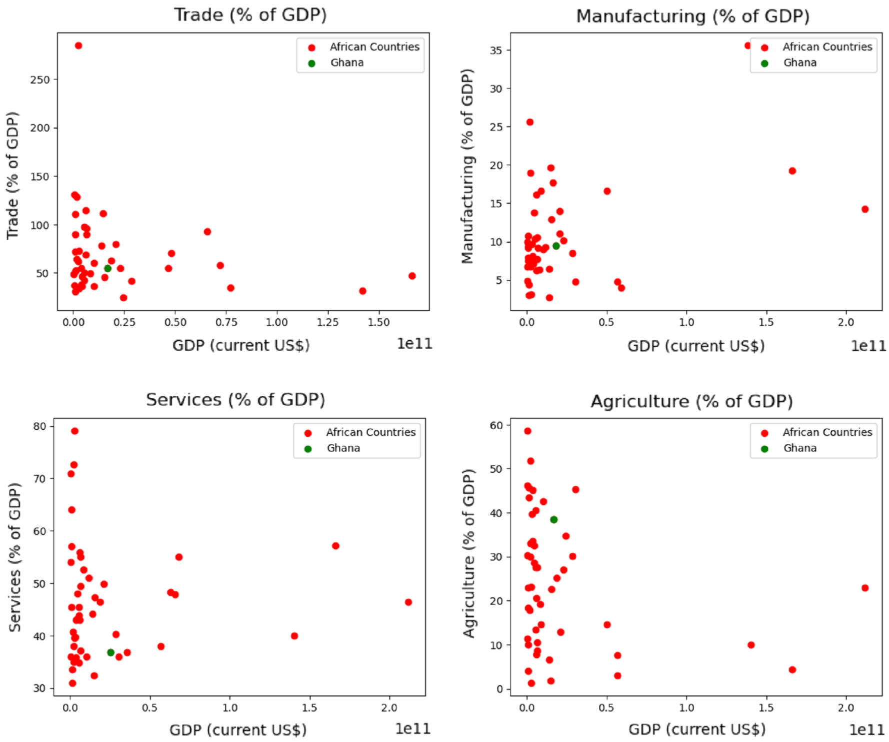


Fig. 5 Comparative analysis of sector composition in Ghana's economy and other African economies. The data are average data from 1965 to 2021 (trade data are from 1975 to 2021). African countries with missing data were dropped

to have been only one instance when the business cycles of all four countries (i.e., Ghana and its three neighbors) moved in unison due to a severe drought that affected nearly the entire West African region (Fig. 4).

Furthermore, as mentioned in Ameyaw (2023), a low degree of synchronicity is also observed when Ghana's business cycle is compared to that of its trading partners, the OECD, and the global business cycle. In our view, these pieces of evidence, again, point to a limited influence of external factors in driving Ghana's business cycle, particularly, via the trade sector.

Focusing on key sectors such as trade (as a percentage of GDP), agriculture (as a percentage of GDP), manufacturing (as a percentage of GDP), and services (as a percentage of GDP), Fig. 5 also provides a comparative analysis of Ghana's economy relative to other African economies (including those outside the SSA region). The data plotted are averages from 1965 to 2021 (trade data, however, are from 1975 to 2021). As shown, Ghana's average trade (as a percentage of GDP) from 1975 to 2021 was about 54.82%, which is below the 68.84% average for the countries in the sample. This result reveals Ghana's lower dependence on trade (relative to many other African economies). Comparatively[5], it suggests Ghana's lower exposure to fluctuations in global demand and other external shocks (such as changes in international commodity prices) relative to other African economies.

Figure 5 also indicates that Ghana's agricultural sector, accounting for approximately 38.53% of Ghana's GDP on average from 1965 to 2021, is above the 24.30% average (for the countries in the sample). This observation further highlights Ghana's economy as less susceptible to external shocks compared to other African economies, given the relatively strong resilience of the agricultural sector to foreign disturbances (see, Cooke et al. 2015). From 1965 to 2021, Ghana's manufacturing sector accounted for approximately 9.49% of Ghana's GDP, while the services sector accounted for about 36.89%. These figures fall below the estimated average of 10.60% for manufacturing and 45.96% for services (for the countries in the sample).

Analytical framework

Chari, Kehoe, and McGrattan's (CKM) BCA model features four wedges that can be estimated using real data and the equilibrium conditions of what CKM calls a prototype model economy. The estimated wedges can then be mapped to detailed model economies featuring a variety of policy shocks and frictions (which determines the transmission channels in these detailed models). The wedges—in the prototype model—are considered to distort the household's intratemporal and intertemporal decisions, the firm's production decisions, and the model economy's resource constraint. As a result, any friction or policy shock in the detailed model economy that distorts the household's intratemporal and intertemporal decisions, the firm's production decisions, or the model economy's resource constraint could be linked to a specific wedge in the prototype model economy. A straightforward example is the mapping between a TFP shock in a detailed model economy and an efficiency wedge in a prototype model economy. The TFP shock and the efficiency wedge both distort firms' production decisions, and one can derive that TFP shocks manifest as efficiency wedges in the prototype model economy. Of course, aside from TFP shocks, other frictions and policy shocks may also manifest as efficiency wedges (see, for example, Brinca et al. 2020).

Following the business cycle accounting literature, this study does the following. First, we decompose Ghana's business cycle variations into the four wedges in the BCA. Second, we examine the contribution and relevance of each wedge, holding the other remaining wedges in the model constant. The significance of each wedge is typically measured by how much it predicts the data for a specific variable, say, output or investment. Third, we then determine which classes of frictions are appropriate for modeling specific episodes of Ghana's business cycle using the identified wedges. In Brinca et al. (2020), the authors provide an excellent overview of a map between various frictions and policy shocks in a detailed model economy and their associated wedges in the prototype model economy.

[5] Thus, relative to other African economies.

Our results suggest the following. (i) First, the efficiency wedge is the most important wedge over the entire sample (i.e., 1960–2017). Labor, investment, and government consumption wedges (on average) play insignificant roles in Ghana's output fluctuations from 1960 to 2017. (ii) Second, over the period 1978–1988 (spanning Ghana's deepest recession since its independence), our results suggest that the investment wedge was the most important contributor to the business cycle, contributing about 71.47% of output fluctuations during this period. On the other hands, the efficiency wedge contributed about 12.20%. (iii). Third, regarding Ghana's recent business cycle expansion from 2009 to 2017, our results suggest that the efficiency wedge contributed about 78.80% of output fluctuations during this period. The remaining three wedges played minimal roles individually.

These results have important implications for the macroeconomics literature on Ghana's economy. For example, it suggests that capturing Ghana's 2011 oil boom as productivity shocks in a structural model of economic fluctuations for Ghana's economy is more appropriate than capturing the oil boom as government spending shocks as done in Dagher et al. (2012). Furthermore, our results also have important implications for the design of appropriate output stabilization policies for Ghana's economy, particularly since 2011 (i.e., Ghana's oil production era, which has ushered in large volatilities in the business cycle). Our results suggest that domestic productivity shocks should not be diminished in the design of output stabilization policies for this era.

Model

In the BCA model, it is assumed that stochastic historical events $s_t \in s^t = (s_0, ...s_t)$ [6] drive the state of the macroeconomy, with a $\pi(s^t)$ probability of being in a given state of nature (s_t) at any time t. Precisely, it is assumed that s_t drives the various wedges in the model, which drives the fluctuations in the various macroeconomic variables. With these assumptions, we can estimate the model's wedges with data and infer which specific wedges are relevant for the fluctuations observed in the data. For example, we can investigate which specific wedges drive the fluctuations observed in output. Having identified the relevant wedges, we can map them to a class of frictions or shocks (in a detailed quantitative model economy) to infer which frictions are important for modeling specific episodes of the business cycle of a given economy.

Households

For each time t and each history of events s^t, households choose consumption ($c_t(s^t)$) and labor ($l_t(s^t)$) to maximize their expected lifetime utility;

[6] s_0 is given and s^t is finite.

$$\sum_{t=0}^{\infty}\sum_{s^t}\pi_t\left(s^t\right)\beta^t\frac{\left[c_t(s^t)(1-l_t(s^t))^{\psi}\right]^{1-\sigma}}{1-\sigma} \tag{1}$$

subject to the following budget constraint,

$$c_t\left(s^t\right)+\left(1+\tau_{xt}\left(s^t\right)\right)x_t\left(s^t\right)=\left(1-\tau_{lt}\left(s^t\right)\right)w_t\left(s^t\right)l_t\left(s^t\right)+r_t\left(s^t\right)k_t\left(s^{t-1}\right)+T_t\left(s^t\right) \tag{2}$$

and a law of motion for capital,

$$\left(1+\gamma_z\right)\left(1+\gamma_n\right)\left(k_{t+1}(s^t)\right)=\left(x_t(s^t)\right)+(1-\delta)\left(k_t(s^{t-1})\right), \tag{3}$$

where β is the subjective discount factor, ψ is a labor disutility parameter, and σ is a risk aversion parameter. The utility function is a GHH (Greenwood, Hercowitz, and Huffman) utility function, which helps to curtail consumption smoothing as mentioned in Otsu (2010). We consider this utility function to be appropriate for SSA economies like Ghana, where many households are hand-to-mouth households. In the budget constraint, $x_t(s^t)$ is investment, $w_t(s^t)$ is real wage, $r_t(s^t)$ is real capital rent, and $T_t(s^t)$ is lump-sum transfer. $\tau_{xt}(s^t)$ and $\tau_{lt}(s^t)$ (resembling taxes) are stochastic processes that distort the optimal intratemporal and intertemporal decisions of households. Thus, $\tau_{xt}(s^t)$ and $\tau_{lt}(s^t)$ create a wedge in the first-order conditions of a representative household unit shown below:

$$\frac{\psi\left(c_t\right)}{1-\left(l_t\right)}=\left(1-\tau_{lt}\right)\left(w_t\right)$$

$$\left(1+\tau_{xt}\right)\left(c_t\right)^{(-\sigma)}\left(1-\left(l_t\right)\right)^{\psi(1-\sigma)}=\hat{\beta}E_t\left[c_{t+1}^{-\sigma}\left(1-l_{t+1}\right)^{\psi(1-\sigma)}\right.$$
$$\left.\left((1-\delta)\left(1+\tau_{xt+1}\right)+\left(l_{t+1}\right)^{1-\alpha}\left(l_t\right)^{(-\alpha)}(1-\alpha)\left(k_{t-1}\right)^{\alpha}\right]\right.$$

$\tau_{xt}(s^t)$ creates a wedge in the intertemporal consumption-savings decision of the household, and $\tau_{lt}(s^t)$ creates a wedge in the intratemporal work–leisure decision of the household. The law of motion for capital in Eq. 3 is of the type used in Otsu (2010), which results from detrending all model variables with a constant population growth rate (γ_n) and a constant technological-progress growth rate (γ_z)[7].

Firms

A representative firm in the model produces output ($y_t(s^t)$) using the following production function,

$$y_t(s^t)=k_t(s^{t-1})^{\alpha}(z_t(s^t)l_t(s^t))^{1-\alpha} \tag{4}$$

and solves the following profit maximization problem,

[7] Thus, $k_t(s^{t-1})=\frac{K_t(s^{t-1})}{N_t(s^t)Z_t(s^t)}\equiv\frac{K_t(s^{t-1})}{N_t(s^t)(1+\gamma_z)^t}$, $c_t(s^t)=\frac{C_t(s^t)}{N_t(s^t)Z_t(s^t)}\equiv\frac{C_t(s^t)}{N_t(s^t)(1+\gamma_z)^t}$, and so on where $Z_t(s^t)=(1+\gamma_z)^t$ (see also, Brinca et al. (2020))

$$\max\ \Pi_t(s^t) = y_t(s^t) - w_t(s^t)l_t(s^t) - r_t(s^t)k_t(s^{t-1}), \tag{5}$$

where α is the capital share of income, and $z_t(s^t)$ is an efficiency wedge that distorts the efficient use of resources. The first-order conditions of the firm's problem are the following:

$$\alpha z_t(s^t)^{1-\alpha}k_t(s^{t-1})^{\alpha-1}l_t(s^t)^{1-\alpha} - r_t(s^t) = 0,$$
$$(1-\alpha)z_t(s^t)^{1-\alpha}k_t(s^{t-1})^{\alpha}l_t(s^t)^{-\alpha} - w_t(s^t) = 0.$$

Government sector

The government is assumed to maintain a balanced budget where stochastic government spending ($g_t(s^t)$) balances lump-sum transfers to households. $g_t(s^t)$ is considered a wedge (i.e., government consumption wedge) as it distorts the consumption and investment decisions of households in the model, and it comprises both government spending and net export.

$$g_t\left(s^t\right) = T_t\left(s^t\right). \tag{6}$$

Equilibrium and market clearing

The goods market clears, generating the following resourcing constraint,

$$y_t\left(s^t\right) = c_t\left(s^t\right) + x_t\left(s^t\right) + g_t\left(s^t\right). \tag{7}$$

The model's competitive equilibrium consists in finding a sequence of the endogenous variables $\left\{c_t(s^t), l_t(s^t), x_t(s^t), w_t(s^t), r_t(s^t), k_{t+1}(s^t), y_t(s^t)\right\}_{t=0}^{\infty}$ given a price system $\left\{w_t(s^t), r_t(s^t)\right\}_{t=0}^{\infty}$, an initial value of capital (k_0), and a sequence of stochastic processes ($\left\{\tau_{xt}(s^t), \tau_{lt}(s^t), z_t(s^t), g_t(s^t)\right\}_{t=0}^{\infty}$) such that the equilibrium conditions of the model are satisfied.

Data and definition of wedges

We use the same definitions of wedges as used in Chari et al. (2007). The efficiency wedge ($Aw_t(s^t)$) is defined as $Aw_t(s^t) = z_t(s^t)^{1-\alpha}$, which is essentially TFP (by rewriting the production function). $Aw_t(s^t)$ distorts the firm's production process. The investment wedge ($Xw_t(s^t) = \frac{1}{1+\tau_{xt}(s^t}$)) distorts the household's intertemporal equilibrium condition, and the labor wedge ($Lw_t(s^t) = 1 - \tau_{lt}(s^t)$ distorts the household's intratemporal equilibrium condition. The government wedge ($Gw_t(s^t)$)[8] is estimated from the resource constraint using data on consumption per capita (c_t^d),

[8] The government wedge is estimated using a log-linearized version of the resource constraint (following Chari et al. (2007)): $Gw_t(s^t) = g_t = \left[y_{ss}y_t^d - x_{ss}x_t^d - c_{ss}c^d{}_t\right]/g_{ss}$, where ($y_{ss}, c_{ss}, x_{ss}, g_{ss}$) are steady-state values.

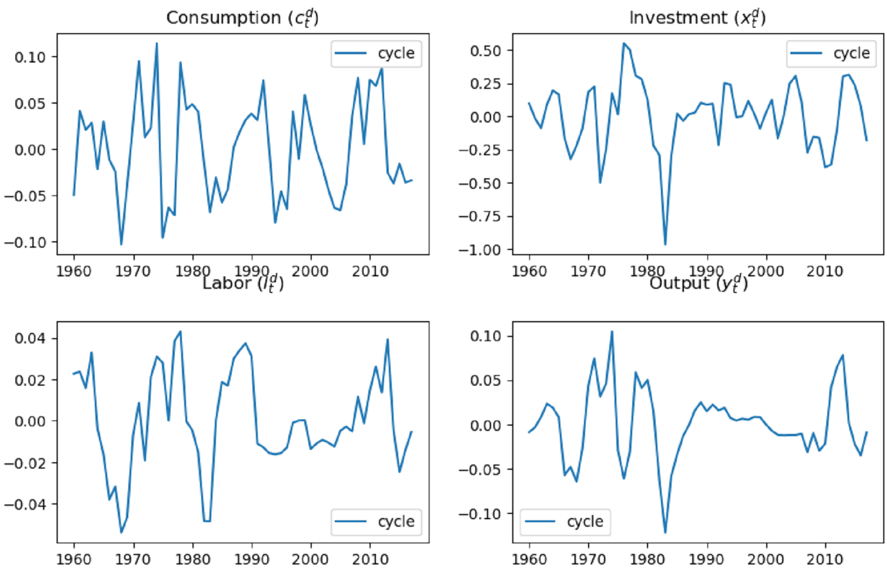


Fig. 6 Estimated HP-filtered wedges and observed output

investment per capita (x_t^d), output per capita (y_t^d), and the estimated parameters of the model[9]. c_t^d, x_t^d, and y_t^d are obtained from the World Bank's WDI dataset (at an annual frequency). Our labor data (l_t^d) are obtained from the Penn World Tables (PWT) dataset. l_t^d is computed as $l_t^d = \frac{h_t^d e_t^d}{N_t^d}$, where e_t^d is the number of people employed and N_t^d is the total population. There are no data on hours worked per capita (h_t^d), so we fix $h_t^d = 1$ for the entire sample. Each data series is in real per capita terms and linearly detrended before estimation.

The data spans the period 1960–2017 (at an annual frequency) and the specific data series used are the following (the mnemonic for each variable is in parentheses): from the WDI dataset, we obtained gross domestic product (NY.GDP.MKTP.KN), GDP deflator (NY.GDP.DEFL.ZS), gross capital formation (NE.GDI.TOTL.CN), final consumption expenditure (NE.CON.TOTL.CN), and working population (aged 15–64) (SP.POP.1564.TO.ZS). Our total employment data (emp) was obtained from the Penn World Tables (PWT) dataset.

All variables in the resource constraint were transformed into real per capita terms so that y_t^d, for example, is the gross domestic product deflated by the GDP deflator and divided by the working population (aged 15–64). c_t^d is the final consumption expenditure deflated by the GDP deflator and divided by the working population (aged 15–64), and x_t^d is gross capital formation deflated by the GDP deflator and divided by population (aged 15-64). And our labor data (l_t^d) is total employment

9 We ignore discussions on potential sources of the four wedges in this study. They are widely discussed in the literature.

divided by the working population (aged 15-64). The HP-filtered cyclical components of the data—y_t^d, x_t^d, l_t^d, and c_t^d—are shown below in Fig. 6.

Stochastic processes

Stochastic random events ($s_t \in s^t$) are assumed to follow a VAR(1) process. Thus,

$$s_t = P_0 + Ps_{t-1} + \epsilon_t,\ \epsilon_t \sim_{iid} N(0, V),\ \ -M \le \epsilon_t \le M, \tag{8}$$

where $s_t = [s_{zt} = z_t(s^t),\ s_{lt} = \tau_{lt}(s^t),\ s_{xt} = \tau_{xt}(s^t),\ s_{gt} = g_t(s^t)]'$. In Chari et al. (2007), s_{gt} is estimated directly from the data, while in this study, it is estimated from the model since our government consumption (plus net exports) data contains negative values, and hence we cannot take logs.

Equilibrium conditions

The equilibrium conditions of the model (forming the non-stochastic block of the model) are summarized below.

$$\begin{aligned}
&\left(c_t\right) + \left(g_t\right) + \left(1 + \gamma_z\right)\left(1 + \gamma_n\right)\left(k_t\right) - (1 - \delta)\left(k_{t-1}\right) = \left(y_t\right)\\
&\quad \left(1 + \gamma_z\right)\left(1 + \gamma_n\right)\left(k_t\right) = \left(x_t\right) + (1 - \delta)\left(k_{t-1}\right)\\
&\quad \left(y_t\right) = \left(\left(z_t\right)\left(l_t\right)\right)^{1-\alpha}\left(k_{t-1}\right)^{\alpha}\\
&\quad \frac{\psi\left(c_t\right)}{1 - \left(l_t\right)} = \left(1 - \tau_{lt}\right)\left(w_t\right)\\
&\quad \left(1 + \tau_{xt}\right)\left(c_t\right)^{(-\sigma)}\left(1 - \left(l_t\right)\right)^{\psi(1-\sigma)} = \hat{\beta} E_t(\left(c_{t+1}\right)^{(-\sigma)}\left(1 - \left(l_{t+1}\right)\right)^{\psi(1-\sigma)}\big[\\
&\quad (1 - \delta)\left(1 + \tau_{xt+1}\right)\\
&\quad + \left(l_{t+1}\right)^{1-\alpha}\left(l_t\right)^{(-\alpha)}(1 - \alpha)\left(k_{t-1}\right)^{\alpha}\big].
\end{aligned}$$

The other block of the model—the stochastic block (i.e., Eq. 8)—is shown below. These two blocks, together, form a state-space model.

$$\begin{aligned}
z_t &= P_0{}^{z} + P_{zz} z_{t-1} + P_{zl}\tau_{lt-1} + P_{zx}\tau_{xt-1} + P_{zg} g_{t-1} + \varepsilon_t^{z},\\
\tau_{lt} &= P_0^{\tau l} + P_{lz} z_{t-1} + P_{ll}\tau_{lt-1} + P_{lx}\tau_{xt-1} + P_{lg} g_{t-1} + \varepsilon_t^{\tau_l},\\
\tau_{xt} &= P_0^{\tau x} + P_{xz} z_{t-1} + P_{xl}\tau_{lt-1} + P_{xx}\tau_{xt-1} + P_{xg} g_{t-1} + \varepsilon_t^{\tau_x},\\
g_t &= P_0{}^{g} + P_{gz} z_{t-1} + P_{gl}\tau_{lt-1} + P_{gx}\tau_{xt-1} + P_{gg} g_{t-1} + \varepsilon_t^{g}.
\end{aligned}$$

Estimation strategy

Our estimation methodology is similar to the one used in Otsu (2010). First, given the parameters in the non-stochastic block of the model $(\alpha, \delta, \beta, \sigma, \gamma_n, \gamma_z, \psi)$, we estimate the parameters in the stochastic block of the model using a maximum likelihood estimator (MLE) and the actual observed data for Ghana's economy (i.e., c_t^d, x_t^d, y_t^d, l_t^d). Second, we compute the steady-state values of the model and initialize capital to its steady-state value. We then compute a series for capital stock (k_t) using the data for investment (x_t^d) and the law of motion for capital.

Using the data (c_t^d, x_t^d, y_t^d, l_t^d) and k_t, we can easily obtain the stochastic processes z_t, g_t, τ_{lt} from the non-stochastic block of the model. To obtain τ_{xt}, however, we need to use the model's decision rule for investment since the Euler equation contains expectations about the future. The decision rule specifies how the endogenous variables (or decision variables) in the model depend on the model's exogenous state variables $(k_t, z_t, g_t, \tau_{lt}, \tau_{xt})$. In this case, the decision rule for investment can be written as,

$$x_t - x_{ss} = m_0(k_t - k_{ss}) + m_1(z_t - z_{ss}) + m_2(g_t - g_{ss}) + m_3(\tau_{lt} - \tau_{lss}) + m_4(\tau_{xt} - \tau_{xss}), \tag{9}$$

where $k_{ss}, z_{ss}, \tau_{lss}, \tau_{xss}$ are steady-state variables and m_0, m_1, m_2, m_3, m_4 are decision rule coefficients. Equation 9 can be used to compute τ_{xt} since all variables and parameters are known, except for τ_{xt}.

Having computed series for the distortions $z_t(s^t)$, $\tau_{lt}(s^t)$, $\tau_{xt}(s^t)$, and $g_t(s^t)$, the wedges (i.e., $Xw_t(s^t)$, $Gw_t(s^t)$, $Lw_t(s^t)$, $Aw_t(s^t)$) as defined in Sect. 4.2, can then be computed[10]. To predict endogenous variables like output, we can plug each individual wedges (or a combination of them) into the model while keeping other wedges (which are not of interest) constant at their steady-state values. When all four wedges are plugged into the model, the model's predictions of the endogenous variables exactly match the data.

Calibration

To simulate the model, we estimate the parameters in the stochastic block of the model (P_0, P) using the maximum likelihood estimator. The remaining parameters $(\alpha, \delta, \beta, \sigma, \gamma_n, \gamma_z, \psi)$—in the non-stochastic block of the model—however, are calibrated. We set the capital income share (α) to 0.4. Based on the literature, the value of α for sub-Saharan African (SSA) economies appears not to be very different from that of developed economies. Jones (2016), for example, sets α to 1/3 for Kenya and Malawi and other developed economies. Collins et al. (1996) sets α to 0.35 for non-industrial economies (including SSA economies), which they consider a relatively low estimate. Tahari et al. (2004) sets α to 0.4 in their growth accounting exercise for SSA economies, including Ghana, and Geiger et al. (2019) set α to 0.4 in their growth accounting exercise for Ghana. The value of α used in this paper is based on

[10] An alternative way to compute the wedges is via Bayesian estimation, where they can be estimated using the Kalman filter (see, for example, Pfeifer (2021))

Table 3 Calibrated Parameter Values

Parameters	Value	Source
β	0.960	Based on an estimated DSGE for Ghana by Takyi and Leon-Gonzalez (2020)
α	0.400	Based on previous studies for Ghana by Geiger et al. (2019) and Tahari et al. (2004)
ψ	2.000	Standard value in the literature
δ	0.057	Based on Penn World Tables data for Ghana
γ_z	0.006	Based on GDP data for Ghana
γ_n	0.026	Based on population data for Ghana

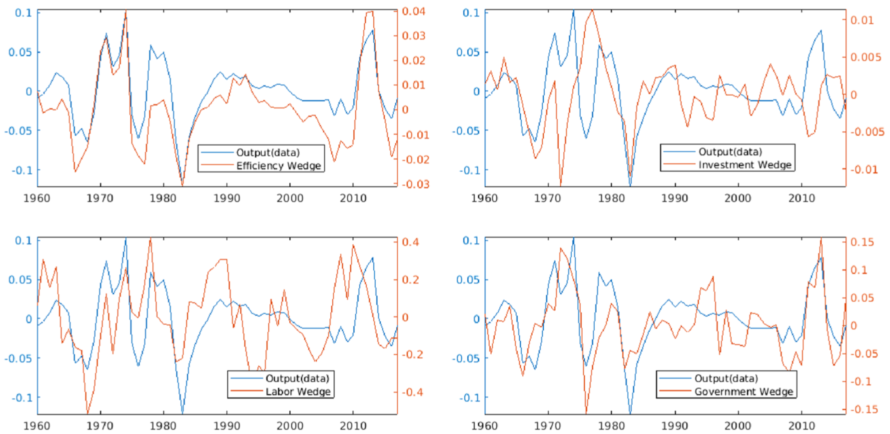


Fig. 7 Estimated HP-filtered wedges and observed output

this literature, making our study consistent with existing studies. Besides, we do not have any empirical evidence to suggest that α is much lower or much higher than what is being used in the literature.

We set ψ to 2, a little lower than the value used in Chari et al. (2007). The population growth rate parameter $\left(\gamma_n = \left(\frac{\mathrm{pop}_t}{\mathrm{pop}_0}\right)^{\frac{1}{n}} - 1 = 0.0258\right)$ is computed using Ghana's population data from 1960 to 2017. We set δ to 0.057, which is the average annual depreciation rate of capital for Ghana in the Penn World Tables (PWT) data. As a standard procedure in the business cycle accounting literature, we calibrate the growth rate of technological progress (γ_z) to 0.006 so that the mean of detrended log output per capita is zero. Lastly, we set $\beta = \frac{\hat{\beta}}{1+\gamma_z}$, where $\hat{\beta} = 0.96$ (based on previous studies for Ghana), and we set $\sigma = 1$ (implying the utility function specified in Eq. 1 reduces to $U(s^t) = \log c_(s^t) + \psi \log(1 - l_t(s^t))$). Later, we estimate these parameters as part of our robustness checks and sensitivity analysis in Sect. 6 (Table 3).

Table 4 Correlation and volatility for HP-filtered wedges and observed output

	$Aw_t(s^t)$	$Xw_t(s^t)$	$Lw_t(s^t)$	$Gw_t(s^t)$	Output	(σ_W)
$Aw_t(s^t)$	1					0.0154
$Xw_t(s^t)$	−0.0792	1				0.0043
$Lw_t(s^t)$	0.1847	0.4716	1			0.2085
$Gw_t(s^t)$	0.7019	−0.3902	−0.1394	1		0.0586
Output	0.8862	0.1502	0.3755	0.6361	1	0.0397

Simulation results

Estimated HP-filtered wedges and observed output

In this section, we discuss the statistical properties of each estimated wedges and how they relate to other wedges and observed output. It is important here to reiterate the distinction between wedges (i.e., $Xw_t(s^t)$, $Gw_t(s^t)$, $Lw_t(s^t)$, $Aw_t(s^t)$), distortions ($z_t(s^t)$, $\tau_{xt}(s^t)$, $\tau_{lt}(s^t)$, $g_t(s^t)$), and shocks ($\varepsilon_t = (\varepsilon_t^{\tau_x}, \varepsilon_t^{\tau_l}, \varepsilon_t^{z}, \varepsilon_t^{g})$). Shocks drive the distortions, which then drive the wedges.The estimated HP-filtered wedges and observed output are shown in Fig. 7 (the series are filtered using a smoothing parameter of 100 as suggested by the literature for annual data). Table 4 shows the correlation among the wedges, the correlation between output and the wedges, and the volatility of each wedge. The labor wedge is the most volatile, suggesting large shocks hitting the labor supply over the entire sample (see Fig. 16). We also find that the labor wedge weakly correlates with output, particularly after the mid-1980s. This suggests that structural explanations for fluctuations in the labor wedge (for example, attributing it to specific primitive shocks) should not be strongly correlated with output. In table 4, we also see that the same is true for the investment wedge, which is also weakly associated with output over the entire sample. It should, however, be noted that for specific episodes of the business cycle, like the 1980s recessionary episode, the correlation between the investment wedge and output is relatively stronger.

In contrast to the labor and investment wedges, the estimated efficiency and government consumption wedges are strongly correlated with output over the entire sample, suggesting that promising structural explanations of these two wedges should also be strongly associated with fluctuations in output. For example, suppose one believes that certain primitive shocks like government spending or political shocks are the drivers of $Gw_t(s^t)$ and $Aw_t(s^t)$. Then, in that case, such primitive (or structural) shocks should also be strongly associated with fluctuations in output. Christiano and Davis (2006), for example, link specific structural shocks to the estimated wedges via the following relationship,

$$\varepsilon_t = Ce_t, \tag{10}$$

where ε_t are the shocks driving the distortions in the BCA model (with no structural interpretations), and e_t are the primitive or structural shocks of interest (also referred to as fundamental economic shocks). Using our BCA model, we have only

Table 5 Correlation matrix for structural shocks

	ε_t^z	$\varepsilon_t^{\tau_x}$	$\varepsilon_t^{\tau_l}$	ε_t^g
ε_t^z	1			
$\varepsilon_t^{\tau_x}$	−0.0184	1		
$\varepsilon_t^{\tau_l}$	−0.1654	0.4976	1	
ε_t^g	0.5009	0.3649	0.2119	1

Table 6 Standard deviations and correlations between predicted output and observed output (1960–2017)

Standard Deviations		Correlations					
σ_{Y_A}/σ_Y	$\sigma_{Y_{\tau_l}}/\sigma_Y$	$\sigma_{Y_{\tau_x}}/\sigma_Y$	σ_{Y_g}/σ_Y	$\rho_{Y_A,Y}$	$\rho_{Y_{\tau_l},Y}$	$\rho_{Y_{\tau_x},Y}$	$\rho_{Y_g,Y}$
0.58	0.91	1.38	2.42	0.95	0.080	0.19	0.14

identified ε_t and not e_t. While we leave the identification of e_t for future research, we can infer the following. First, any promising candidate(s) in e_t that are believed to explain movements in ε_t^z and ε_t^g (and hence efficiency and government consumption wedges) need to be strongly associated with changes in output. Second, any promising candidate(s) in e_t that are believed to explain movements in $\varepsilon_t^{\tau_x}$ and $\varepsilon_t^{\tau_l}$ (and hence investment and labor wedges) need not be strongly associated with changes in output based on our results. Note that the correlations in Table 4 do not indicate the relevance of the wedges in explaining the fluctuations in output (see Brinca et al. 2020). Rather, they only hint to researchers regarding promising structural explanations for the estimated wedges (ε_t). However, this is not the main goal of this research, so we leave that for future studies.

Table 5 shows the correlation matrix for the four identified shocks. The estimated correlation coefficients are generally low except for the correlation coefficient between the efficiency wedge and the government consumption wedge. We consider these uneven and generally low correlation coefficients to indicate that the innovations ε_t driving the wedges (in the model) are likely not overlapping combinations of a given set of fundamental economic shocks (e_t).

Relevance of the wedges over the entire sample

This section discusses the importance of the four wedges in accounting for output fluctuations over the entire sample—1960–2017. Following the literature, we simulate 'one-wedge-on' model economies[11] and compare the simulated output with the observed output. Following Brinca et al. (2016), we use the correlation coefficients between the simulated output(s) and observed output as our primary measure of the relevance of the wedges over the entire sample. We also report the relative volatility between the simulated output(s) and observed output, which we only consider as secondary measures of the relevance of the wedges.

[11] Thus, we feed the estimated distortions ($z_t(s^t)$, $\tau_{xt}(s^t)$, $\tau_{lt}(s^t)$, $g_t(s^t)$) one at a time into the model, holding the other distortions constant—which is same as holding all wedges constant except for one wedge.

The results suggest that, over the entire sample, the efficiency wedge is the most important wedge accounting for short-run movements in Ghana's output. The estimated correlation coefficient between actual and simulated output (using just the efficiency wedge, i.e., ρ_{Y_A}/ρ_Y) is about 0.95, and the relative volatility is about 0.58. In contrast, the volatility of the simulated output due to the other three wedges—i.e., labor, investment, and government consumption wedges—are relatively more volatile (about 0.91, 1.38, 2.42 respectively). However, they are all less correlated with observed output, with a correlation coefficient lower than 0.15 (Table 6).

These results suggest a limited role of external shocks (captured via the government consumption wedge) in driving output fluctuations in Ghana. Thus, commodity price shocks and shocks emanating from the international financial market may be important in other areas of the Ghanaian economy. However, our results suggest they are less relevant regarding Ghana's short-run aggregate output fluctuations. This is true even before the mid-1980s, when Ghana's business cycle was very volatile (see Table 11 in the appendix). Thus, external shocks contributed little to Ghana's economic fluctuations during this period (i.e., from 1960 to 1984). Our results also suggest that external shocks played no significant role in Ghana's business cycle moderation which started in the mid-1980s until about 2010. Given that the government consumption wedge comprises both government spending and net export, our results suggest that government spending shocks are not significant drivers of Ghana's post-independence business cycle.

In the subsequent sub-sections, we analyze two pivotal phases in Ghana's business cycle: the early 1980s economic downturn and the 2011 oil boom. Our findings highlight the importance of domestic factors, particularly domestic productivity shocks, over external factors. These results challenge the commonly held perception that external shocks are potential (if not primary) drivers of Ghana's business cycle. Certainly, Ghana is an open economy, as no economy is a complete autarky. However, its business cycle is mostly driven by domestic factors, as we have shown. In terms of building a structural model of economic fluctuations for Ghana's economy, these results suggest that a closed-economy model may suffice.

In the subsequent sub-sections, we provide an in-depth analysis of two pivotal phases in Ghana's business cycle: the early 1980s economic downturn and the 2011 oil boom. Between 1978 and 1983, Ghana witnessed its longest and most severe economic contraction since gaining independence. Scholars have attributed this slump to various factors, including the severe droughts in 1982 and 1983, the 1982 global recession (which resulted in the Western nations losing interest in Ghana's economy), ineffective government policies, and the return of around one million Ghanaians from Nigeria, among other factors.

Not many researchers have attributed the 1980s recession to domestic investment-related factors. However, Figs. 6, 7 and 8 all suggest that investment-related factors might have dominated that particular recession relative to other factors. In Fig. 7, for example, the decline in the investment wedge between 1978 and 1983 was the deepest among the four wedges. Moreover, we can also observe in Fig. 8 that the decline in the simulated output (when only the investment wedge is active in the model) is the deepest from 1978 to 1983. The correlation coefficient between the simulated output (when only the investment wedge is active in the model) and actual output is

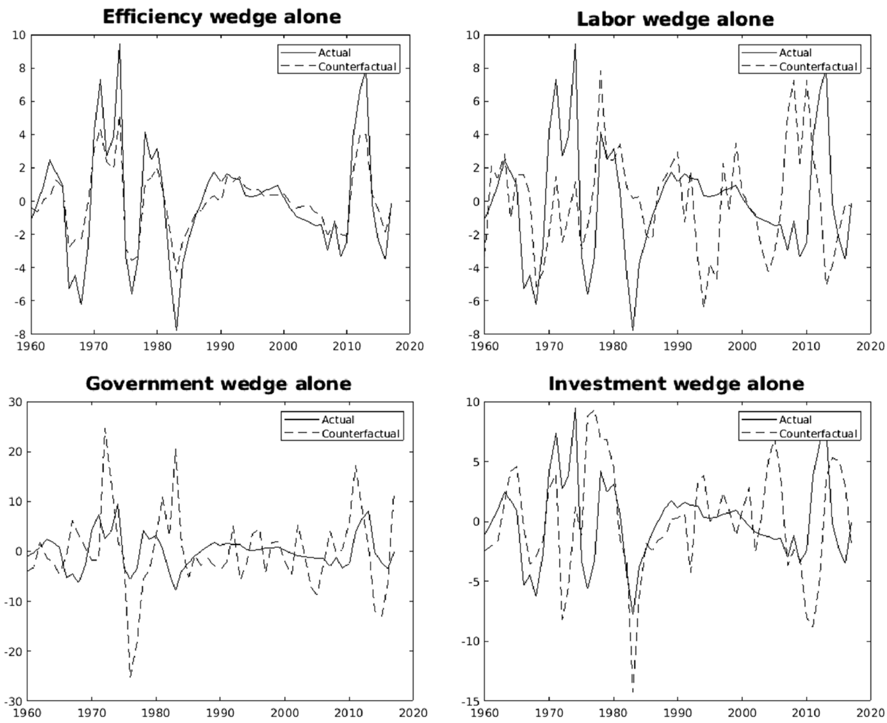


Fig. 8 Predicted output (using one-wedge-on model economies) and observed output. All series are logged and HP-filtered

stronger between 1978 and 1988—about 0.91—and weaker in the other periods of the business cycle[12]. In the next subsection, we examine the role of the investment wedges relative to other wedges during the 1980s economic contraction.

Also, in Fig. 7, we can observe a strong correlation between the efficiency wedge and actual output, and also between the government consumption wedge and actual output during the 2011 oil expansion. But, how should one capture this boom (in Ghana's oil sector) in a structural macroeconomic model for Ghana's economy? In Gottschalk et al. (2010), for example, the authors captured it as a shock to government spending in their DSGE model for Ghana's economy. However, one may also capture it as productivity shocks which will affect the designing of appropriate policy tools to mitigate the negative impact of such shocks. In Sect. 5.1, we show that it is better to capture the 2011 economic boom as productivity shocks than as government spending shocks.

[12] In the right-bottom plot of Fig. 8, the correlation coefficient between the simulated out (when only the investment wedge is active in the model) and actual output is about 0.31 between 1960 and 1984, 0.92 between 1978 and 1988, and – 0.004 between 1985 and 2017.

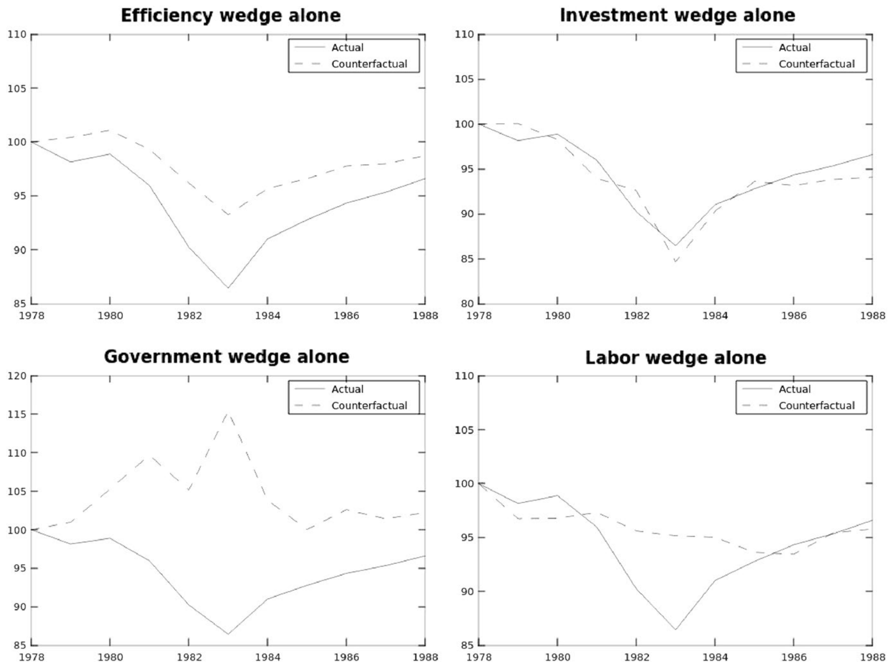


Fig. 9 Model vs data: output during the 1980s recession (1978 = 100)

1980s recession

In the 1980s (just before Ghana's business cycle great moderation), Ghana experienced what could be considered its longest and deepest recession since its independence. As discussed above and also in Kraus (1991), the cause of the recession was allegedly due to a combination of factors. This section examines which wedges were instrumental during this period (specifically, from 1978 to 1988).

In Fig. 9, we plot observed output against simulated output using the 'one-wedge-on' model economies[13]. The results show that the 1980s recession was driven mainly by the investment wedge, contributing about 71.47% of the recession. Thus, although the efficiency wedge is the most important over the entire sample, it played a lesser role during the 1980s recession. In many growth accounting models for Ghana's economy, many authors have attributed the switch in Ghana's long-run economic growth (from negative to positive) to a change in productivity growth caused by the 1983 economic reform programs. However, the short-run fluctuations in the business cycle during this period were mainly due to the investment wedge. Indeed, the 1978–1988 episode of the business cycle seems to be the only period over the entire sample that the investment wedge was the dominant factor, contributing the most to the fluctuations in the business cycle. We suggest that calibrated structural

13 'One-wedge-off' model economies are shown in the appendix.

Table 7 Contribution of each wedge (%)

ϕ Statistic	ϕ_A	ϕ_{τ_l}	ϕ_{τ_x}	ϕ_g
1983 recession				
One wedge economies	12.20	15.12	71.47	1.21

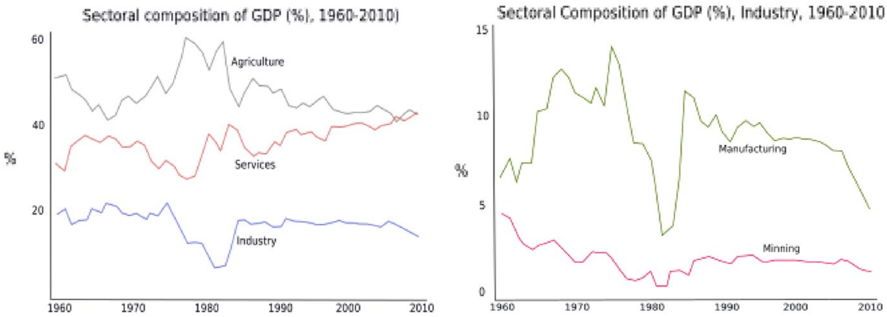


Fig. 10 Characteristics of Ghana's economy during the 1980s recession. Source: Jedwab and Osei (2012)

models that seek to study Ghana's business cycle during this period should focus on frictions that manifest mainly as investment wedges in the prototype BCA model.

For a more rigorous quantitative analysis of the contribution of the wedges to the recession, we use the quantitative measure mentioned in Brinca et al. (2016)—the ϕ statistic—to measure the contribution of the wedges. The ϕ statistic decomposes fluctuations in observed output into the contribution of each wedge such that the sum of the contributions is equal to one, shown below,

$$\phi_i^Y = \frac{1/\sum_t (Y_t - Y_{it})^2}{\sum_j \left(1/\sum_t (Y_t - Y_{jt})^2\right)}, \tag{11}$$

where $i = (A, \tau_l, \tau_x, g)$, Y_{it} = simulated output from the one-wedge-on model economies where only the *ith* wedge is variable, and $\sum_j \left(1/\sum_t (Y_t - Y_{jt})^2\right) = 1/\sum_t (Y_t - Y_{At})^2 + 1/\sum_t (Y_t - Y_{\tau_l t})^2 + 1/\sum_t (Y_t - Y_{\tau_x t})^2 + 1/\sum_t (Y_t - Y_{gt})^2$. In effect, ϕ_i^Y is the inverse of the mean-squared error for each wedge appropriately scaled so that $\phi_A^Y + \phi_{\tau_l}^Y + \phi_{\tau_X}^Y + \phi_G^Y = 1$ (see Brinca et al. 2016). The results, shown below, suggest that the investment wedge contributed about 71.47 percent to output movements during the 1980s recession while the efficiency wedge contributed only about 12.20 percent (Table 7).

Among the three sectors of Ghana's economy, the industrial sector experienced the largest decline during the 1980s recession, primarily caused by a large decline in manufacturing. Our results suggest that this decline in manufacturing was not primarily due to the efficiency wedge or unfavorable productivity shocks as mentioned in Jedwab and Osei (2012), but instead, it was driven by the investment wedge. Thus, the investment-financing frictions in the economy at the time (Fig. 10).

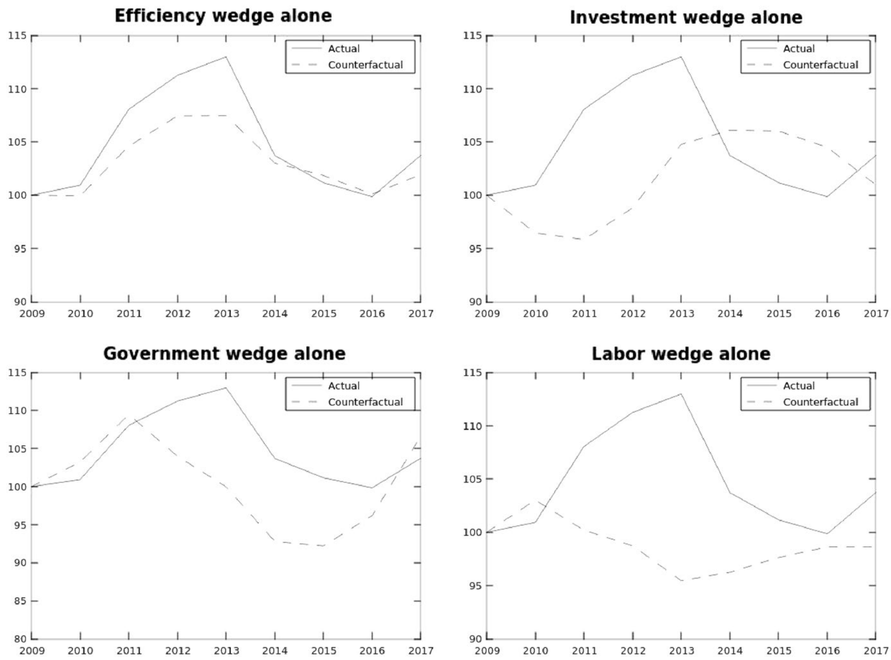


Fig. 11 Model vs data (2009 = 100)

Table 8 Contribution of each wedge (%)

ϕ Statistic	ϕ_A	ϕ_{τ_l}	ϕ_{τ_x}	ϕ_g
2009 expansion				
One wedge economies	72.63	7.17	10.18	10.02

2009 expansionary episode

Since 2009, Ghana's business cycle has become more volatile than in the preceding two decades, and the strong moderation of Ghana's business cycle which started in the mid-1980s, seems to have ended. In this section, we examine the contribution of the four wedges to Ghana's output fluctuations from 2009 to 2017. First, our results suggest that the efficiency wedge played a relatively bigger role, contributing about 72.63 percent of the output fluctuations during this period. Our results indicate that the contributions of the other wedges to Ghana's 2011 oil boom were relatively insignificant. Therefore, it can be contended that a structural model with productivity shocks offers a more effective framework for capturing the dynamics of Ghana's oil boom during this period, as opposed to a structural model with government spending shocks. The government consumption wedge contributed only about 10.2% of the total fluctuations in the business cycle during this period. These results have important implications for designing monetary and fiscal stabilization policies

Table 9 Contribution of each wedge over the entire sample (1960–2017) (%)

ϕ Statistic	ϕ_A	ϕ_{τ_l}	ϕ_{τ_x}	ϕ_g
Entire sample (1960–2017)				
One wedge economies	78.80	10.70	7.58	2.92

for Ghana's economy using structural models like DSGE models. A prerequisite for building such models is knowledge of the main sources of economic fluctuations and which shocks should be used to capture them (Table 8, Fig. 11).

While there has been an increase in Ghana's business cycle volatility since 2011, our results confirm that it is not mainly due to external shocks hitting Ghana's aggregate demand via the trade sector (or the export sector). As shown in Fig. 2, for example, the fluctuations in the business cycle since 2011 are not due to imbalances between Ghana's exports and imports. Thus, these findings, in our opinion, challenge the common notion that external shocks, such as fluctuations in international commodity prices cause a temporary imbalance between Ghana's exports and imports, thereby inducing a short-term deviation of Ghana's output from its long-term trend. Instead, Ghana's business cycle since 2011 is primarily driven by supply-side factors that impact production efficiency—captured as efficiency wedges (in our prototype BCA model) or as productivity shocks (in a detailed business cycle model). The sources of these efficiency wedges or productivity shocks since 2011 may be multifaceted and may have originated from various sources, including the many oil discoveries since 2011 and Ghana's banking crisis which started in 2017 (leading to the closure of more than 400 banking institutions). As discussed in Chari et al. (2007) and Brinca et al. (2020), such financial frictions can also be associated with variations in the efficiency wedge. It should be noted, however, that these are only speculations as our primary goal in this paper is not to unpack the various specific historical events underlying the estimated efficiency wedge.

Over the entire sample, the efficiency wedge explains about 78.80% of the fluctuations in the business cycle while the government consumption wedge explains only about 2.92%. This finding contradicts the commonly held belief that external shocks such as international commodity price shocks are dominant drivers of Ghana's business cycle (Table 9).

Some plausible reasons why international cocoa and gold price shocks do not drive Ghana's business cycle may include the following. First, to mitigate market volatility, the Ghanaian government forward sells a significant portion of Ghana's annual cocoa production each year, about 70–80% (Bymolt et al. 2018; Aidenvironment 2018). This policy protects the cocoa industry and Ghana's economy as a whole from unforeseen cocoa price fluctuations. Second, regarding gold price shocks, many of the gold companies operating in Ghana are foreign-owned, and hence a large proportion of their profits (in USD) are repatriated back to their home countries rather than being retained and converted to Ghana cedis (Adu and Owusu 2018). Undoubtedly, this weakens the amplification channel via which gold price shocks affect Ghana's business cycle.

Table 10 Prior and Posterior distributions

Params	Dist.	Prior Mean	Posterior Mean	90% HPD inf	90% HPD sup
β	Normal	0.960	0.9767	0.9767	0.9768
α	Beta	0.400	0.4086	0.4066	0.4102
ψ	Normal	2.000	2.9713	2.9432	2.9942
δ	Normal	0.057	0.0100	0.0100	0.0110

Robustness checks and sensitivity analysis

In our model calibration in Sect. 4.5, we set ψ to 2, which is a little lower than the value used in Chari et al. (2007). There is no consensus in the literature on whether labor disutility is relatively higher or lower in developing and less-developed economies than in developed countries. Different societies may have different cultural attitudes towards work, which are not easily quantifiable. One could argue, for example, that government-sponsored social safety nets—such as unemployment insurance—are almost non-existent in less-developed economies. Hence, households in such economies would tend to have lower labor disutility relative to households in developed economies. Moreover, there also tend to be limited job opportunities in less-developed economies, suggesting a limited dislike for work than in advanced economies. While these arguments support lower labor disutility in less developed economies, others have argued otherwise that less developed economies tend to have informal or traditional social safety nets that may encourage dislike for work, leading to a higher labor disutility. Given the lack of consensus on the topic, we set ψ to 2 in Sect. 4.5, which is largely standard in neoclassical growth and business cycle models. In this section, we consider other parameterizations of our BCA model.

First, we consider other parameterizations of ψ based on a study by Bick et al. (2018). In Bick et al. (2018), the authors use the equilibrium labor supply equation ($h_t = f(\psi, \Omega, X_t)$) of the basic neoclassical growth model to study how hours worked vary with income across countries. They did not report values for ψ for the different countries in their paper. However, they presented data on the other parameters in the model (which is Ω), and on the other macroeconomic variables in the equilibrium labor supply equation (X_t). Hence, one can infer the value of ψ for the countries considered in their analysis, including Ghana. Comparing the inferred value of ψ for Ghana and the US, we found that the value of ψ for Ghana exceeded that of the US by about 43.57%—which is an indication of a higher labor disutility in Ghana than in the US. Given that Chari et al. (2007) set $\psi = 2.24$ for the US in their BCA model, we set $\psi = 3.216$ for Ghana (keeping the other parameters in Sect. 4.5 unchanged). This modification of ψ had no significant effect on our main results.

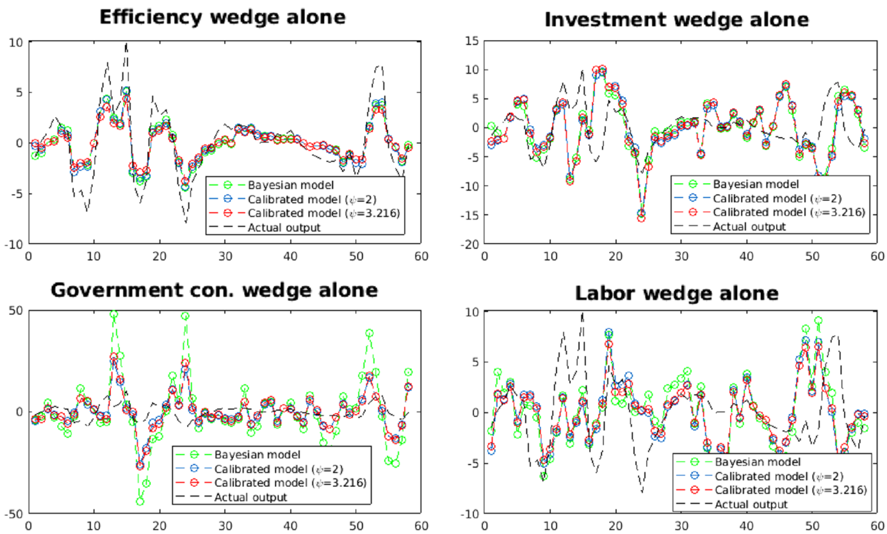


Fig. 12 Predicted output (using one-wedge-on model economies) and observed output. All series are logged and HP-filtered

Lastly, we also estimate the parameters β, α, ψ, and δ of our BCA model using Bayesian methods[14] to further check for the robustness of our results. The estimated parameters are presented in Table 10 below.

In Fig. 12, we plot the simulated outputs from our 'one-wedge-on' model economies for each of our three models: i.e., the model with $\psi = 2$, the model with $\psi = 3.216$, and the model with Bayesian estimated parameters. We do not observe big differences in the results across the three models. Thus, regarding which wedges drive Ghana's business cycle. For the entire sample, the efficiency wedge is the dominant factor driving Ghana's business cycle across the three models. All of our earlier results hold up, and they are robust to changes in the parameters in the model.

Conclusion

External factors may be an important driver of economic fluctuations in less-developed countries (LDCs). However, not all LDCs are the same and there are some LDCs that do not fit this widely held belief. In this paper, we have demonstrated that external factors—captured by the government consumption wedge in a business cycle accounting (BCA) model—play an insignificant role in Ghana's short-run output fluctuations. The same results can be observed both during times of heightened economic instability and during times of reduced economic instability during Ghana's post-independence business cycle. These results imply that Ghanaian

[14] A full description of the Bayesian estimation method is beyond the scope of this paper.

policymakers may need to focus less on policies designed to mitigate the impact of external shocks on Ghana's economy, and instead focus more on policies aimed at building resilience to domestic shocks, particularly, domestic productivity shocks.

Since 2011, Ghana's business cycle has become more volatile after it began producing crude oil in commercial quantities. In building a structural model of economic fluctuations for this episode of the business cycle, our results suggest that capturing these shocks as productivity shocks may be more appropriate than capturing them as government spending shocks as some have done in the literature. The specification of shocks has significant implications for model development, particularly with regard to the design of optimal monetary and fiscal policies geared toward output stabilization.

Lastly, our results suggest that a closed-economy model may suffice for modeling Ghana's economy although Ghana is a heavy exporter of commodities. In the data, external shocks seem to affect Ghana's short-run export and import fluctuations in the same manner (i.e., both direction and magnitude), making external shocks less significant in driving Ghana's output fluctuations. One key implication of these observations is that an open-economy model designed for Ghana's economy should incorporate frictions that account for similar fluctuations in exports and imports following an external shock to the import or export sector. Future work is needed to construct such a model. Overall, these results have important implications for the open macroeconomic literature. In particular, for some commodity-dependent economies, shocks to the import and export sectors seem to be related rather than occurring in isolation.

Our study has several limitations, including the fact that the government consumption wedge includes both government spending and net exports. Nonetheless, if net exports mattered for Ghana's business cycle fluctuations, they would have been captured by the model.

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Data Availability The datasets analyzed during the study are available at https://github.com/EmmanuelAmeyaw. It contains PWT and WDI datasets for Ghana's economy.

Declarations

Conflict of interest This study received no grant, and the authors have no financial interest in any material discussed in this article.

Ethical approval No human participants were used in this research.

Informed consent Not applicable.

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