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Harnessing Oil Revenues in Ghana

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Harnessing Oil Revenues in Ghana*

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Abstract

Ghana has recently started producing oil from the offshore Jubilee field. This paper addresses the question of how Ghana should best harness these oil revenues. This is done in two sections. In the first, it considers whether Ghana should spend or save the windfall, comparing spending rules under a range of assumptions to the permanent income (PI) benchmark. On balance we find that Ghana should bring spending further forward than is suggested under PI, to promote development. In the second, it considers how the windfall should be used, comparing the alleviation of capital scarcity, accumulation of foreign assets and investment in domestic public capital to boost growth and development. We find that the problem of capital scarcity should be alleviated first if Ghana is facing a premium on borrowing costs. The remainder of the windfall should primarily be used to invest in domestic capital, but some funds may temporarily be parked in foreign assets if there are absorption constraints in the non-traded sectors.

1 Introduction

Ghana has recently started producing oil from the offshore Jubilee field. This field straddles two licenses: Deepwater Tano and West Cape Three Points, off Ghana's western coast as illustrated in Figure 1. Estimates of Ghana's total commercial oil reserves lie between 780 and 4000 million barrels. However, these estimates vary widely and are being revised frequently. In Appendix 7.1 we construct an estimate based on a single source from the Jubilee field's unit operator, Tullow Oil, that provides the most comprehensive picture of the entire find. Based on current proven reserves, production from the Jubilee field is expected to peak from 2013-2015 at 120,000 barrels of oil per day, and last for 20 years (Oil, March 2011). This has the potential to generate up to USD 1.8 billion per annum at peak production, as illustrated in Figure 2.

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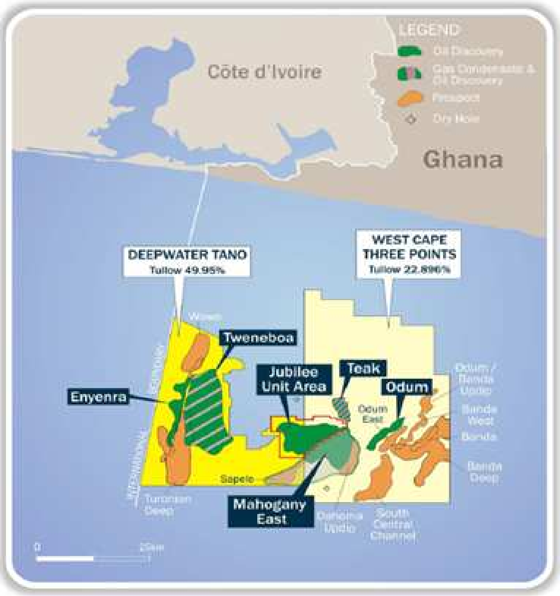


Figure 1: Ghana's Jubilee field straddles two licenses: Deepwater Tano and West Cape Three Points (source: Tullow Oil, 2010)

Ghana's oil reserves are relatively small on a global scale. Even if these reserves are ultimately at the upper end of estimates they will still place Ghana approximately 50th in the world by proven oil reserves. Ghana's potential 4 billion barrels are significantly below those of major oil producers such as Saudi Arabia with 265 billion, Canada with 175 billion, Venezuela with 98 billion and Nigeria with 38 billion. When considered in terms of oil per capita, at 160 barrels of oil per person Ghana's deposits are far less than those of Kuwait with 40,000 bopp, Saudi Arabia with 10,000 bopp, Venezuela with 3,500 bopp and Nigeria with 240 bopp (CIA, 2011).

However, due to Ghana's current levels of income, the reserves are likely to comprise a relatively significant proportion of its GDP. If most of Ghana's estimated reserves are accessible then Figure 3 shows it will be approximately fifteenth in the world by barrels of oil per dollar of GDP, roughly on par with Angola and Nigeria (CIA, 2011). When considered as a proportion of the Ghanaian government's annual income, production from the Jubilee field at its peak will generate up to 30% of the government's income, if oil is at $75/barrel, based on our analysis. As shown in Figure 2, the major part of government income is income tax. The additional oil entitlement and GNPC commercial profits are considerable as well, however, royalties are a relatively small component.

To determine the most appropriate strategy for harnessing Ghana's oil windfall, the unique characteristics of the Ghanaian economy must be considered. First, Ghana is a low income country, with GNI per capita of $1,190. It also has both low physical and human capital, with 1 percent and 63 percent of that in the US respectively. Third, Ghana is only at the beginning of the process of structural transformation, with a large and unproductive agricultural sector. The productivity of labour in agriculture is $998 per worker per annum. Fourth, Ghana has a large stock of foreign debt, of 38 percent of GNI in 2009. Fifth, Ghana has relatively high inflation at 9.2 percent (WDI, 2009).

Many oil-rich countries fall into the trap of the natural resource curse and end up with disappointing growth performance (van der Ploeg, 2011). This arises due to to a number

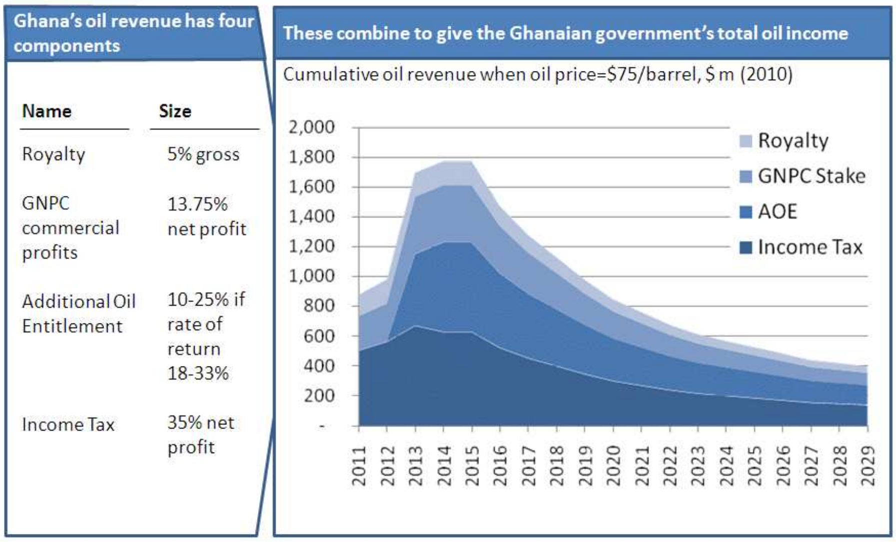


Figure 2: The Ghanaian government's oil income has four components (source: Dessus et al., 2009; Tullow Oil, 2010, team analysis)

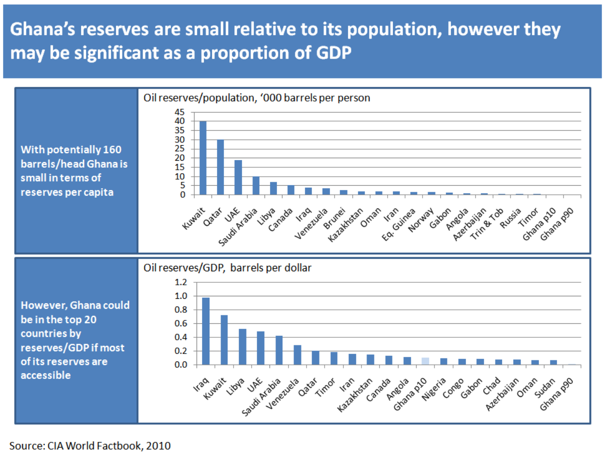
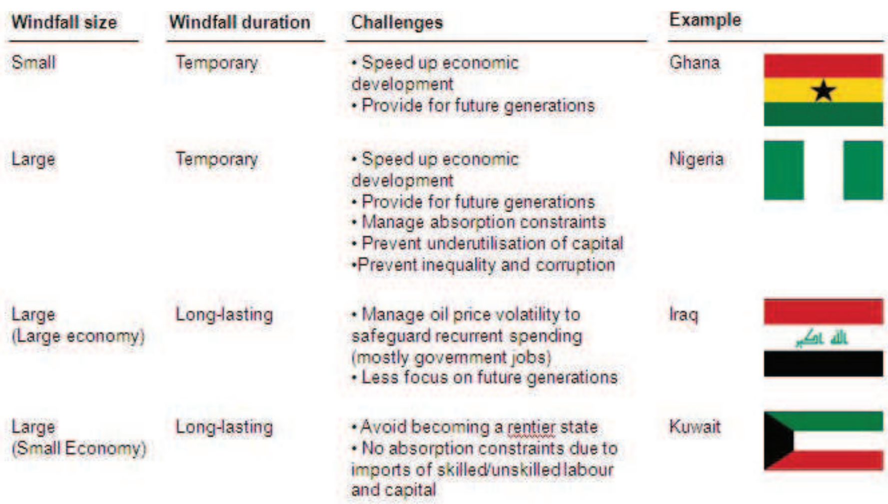


Figure 3: Ghana's oil reserves are small relative to its population, but may be significant as a proportion of GDP.



Windfall size	Windfall duration	Challenges	Example
Small	Temporary	• Speed up economic development • Provide for future generations	Ghana
Large	Temporary	• Speed up economic development • Provide for future generations • Manage absorption constraints • Prevent underutilisation of capital •Prevent inequality and corruption	Nigeria
Large (Large economy)	Long-lasting	• Manage oil price volatility to safeguard recurrent spending (mostly government jobs) • Less focus on future generations	Iraq
Large (Small Economy)	Long-lasting	• Avoid becoming a rentier state • No absorption constraints due to imports of skilled/unskilled labour and capital	Kuwait

Figure 4: Comparison of different types of resource rich countries.

of reasons. First, their manufacturing and agricultural export sectors, such as cocoa in the Ghanaian case, become uncompetitive (Dutch disease). Second, the notorious volatility of oil prices introduces volatility into the economy. Third, natural resource wealth can encourage corruption and worsening of the quality of institutions, and sustain bad policies such as excessive borrowing, subsidizing uncompetitive industries, fuel subsidies and over investing in partisan projects. The challenge should be to use the oil wealth to promote growth.

Thus, Ghana's small and temporary windfall presents a particular set of policy challenges. Ghana must harness its oil revenues to both promote sustainable economic growth and provide for future generations. This differs from countries with a large and temporary windfall, such as Nigeria, which must also focus on managing absorption constraints and preventing inequality and corruption. It also differs from the challenges facing countries with essentially permanent windfalls. When such a country is large, like Iraq, the focus shifts to managing oil price volatility to safeguard recurrent spending on things like government jobs. When such a country is small, like Kuwait, they no longer need to worry about absorption constraints, as labour and capital can be imported, but must try to avoid becoming a rentier state. For a summary of these arguments, see Figure 4.

To address these challenges Ghana must consider all aspects of its oil production: from initial extraction to final depletion. This paper focuses specifically on the strategic options facing Ghana's government, once the revenues have been received. In doing so this paper addresses two major questions: first, whether to spend or save the oil windfall revenue, and second, how it should be spent or saved.

In the next section, this paper addresses the question of whether Ghana should spend or save its windfall. The distinction between spending and saving is a simplification, which helps to clarify the analysis. In its purest sense spending is domestic consumption, which yields a benefit in the current period. Saving can be considered as investment in foreign assets, which yield benefits in the future. This abstracts from the case of investment in domestic assets as it has characteristics of both spending and saving: in the short term it leads to consumption through wage income, and in the long term it yields benefits through accumulating capital. Investment in domestic assets, and how this can promote growth and development, is considered in Section 5.

To determine the balance between spending and saving we compare spending rules under different assumptions. The decision to spend or save lies on a spectrum, from spending all revenues immediately to saving all revenues and consuming only the permanent income. We determine how a series of assumptions alter the results of the permanent income hypothesis and, on balance, find that spending should be brought slightly forward. We then use this analysis as a basis for evaluating Ghana's Petroleum Revenue Management Act, 2011. We find that the Act may be weighted too heavily towards short-term spending, particularly given Ghana's stock of outstanding debt, which may be affecting the cost of borrowing. If the windfall is to be spent in this way, then it should be allocated to building public capital and reducing distortionary taxation, to stimulate private investment.

In the third section, this paper addresses the question of how Ghana should spend or save its windfall. We focus on investment and in doing so consider three options: alleviating capital scarcity, accumulating foreign capital and accumulating domestic capital.

We find that Ghana should first reduce the stock of foreign debt, to lower the cost of borrowing, and alleviate capital scarcity. Some of the remaining windfall may temporarily be parked in foreign assets, if there absorption constraints in the non-traded sectors. However, the majority of the remaining windfall should be used to invest in domestic capital. This is elaborated in Sections 4 and 5.

In Section 4 we address the question of what is driving Ghana's low growth rate. Using the method of growth accounting we show that, while TFP growth has played an increasing role in Ghana's overall growth, capital accumulation has made a very small contribution to GDP growth. This suggests that Ghana is far away from its steady state, so to capture the effects of oil on the economy we must capture its transition path. This is modelled in Section 5.

Section 5 uses a three-sector model of structural transformation to show that the oil windfall is a once in a lifetime opportunity to boost the capital stock and increase growth rates. This model addresses the issue that, as Ghana is far from its steady state, standard business cycle models that are appropriate for richer countries are not appropriate for Ghana. Calibrating the model to Ghana we show that, in the presence of an oil shock, domestic capital should be consumed before, and quickly accumulated during the shock, before slowly returning to the non-oil growth path once the shock has finished. The shock will be accompanied by both "Dutch disease" and fluctuations in the real exchange rate. Ultimately, the associated jump in investment will move Ghana more quickly along the path of structural transformation.

2 Should Ghana spend or save its windfall?

This section addresses the question of whether Ghana should spend or save its windfall. The decision to spend or save lies on a spectrum. The spend-all rule, where oil revenue is spent as it is received, lies at one end. The permanent income rule, where spending is perfectly smoothed across all periods, is at the other. Using the permanent income rule as a benchmark we then test various assumptions to determine their effect on the spending profile. Although each of these assumptions could be built into a single model, we isolate each to gain a clearer understanding of their respective importance. The assumptions are then calibrated to the Ghanaian economy to ascertain their practical relevance and show that on balance the forces delaying spending are outweighed by those bringing it forward. Thus, Ghana may best best to spend more in the short-term than is suggested by the permanent income hypothesis, so as to stimulate development. Finally, we evaluate the appropriateness of Ghana's Petroleum Revenue Management Act, which was passed by Parliament in May 2011. We find that it may be weighted too heavily towards short-term spending, particularly given Ghana's stock of outstanding debt, which may be affecting the cost of borrowing. If the windfall is to be spent in this way, then it should be allocated to building public capital and reducing distortionary taxation, to stimulate private investment.

2.1 The spectrum of spending options: benchmarks from spend-all to permanent income

As previously mentioned, the decision to spend or save an oil windfall lies on a spectrum. At one end is the policy of spending only the permanent income received from saving in foreign assets. This can be illustrated with a very simple model of a small open economy facing permanent, temporary and anticipated and temporary oil windfalls. At the other end is the sub-optimal policy of spending all oil income as it is received. Between these two rules is the bird-in-hand rule, which is the form that Norway's often praised resource management plan takes. These rules are then illustrated for Ghana.

The policy of spending only the permanent income received from foreign assets can be illustrated with a simple model of a small open economy. Let the economy borrow or lend unlimited amounts at the exogenous world interest rate r, and hold net foreign assets F. This economy has an exogenous flow of windfall revenue from the sale of natural resources to the rest of the world N, and has constant exogenous non-resource output Y. Its budget constraint is thus $\dot{F} = rF + Y + N - C$, with initial asset holdings F_0. It chooses consumption C and assets F to maximise social welfare, $U = \int_0^\infty \frac{C(t)^{1-1/\sigma}}{1-1/\sigma} e^{-\rho t} dt$ where σ is the elasticity of intertemporal substitution and the rate of time preference is ρ. This gives $\dot{C}/C = \sigma(r - \rho)$. If the interest rate equals the rate of time preference, $r = \rho = 2.5\%$, maximisation subject to the budget constraint yields the intertemporal efficiency condition that consumption should be smoothed over time, so $\dot{C} = 0$.

Let the economy face three types of oil windfall: permanent, temporary and anticipated and temporary. For a permanent windfall, its present value at the date of discovery, $t = 0$, is $V(0) \equiv \int_0^\infty N(t)e^{-rt}dt$. The permanent income flow from this is $rV(0)$. So, the permanent level of consumption is $C = Y + r\left[V(0) + F_0\right]$. The corresponding surplus on the current account equals $\dot{F} = N - rV$. If the windfall is not constant through time, permanent consumption levels are maintained by changing the level of debt/ assets held according to the flow budget constraint. This requires that the non-windfall deficit must equal the return on resource wealth, i.e., $-\dot{F} - N = rV$, because this ensures that total assets $V + F$, and thus consumption, C, are held constant over time. Notice that $V(t) \equiv \int_t^\infty N(s)e^{-r(s-t)}ds$, so $\dot{V} = N - rV$.

For a temporary windfall of $N(t) = \bar{N}e^{-\eta t},\ \eta > 0, \bar{N} > 0$, its present value at the date of discovery is $V(0) = \frac{\bar{N}}{r+\eta}$. The level of foreign assets is $F(t) = \left(1 - e^{-\eta t}\right)\frac{\bar{N}}{r+\eta} + F_0$, and the permanent level of consumption is $C = Y + r\left[\frac{\bar{N}}{r+\eta} + F_0\right]$. The surplus on the current account is $\dot{F} = \eta e^{-\eta t}\frac{\bar{N}}{r+\eta}$. So declining future windfall revenue implies that the economy must transform dwindling mineral wealth V into foreign assets in order to realise a permanent increase in consumption. Indeed, due to gradually declining surpluses on the foreign account, foreign assets gradually increase from F_0 to $F_O + \frac{\bar{N}}{r+\eta}$.

For an anticipated, temporary windfall that begins at time T_0, its present value at the date of discovery is $V(0) \equiv \int_{T_0}^\infty N(t)e^{-rt}dt$. Before the revenue flow, $t \in [0, T_0]$, there is borrowing (a current account deficit). During the period of revenue flow,$t \in [T_0, T_1]$, there is asset accumulation, paying off foreign debt and building a SWF by running a current-account surplus. The foreign assets that are built up at the end of the windfall, $F(T_1) = V(0) + F_0$, generate just enough interest revenue to finance the permanent rise

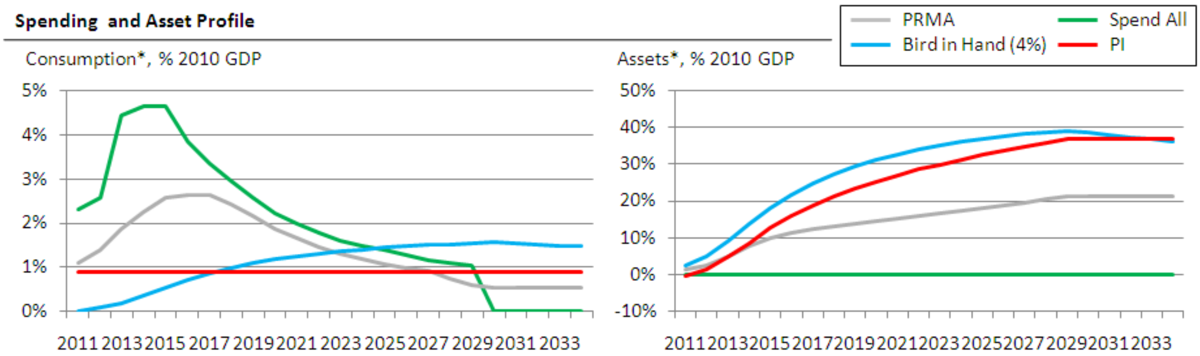


Figure 5: Government spending and accumulation of foreign assets under the spend-all, permanent-income, bird-in-hand and Petroleum Revenue Management Act rules.

in total consumption, that is $rV(0) = \Delta(C + G)$. This policy of borrowing, then saving and finally living on the return on the SWF thus transforms an anticipated temporary windfall revenue into a permanent increase in public and private consumption. In each of these cases, under the simple assumptions of this model, the permanent income policy rule is optimal.

The permanent income rule can be contrasted to the policy of spending all oil income as it is received. The spend-all policy simply sets $C = Y + N$ and consequently there is no effect on asset dynamics. A temporary windfall will only lead to temporary rather than permanent increases in consumption. This is not an optimal policy in any model with a motive to intertemporally smooth consumption.

An alternative to the permanent income and the spend-all rules is the bird-in-hand rule. This corresponds to the resource management plan adopted by Norway, which is often praised and serves as another reference point against which policies can be assessed. The bird-in-hand policy does not borrow in advance of a windfall, puts the windfall into a sovereign wealth fund, and takes a fixed percentage out of the fund, such as 4 per cent in Norway. Consumption thus follows the rule $C = Y + 0.04F$. The dynamics of the current account and consumption are then given by $\dot{F} = -(0.04 - r)F + N$ and $\dot{C} = -(0.04 - r)(C - Y) + 25N$.

The implications of the permanent income, spend-all and bird-in-hand rules for Ghana's consumption and foreign assets are illustrated in Figure 5. The analysis is based only on the 500 million barrels of 90% proven reserves in the Jubilee field, to be exhausted after 20 years using current estimates of the output schedule. It also assumes oil is constant at the long-run level of USD 75/barrel. It is expressed in as a percentage of 2010 GDP, and ignores Ghana's current debt position.

2.2 Reasons to spend more than the permanent income rule: impatience, substitutability, finite lives and productivity growth

There are a number of reasons for spending more than the amount suggested by the permanent income rule. If the policymaker is impatient then consumption will be higher

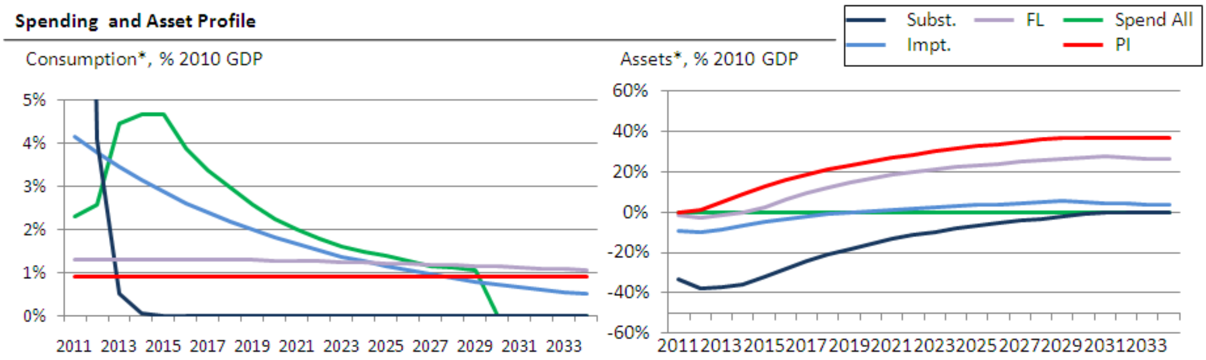


Figure 6: Government spending and accumulation of foreign assets under impatience, intertemporal substitution and finite lives, against the spend-all and permanent-income benchmarks

in the short term. Similarly if they have a high intertemporal elasticity of substitution, consumption will be brought forward to avoid the costs of discounting. If the policymaker's time horizon is limited by mortality, consumption will again be brought forward, as it will if future generations are likely to be more wealthy. Calibrating each effect to Ghana we find that impatience and substitution bring consumption forward more than finite lives. If productivity grows with certainty and the economy faces no borrowing constraints then permanent income suggests that the entire windfall should be brought forward, to smooth consumption across generations. This is not likely to happen in practice.

Impatience and substitution If the policymaker is impatient then consumption will be higher in the short term. Taking the small open economy model described in Section 2.1, the optimal path of consumption is given by $\dot{C}/C = \sigma(r - \rho)$. The associated consumption function is $C = Y + [(1-\sigma)r + \sigma\rho]\,[V(0) + F_0]$. If the policymaker is impatient then $r < \rho$. Consumption will initially be higher than under permanent income, and will decrease over time. The effect of a slight disparity between ρ and r is exacerbated by a high intertemporal elasticity of substitution σ. This again results in a higher initial level of consumption and decreasing consumption over time.

To determine the relevance of this effect in Ghana we continue with the calibration assumptions used in Section 2.1. To gain a basic understanding of the relative importance of impatience we relax the assumption that $r = \rho$ and let $r = 2.5\%$, $\rho = 20\%$ and $\sigma = 0.5$. This degree of impatience is consistent with a self interested government facing a probability of losing office of 17.5% each year. It is shown to have a significant effect. To understand substitution we then let $\sigma = 5$ and find that consumption is again brought forward significantly. These results are shown in Figure 6.

Finite lives If the policymaker's time horizon is limited by mortality then consumption will also be brought forward. To examine this we introduce a constant instantaneous rate of death in each period, β (e.g. Heijdra and van der Ploeg, 2002). For simplicity we suppose a constant population, so the birth rate equals the death rate, and let cohorts be large to allow the law of large numbers to hold. To ensure an individual's wealth is not destroyed at death we introduce an actually fair life insurance company. This company pays individuals a life annuity whilst they are alive, and redistributes their assets to future generations when they die. Thus, consumption is based on expected lifetimes and the focus of the model is on shorter household horizons, rather than lifetime risk

Individual households born at time v and alive at time t maximise expected utility subject to a budget constraint:

$$EU(v,t) = \int_t^{\infty} [1 - F(\tau - t)] \frac{C^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}} e^{\rho(t-\tau)} d\tau \quad (1)$$

$$= \int_t^{\infty} \frac{C(v,\tau)^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}} e^{(\rho+\beta_D)(t-\tau)} d\tau \quad (2)$$

$$st \quad (3)$$

$$\dot{A}(v,\tau) = [r+\beta]A(v,\tau) + Y(\tau) - C(v,\tau) \quad (4)$$

Where $F(\tau - t)$ is the cumulative probability of death between t and τ, and $\beta A(v,\tau)$ is an annuity payment received from the insurance company. The insurer also faces a solvency condition, $\lim_{\tau\to\infty} e^{-(r+\beta)(\tau-t)} A(v,\tau) = 0$. Combining this with the budget constraint, and taking first order conditions, yields each cohort's Euler equation $\dot{C}(v,\tau) = \sigma(r-\rho)C(v,\tau)$, and consumption function $C(v,t) = ((1-\sigma)r + \sigma\rho + \beta)[A(v,t) + H(v,t)]$. The Euler equation is unchanged as the rate of death is constant. However, individual consumption as a function of assets $(A(v,t))$ and expected future earnings $(H(v,t))$ is higher in each period, as lifetimes are finite in expectation. Thus, consumption is brought forward due to the shortened decision horizon.

To find the behaviour of aggregate assets and consumption we integrate across all cohorts v, each of which has size $\beta e^{\beta_D(v-t)}$ at time $t \geq v$. The dynamics of aggregate assets are given by $\dot{A}(t) = 0 - \beta A(t) + [r+\beta]A(t) + Y(t) - C(t) = rA(t) + Y(t) - C(t)$. The first term is the wealth of newborns at time t, the second the wealth of those that die, and the third is the increase in the assets of those that live - including the annuity transfer. Aggregate consumption is given by $C(t) = ((1-\sigma)r + \sigma\rho + \beta)[A(t) + H(t)]$. Differentiating this by application of Liebnitz's rule gives the aggregate Euler equation $\dot{C}(t) = \sigma(r-\rho)C(t) - \beta((1-\sigma)r + \sigma\rho + \beta)A(t)$.

Calibrating these results with $r = \rho = 2.5\%$ and $\beta = 0.88\%$ we find that the effects of death on altering the decision profile of consumers is small, as seen in Figure 6. Testing $\beta = 1.4\%$ so that expected lifetime is 71 gives much the same result.

Productivity growth If productivity growth is positive and certain then, all else equal, consumption should be smoothed across generations to take account of future wealth. In practice this would involve significantly higher consumption in the short term, which would likely overshadow the size of the windfall. Taking the permanent income model in Section 2.1 and letting output grow exogenously at rate π, the Euler equation remains $\dot{C}(t) = 0$, but the consumption equation becomes $C(0) = r\left[F_0 + V(0) + \frac{Y_0}{r-\pi}\right]$. The inclusion of the growth rate in output increases the level of consumption in each period.

In practice, borrowing with future growth in income as collateral is unlikely to happen due to imperfect capital markets and uncertainty about future growth rates..

Continuing with the calibration discussed above, we let output grow conservatively at a constant rate of 0.5% in perpetuity. The permanent level of government spending would jump from USD 7,650m (assuming no oil or growth) to USD 9,950m (assuming both oil and growth). In contrast, the permanent effect of the oil windfall alone raises consumption to just USD 8,000m. If taken literally this would suggest that the government should borrow beyond the windfall to smooth consumption across generations, though this is unlikely to hold in practice.

2.3 Reasons to spend less than the permanent income rule: population growth and precautionary savings

Offsetting the motives to consume the oil windfall earlier than under the permanent income rule are forces delaying consumption even further. Population growth will delay consumption of the oil windfall to provide for a greater number of people alive in the future. Precautionary savings delays consumption, building up a buffer stock of foreign assets to offset the volatility of oil prices. While these forces change the shape of the consumption profile, they are not likely to wholly offset the motives for bringing consumption forward.

Population growth Population growth will delay consumption of the oil windfall to provide for a greater number of people alive in the future. To illustrate this we modify the permanent-income rule by adding population growth, but stick to infinite horizons by assuming there is a bequest motive. We also allow the interest rate to differ from the rate of time preference but suppose for convenience that it is constant. Maximizing a utilitarian social welfare function, $U \equiv \int_0^\infty \left(L(t) \frac{[C(t)/L(t)]^{1-1/\sigma}}{1-1/\sigma} \right) e^{-\rho t} \mathrm{d}t$, where $L(t) = e^{\upsilon t}$indicates the population size which grows at the rate υ, subject to the budget constraint$\dot{F} = rF + Y + N - C$, we obtain the Euler equation for the growth in aggregate consumption, $\dot{C}/C = \sigma(r - \rho) + \upsilon$.Using this in the present-value budget constraint, $\int_0^\infty C(t) e^{-rt} dt = F_0 + V(0) + Y/(r - \upsilon)$, we obtain the aggregate consumption function: (NB: this doesn't hold if $r < \nu$)

$$C(0) = [(1-\sigma)r + \sigma\rho - \upsilon] \left[F_0 + V(0) + \frac{Y_0}{r - \upsilon} \right],$$

where $Y(0) = Y_0$. Hence, consumption is a given fraction of total financial, human and oil wealth. The fraction is an increasing function of the interest rate if the income effect dominates the intertemporal substitution effect, i.e., if $\sigma < 1$. Otherwise, it is a decreasing function of the interest rate. Consumption per head can be written as follows:

$$\frac{C}{L} = [(1-\sigma)r + \sigma\rho - \upsilon] \left[\frac{F}{L} + \frac{V}{L} + \frac{Y/L}{r - \upsilon} \right].$$

The asset dynamics under the permanent income rule are given by:

$$\begin{aligned} \dot{F} &= rF + Y + N - [(1-\sigma)r + \sigma\rho - \upsilon] \left[F + V + \frac{Y}{r - \nu} \right] \\ &= [\sigma(r - \rho) + \upsilon] F + \left[\frac{\sigma(r - \rho)}{r - \nu} \right] Y + N - [(1-\sigma)r + \sigma\rho - \upsilon] V \end{aligned}$$

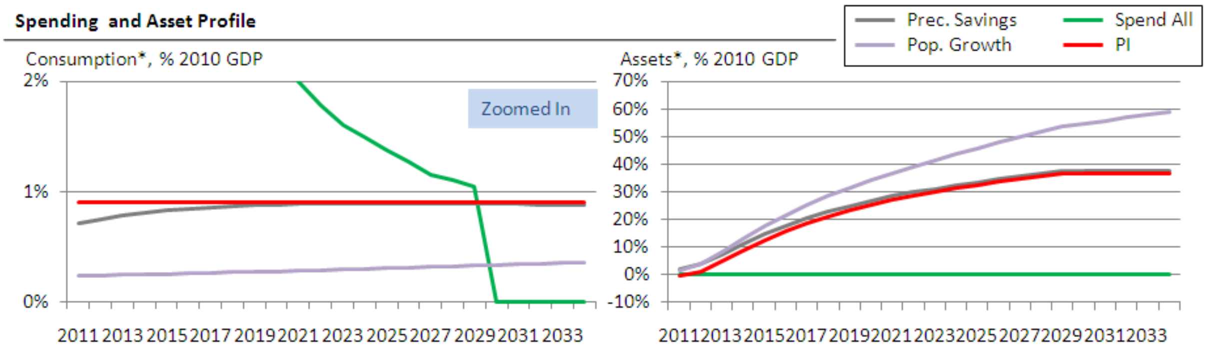


Figure 7: Government spending and accumulation of foreign assets under precautionary savings and population growth, against the spend-all and permanent-income benchmarks

For the special case that $r = \rho$, per-capita consumption is smoothed, $\dot{C}/C = \upsilon$,the propensity to consume out of total wealth becomes $r-\upsilon$, and the per-capita asset dynamics are given by:

$$(\dot{F/L}) = \frac{N}{L} - (r - \upsilon)\frac{V}{L} - .$$

We then see that consumption smoothing requires that the countries saves (borrows) assets whenever current oil revenue exceeds (falls short of) permanent windfall revenue, i.e., during (in anticipation) of an oil windfall. Here permanent windfall revenue is calculated with the interest rate corrected for the rate of population growth. A country with population growth ($\upsilon > 0$) thus has smaller permanent windfall revenue, so that it has a tendency to save more to provide for the future, more numerous generations. The permanent income hypothesis thus suggests that poor countries with rapid population growth and stagnating or negative productivity growth should save because there will be more people in the future to share the windfall, which is not likely for many of the poorest countries trying to survive.

Using the calibration above, adding Ghana's population growth rate of 1.82%, gives the spending profile in Figure 7. We see that population growth encourages a significant amount of the permanent income to be delayed to the future.

Precautionary savings Precautionary savings delays consumption, building up a buffer stock of foreign assets to offset the volatility of oil prices. This can be illustrated using dynamic programming, following Skinner [1988]. For precautionary savings to occur oil price shocks must be persistent, otherwise each shock does not alter future income in expectation. We calibrate the model to the Ghanaian economy to illustrate the optimal level of precautionary savings. This is found to be relatively modest compared to other motives affecting the spend/save decision for the oil windfall.

Precautionary savings can be illustrated using dynamic programming. We use the constant relative risk aversion (CRRA) utility function. This function is suitable as it exhibits both constant relative risk aversion and prudence, so the absolute level of prudence decreases with consumption. However, the key parameter in this function, σ, plays four roles, defining: the elasticity of intertemporal substitution, the elasticity of intergenerational inequality aversion, $1/\sigma$, the coefficient of relative risk aversion, $1/\sigma$, and the coefficient of relative prudence, $1/\sigma + 1$. This can be a problem when distinguishing the effect of each parameter. Epstein-Zin preferences allow one to distinguish intertemporal substitution and relative risk aversion, but we will not go into that here.

We assume oil prices are fully persistent, and oil output is temporary, variable and follows the output schedule for Ghana's Jubilee field. Oil prices follow a log random walk, $\ln P_t = \ln P_{t-1} + \epsilon_t$, where $\epsilon \sim N(0, \sigma_U^2)$. This gives $E_{t-1}[P_t] = P_{t-1}e^{\sigma_U^2/2}$, and the ratio $Var_{t-1}(P_t)/\bar{P}_t^2 = \exp(\sigma_U^2 - 1) \approx \sigma_P^2$. Oil output Y_t, $t = 2011, \ldots 2029$, varies in each period according to the output schedule for Ghana's Jubilee field. Intuitively, the effect of a price shock on consumption will be determined by i) its size and ii) the proportion of total output remaining in the future which will be affected by the shock.

Households maximise expected lifetime utility, $U_0 = E_0[\sum_{t=0}^{\infty}(1+\rho)^{-t}\frac{C_t^{1-1/\sigma}}{1-1/\sigma}]$, subject to the budget constraint, $A_t = (A_{t-1} - C_{t-1})(1+r) + P_tY_t$, where A_t is foreign assets. We let $r = \rho$ to focus on the precautionary savings motive, yielding the Euler equation, $C_{t-1}^{-1/\sigma} = E_{t-1}[C_t^{-1/\sigma}]$. To solve this for the precautionary premium explicitly we use dynamic programming. This requires a terminal condition. We assume that oil income ends at time $t = T$, at which point all income has been realized and the household consumes the permanent value of assets accumulated at that time: $C_T = A_T\frac{r}{1+r} \quad \forall t \geq T$. Substituting the terminal condition into the Euler equation at time $t = T$, and using the budget constraint gives us consumption at $t = T - 1$:

$$C_{T-1}^{-\frac{1}{\sigma}} = E_{t-1}[(\frac{r}{1+r}((A_{T-1} - C_{T-1})(1+r) + P_TY_T))^{-\frac{1}{\sigma}}] \tag{5}$$

Taking a second order Taylor expansion of equation 5, evaluated at $E_{T-1}[P_t] = \bar{P}_T$, gives:

$$\begin{aligned} C_{T-1}^{-\frac{1}{\sigma}} &\approx (r(A_{T-1} - C_{T-1}) + \frac{r\bar{P}_TY_T}{1+r})^{-\frac{1}{\sigma}} \\ &\times \left(1 + \frac{\frac{1}{\sigma}(\frac{1}{\sigma}+1)}{2}(r(A_{T-1} - C_{T-1}) + \frac{r\bar{P}_TY_T}{1+r})^{-2}(\frac{rY_T}{1+r})^2Var_{T-1}[P_T]\right) \end{aligned} \tag{6}$$

To simplify this expression, define lifetime wealth as current assets plus expected future income, $L_t = A_t + \sum_{s=t+1}^{\infty}E_t[\frac{P_sY_s}{(1+r)^{s-t}}]$ and $E_{T-1}[L_t] = \bar{L}_T$. Using this let the second term in equation 6 be $\nu_T = \frac{1/\sigma(1/\sigma+1)}{2}(\frac{r\bar{L}_T}{1+r})^{-2}(\frac{rY_T}{1+r})^2Var_{T-1}[P_T]$. Using the expression for ν_T with equation 5 to simplify the Taylor expansion, we get the new Euler equation, $E_{T-1}[C_T] = (1+\nu_T)^{\sigma}C_{T-1}$. A recursive expression for consumption can be found by combining the new Euler equation, the budget constraint, and letting $K_T^{T-1} = (1+\nu_T)^{\sigma}$, to give $C_{T-1} = \frac{L_{T-1}}{1+K_T^{T-1}/r}$.

Moving recursively back one period, consumption at $t = T - 2$ is given by $C_{T-2}^{-1/\sigma} = E_{T-2}[(\frac{L_{T-1}}{1+K_T^{T-1}/r})^{-1/\sigma}]$. The second order Taylor expansion of this, evaluated at $E_{T-2}[L_{T-1}] = \bar{L}_{T-1}$, is $C_{T-2}^{-1/\sigma} \approx (\frac{\bar{L}_{T-1}}{1+K_T^{T-1}/r})^{-1/\sigma}[1 + \frac{1/\sigma(1/\sigma+1)}{2}\bar{L}_{T-1}^{-2}Var_{T-2}(L_{T-1})]$. Using the expression for the oil price process defined above, we find that $Var_{T-2}(L_{T-1}) = (Y_{T-1} +$

$\frac{e^{\sigma_U^2/2}Y_T}{1+r})^2 Var_{T-2}(P_{T-1})$. To rearrange, let $\mu_t = \frac{E_{t-1}\sum_{s=t}^{\infty}\frac{P_s Y_s}{(1+r)^{s-t}}}{\bar{L}_t}$, which is the expected contribution of future income to total wealth. This is not constant over time. Substituting both of these into the second order Taylor expansion yields $C_{T-2}^{-1/\sigma} = (\frac{\bar{L}_{T-1}}{1+K_T^{T-1}/r})^{-1/\sigma}[1 + \frac{1/\sigma(1/\sigma+1)}{2}\mu_{T-1}^2\sigma_P^2]$. To rearrange this into a recursive expression for consumption, let $\nu_{T-1} = \frac{1/\sigma(1/\sigma+1)}{2}\mu_{T-1}^2\sigma_P^2$, $K_{T-1}^{T-2} = (1+\nu_{T-1})^{\sigma}$, and $K_T^{T-2} = K_{T-1}^{T-2}K_T^{T-1}$. This gives the recursive expression for consumption at $t = T-2$, $C_{T-2} = \frac{L_{T-2}}{1+K_{T-1}^{T-2}(1+r)^{-1}+K_T^{T-2}/r(1+r)^{-1}}$. Consumption at earlier ages can be derived by induction to give:

$$C_t = \frac{L_t}{\sum_{i=t}^{T-1} K_i^t(1+r)^{-(i-t)} + K_T^t(1+r)^{-(T-t)}\frac{1+r}{r}} \tag{7}$$

This recursive solution allows us to model the optimal path for consuming the oil windfall, adjusted for the precautionary savings response to oil price volatility. Using the expected output profile from the Jubilee field, with $r = 2.5\%$, $P_O = \$75$, $StdDev_O = 7.8$ and $\sigma = [0.1]$ we get the results for expected oil consumption and asset accumulation in Figure 7. Note that this may overstate the precautionary motive, as it excludes other government revenue. These results show that precautionary savings can have an effect at very high levels of prudence ($CRP = 11$). The precautionary buffer also becomes larger with more persistent oil price shocks. However, even under very high prudence and excluding other government revenue the effect is modest: assets peak at \$15.4 billion if $CRP = 11$, \$15.2 billion if $CRP = 3$ and \$14.8 billion if volatility is ignored (the PI rule).

2.4 Ghana's Petroleum Revenue Management Act

The above analysis gives us a framework for evaluating Ghana's recently passed Petroleum Revenue Management Act (PRMA) 2011. The PRMA outlines how government oil revenues are to be used. The revenues are to be allocated between the annual budget and sovereign wealth funds as the income is received. We find that the proposed spending profile is brought forward significantly in comparison to the permanent income benchmark. This may be sub-optimal given Ghana's stock of outstanding foreign debt, and will only be appropriate if the spending stimulates growth through domestic investment and reducing distortionary taxes.

The Petroleum Revenue Management Act outlines how government oil revenues are to be used. The government's oil revenue from the Jubilee field has four components (Dessus et al., 2009). First, a royalty of 5 percent of gross oil revenues. Second, the Ghana National Petroleum Corporation receives 13.75 percent of the field's commercial net profits. Third, an "additional oil entitlement" of 10-25 percent of petroleum revenue, net of royalties and the GNPC interest, is accrued if the project rate of return is between 18 and 33 percent. Fourth, the government levies company income tax on all net profits of 35 percent.

The Petroleum Revenue Management Act allocates government oil revenues between the annual budget and sovereign wealth funds (see Figure 8). The allocation is based on "benchmark revenue", using a seven year moving average of oil prices (including three

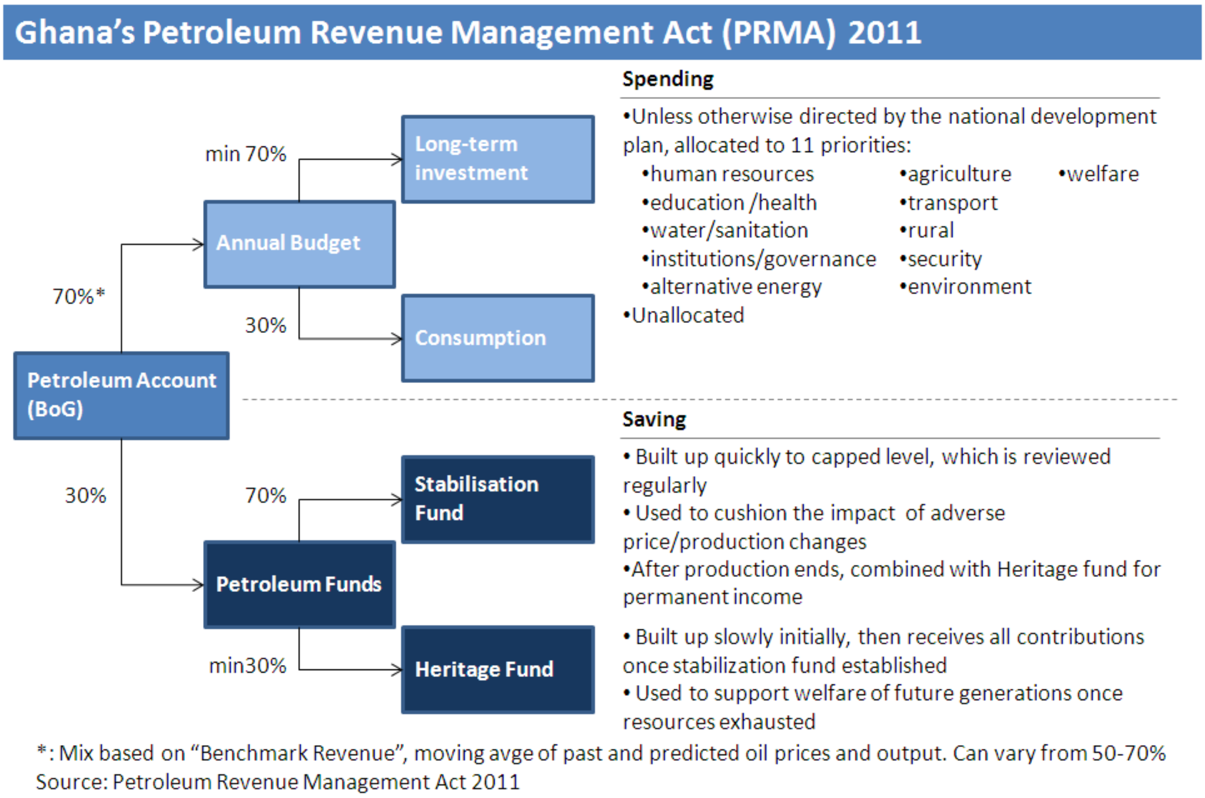


Figure 8: An outline of the spending allocation of oil revenues under Ghana's Petroleum Revenue Management Act, 2011

projected years), and a three year average of output (including projections for the next year. From the benchmark revenue, 50-70% is allocated to the annual budget as it is received. Of this, a minimum of 70% must go to investment in eleven priority areas, the remainder is consumed. The 30-50% of benchmark revenue not allocated to the annual budget is to be placed in sovereign wealth funds, investing in foreign assets. Of this, a minimum of 30% must go to a heritage fund for future generations, the remainder goes to a stabilisation fund. The exact mix is yet to be determined.

The spending profile outlined by the PRMA is brought forward significantly from the permanent income benchmark, as illustrated in Figure 5. It may be too heavily weighted towards short-term spending, particularly given Ghana's outstanding stock of public debt, which may be increasing the cost of borrowing and restricting private investment (discussed in Section 3). If the funds are to be spent in the short term, then they should be used to boost the domestic stock of public capital and reduce distortionary taxes, to raises private investment and promote growth. This is discussed further in the following section.

3 How should Ghana spend or save its windfall?

This section addresses the question of how Ghana should spend or save its windfall, given the shape of the spending profile discussed in Section 2. We focus on investment and consider three options. The first is repaying Ghana's large foreign borrowing. This is an important priority as it will reduce credit spreads and alleviate capital scarcity, stimulating private and public investment and raising wages. The second is to invest in foreign assets through a sovereign wealth fund. This has advantages in smoothing the effects of Dutch disease and absorption constraints, stabilising oil price volatility and providing for future generations. However, if Ghana is facing a premium on borrowing, this strategy should only be pursued once the stock of foreign debt is reduced. The third is to invest in domestic capital, both human and physical, which is discussed in Sections 4 and 5. Section 4 shows that Ghana has both low GDP and low GDP growth, which has been driven by a small and slow-growing stock of domestic capital. Section 5 goes on to show that investment in capital during an oil windfall will boost growth and move Ghana along the path of structural transformation. Effective investment in domestic capital is likely to also involve alleviating capital scarcity and temporary saving in foreign assets. In practice, alleviating capital scarcity is likely to exhaust most of the windfall from Jubilee's current proven reserves. Ghana should only invest in foreign and domestic assets if credit spreads are reduced sufficiently by paying down a fraction of its debt, or if new oil discoveries are made.

3.1 Alleviating Capital Scarcity

To alleviate capital scarcity Ghana can repay foreign debt, reducing credit spreads and in turn stimulating private and public investment, and raising wages. Ghana's stock of foreign debt in 2009 was 37 percent of gross nation income (World Bank), though this was below the peak in 2000 of 125 percent. Although this current level of debt is not as high as in other developing countries, anecdotal evidence from members of the Ministry of Finance suggests that the country is approaching its borrowing constraints. More tellingly, the rating agency Standard and Poor's currently rates Ghana's 2007, ten-year, \$750 million eurobond as "B", three levels below investment grade. Although there are a number of factors affecting this rating, the stock of debt is a likely contributor. There is extensive empirical support for a relationship existing between the stock of foreign debt and the credit spread. If a country faces a convex cost of borrowing, then it is optimal to use a resource windfall to repay debt. If the windfall is small it should be allocated to alleviating capital scarcity by repaying debt and there will not be a sovereign wealth fund. If the windfall is large, then a sovereign wealth fund may become appropriate. If non-resource income is also endogenous, then the reduction in credit spreads is important for stimulating domestic investment and bringing forward the development path.

There is extensive empirical support for a relationship existing between the stock of foreign debt and the credit spread. van der Ploeg and Venables [2011] regress log bond spreads against the ratio of public and publicly guaranteed debt (PPG) to GNI in 25 countries and find a significant positive coefficient of 1.9, controlling for reserves, the output gap and the probability of default. This is consistent with work by Akitoby and Stratmann [2008], amongst others, who find a similar result. These results suggest that the stock of foreign debt decreases the perceived creditworthiness of a country, which increases its costs of borrowing.

If a country faces a convex cost of borrowing, then it is optimal to use a resource windfall to alleviate capital scarcity by repaying debt, as illustrated by van der Ploeg and

Venables (2011). They let the domestic interest rate be kinked at a certain point $\bar{F}$ so that $r = r^*$for $F \leq \bar{F}$, and $r = r^* + \Pi(F)$ for $F > \bar{F}$ where $\Pi(F) > 0, \Pi'(F) > 0, \Pi''(F) \geq 0$. For a household maximising a CRRA utility function, they show that the inclusion of this risk premium alters the Euler equation from the standard $\dot{C}(t) = \sigma(r - \rho)C(t)$ when $F \leq \bar{F}$, to $\dot{C}(t) = \sigma(r^* + \Pi(F) + F\Pi'(F) - \rho)C(t)$ when $F > \bar{F}$. Both converge to the steady state $C = Y + r^*F$. Thus, when the stock of foreign debt is high enough to be affecting credit spreads, consumption is postponed to alleviate capital scarcity, placing consumption on a rising path.

If a windfall is small, it should be used to alleviate capital scarcity, and there is no need to establish a sovereign wealth fund. If the windfall is large, then a sovereign wealth fund may become appropriate. Using the kinked interest rate model described above, van der Ploeg and Venables (2011) plot the dynamics of consumption and foreign debt on a phase diagram. They show that if foreign assets are above the steady state level, consumption will be low and rising. On receiving a small, temporary oil windfall, debt will be rapidly repaid and consumption will jump up, moving the country along the growth path. On receiving a large, temporary windfall, debt will again be rapidly paid down and consumption will jump. However, if the entire windfall is consumed, then consumption will remain too high after the windfall and will deplete the capital stock. To avoid this, a sovereign wealth fund should be established to smooth consumption and raise the steady state level of capital. Thus, a sovereign wealth fund should only be established if the debt stock will be sufficiently reduced by the oil windfall to alleviate capital scarcity.

If non-resource income is also endogenous, then the reduction in credit spreads is important for stimulating domestic investment and bringing forward the development path. Van der Ploeg and Venables (2011) again show this by introducing endogenous non-resource output, by including private capital and public infrastructure, into the model above. If the government can make lump-sum transfers to consumers, then it is optimal to set income tax to zero and make a large transfer to consumers. The remainder is split between infrastructure investment and debt reduction. The debt reduction and increase in demand stimulates private capital formation, and moves the economy quickly along the development path. At the end of the windfall the economy resumes its original growth path, but will reach the optimal consumption level sooner. If the government cannot make lump-sum transfers, it can only control private consumption indirectly through the wage. In this case the government will pay down foreign debt, lower distortionary income tax and raise infrastructure investment. This raises the wage directly by increasing the marginal product of labour, and also attracts private investment. Thus, reducing credit spreads is also important for stimulating domestic investment.

3.2 Investing in foreign assets

Establishing a sovereign wealth fund to invest in foreign assets would provide for future generations, smooth the effects of both Dutch disease and absorption constraints, and stabilise oil price volatility. However, as has been outlined above, this strategy should only be pursued once the stock of foreign debt is reduced if the country is facing a premium on its borrowing rate.

The first role of a sovereign wealth fund is to establish a stock of foreign assets to smooth consumption over generations. Under the permanent income hypothesis and its extensions, discussed in Section 2, the sovereign wealth fund acts as a store of wealth to be consumed across generations. This approach basically dictates replacing the subsoil assets with foreign assets and consuming only the interest income.

The second role of the sovereign wealth fund is to smooth the effects of both Dutch disease and absorption constraints, by smoothing the consumption of the windfall. Dutch disease describes a contraction of the traded sector and a real appreciation during an oil boom, as illustrated by Corden and Neary [1982]. They use a two sector small open economy to show that an increase in oil output causes consumption of both traded and non-traded goods to rise. Increased demand for traded goods is met through imports, which releases labour and capital to move to the non-traded sector. Increased demand for non-traded goods is met by increased production in the sector, and higher non-traded prices. Thus the traded sector contracts and the real exchange rate appreciates. This is a public policy concern if the traded sector has positive externalities, such as knowledge spillovers or learning by doing. By smoothing consumption, the amount of contraction and real appreciation is limited.

Absorption constraints describe the need for non-traded capital to produce capital, which limits the amount that an oil windfall can effectively be absorbed by an economy. van der Ploeg and Venables [2010] illustrate this using a model of a two sector small open economy facing adjustment costs, where sunk capital is costly to redeploy, and non-traded capital is needed in the production of further capital. In practice this can be thought of as roads being an input into the production of hospitals, or teachers being needed to teach new teachers. In the presence of an oil windfall consumption jumps, increasing the demand for non-traded goods for both consumption and investment. This leads to a sharp real appreciation. As capital accumulates this gradually depreciates back to equilibrium. It thus becomes optimal for households to postpone some of their consumption. This is done by temporarily parking some of the windfall offshore in foreign assets whilst the absorption problems are being sorted out.

The third role of a sovereign wealth fund is to stabilise oil price volatility. There is extensive empirical evidence that income volatility slows growth. Poelhekke and van der Ploeg [2009] show that volatile economies grow slowly and resource exporters are more volatile using global panel data. Aghion et al. [2009] find robust evidence for strong and negative link between RER volatility and growth using panel data set. These results are consistent with the work of Ramey and Ramey [1995], Hamilton [1983], Ferderer [1996] and Blattman et al. [2007]. If a country has perfect access to credit, then negative oil price shocks can be smoothed in international capital markets. However, if there are restrictions on borrowing, saving income when oil prices are above a benchmark, to be used when they fall below, can reduce the pass-through of income volatility to the economy. The size of the stabilisation fund will depend on the cost of volatility to the economy, the policymaker's degree of prudence, access to credit, the stochastic process governing the resource and the governance structures surrounding the fun - whether it is lootable or not. However, it is impossible to fully insulate an economy from oil price volatility, due to other channels such as investment in the resource sector and capital mobility. Thus, the economy should be designed to handle excess volatility, by encouraging flexible labour and capital markets, avoiding difficult to reverse commitments, and diversification.

4 What is driving Ghana's low growth rate?

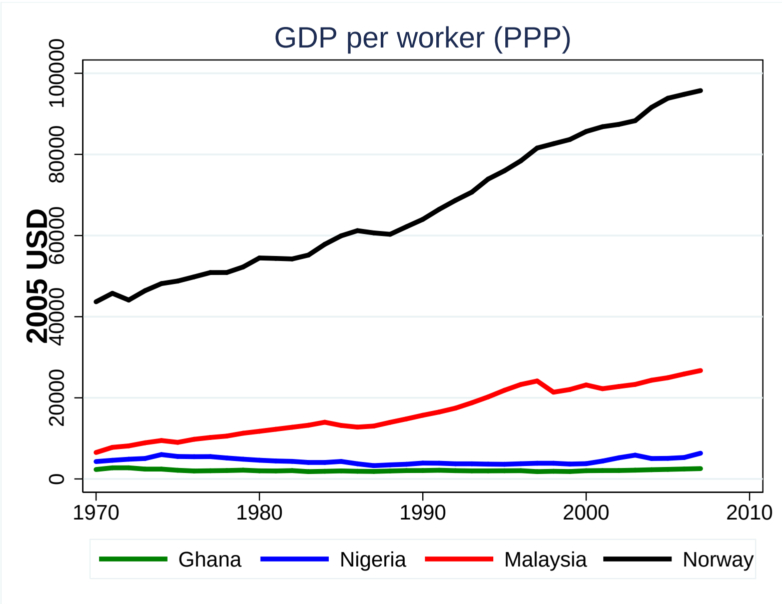


Figure 9: GDP per Capita in Ghana, Nigeria, Malaysia and Norway

This section addresses the question of what is driving Ghana's low growth rate. Figure 9 shows that Ghana has historically had both low GDP per capita and low GDP per capita growth, compared to other resource rich countries like Nigeria, Malaysia or Norway. We analyse the factors driving this by performing a growth accounting exercise. Growth accounting shows that, while TFP growth has played an increasing role in total growth, capital accumulation has made a very small contribution to GDP growth, particularly in agriculture. This suggests that Ghana is far away from its steady state, so to capture the effects of oil on the economy we must capture its transition path. Section 5 uses a model of structural transformation to show that the oil windfall is a once in a lifetime opportunity to boost the capital stock and increase growth rates.

We analyse the factors driving Ghana's growth rate using growth accounting at the sectoral and the aggregate level. To do this, we assume that output in each sector, s, of the economy is produced with a Cobb-Douglas production function, $Y_s = A_s L_s^{\chi_s} K_s^{1-\chi_s}$. Taking Y_s, K_s, L_s and χ_s as given (see Appendix 7.3) we can construct A_s as a residual from the production function. Taking logarithms of this equation and differentiating with respect to time, we can then obtain a decomposition of sectoral GDP growth into its labor, capital and TFP components, $g_{Y,s} = g_{A,s} + \chi_s g_{L,s} + (1 - \chi_s) g_{K,s}$. This decomposition is shown for the aggregate, each ISIC 3 sub sector of the economy and each country in Appendix 7.4.

Growth accounting shows three key results: first, that TFP growth has played an increasing role in total growth; second, that capital accumulation has made a very small contribution to GDP growth; and third, capital accumulation has been especially low in the agricultural sector. First, TFP growth has played an increasing role in aggregate GDP growth in Ghana, Nigeria and Malaysia. In the early parts of the sample, TFP growth contributed negatively to GDP per capita growth, whereas today it contributes positively in all three countries. In Nigeria and Malaysia - unlike Ghana - the low TFP growth

	GDP	TFP	Labor	Capital
Ghana	4.98%	2.16%	2.17%	0.59%
		43.44%	43.53%	11.88%
Nigeria	5.71%	5.04%	1.1%	-0.45%
		88.28%	19.31%	-7.91%
Malaysia	5.64%	1.22%	2.07%	2.32%
		21.56%	36.6%	41.17%
Norway	2.49%	1.24%	0.43%	0.81%
		49.82%	17.28%	32.38%

Table 1: Aggregate growth accounting, 1993-2007. Contribution of individual factors and TFP to GDP growth.

in the early part of the sample was dominated by high rates of capital accumulation in the non-agricultural sectors. This resulted in positive overall GDP growth, despite the low TFP growth. Second, the contribution of capital accumulation to GDP growth have been very low in Ghana (and Nigeria) compared to that of more advanced economies such as Malaysia or Norway. This fact can be clearly seen in Table 1, which shows the average growth rates over the 1993-2007 period, broken down into the components of the decomposition equation. Third, capital accumulation has been especially low in the agricultural sector. Appendix 7.4 shows that capital accumulation has contributed almost nothing to productivity growth in agriculture, resulting in a large, unproductive agricultural sector that employs the majority of the labour force in Ghana.

These results show that Ghana is far away from its steady state. To capture the effects of oil on the economy we must capture its transition path. Section 5 uses a model of structural transformation to show that the oil windfall is a once in a lifetime opportunity to increase capital accumulation and boost growth rates to those found in other resource rich economies.

5 Investing in domestic assets

This section considers how Ghana should invest its oil windfall in domestic assets. It builds on Section 3 by considering how the windfall should be spent on domestic, rather than foreign assets. It builds on Section 4 by considering how this domestic investment will boost growth rates. To analyse this we use a three-sector model of structural transformation. This model addresses the issue that, as Ghana is far from its steady state, standard business cycle models that are appropriate for richer countries are not appropriate for Ghana. The model is calibrated to the Ghanaian economy. We then show that, in the presence of an oil shock, domestic capital should be consumed before, and quickly accumulated during the shock, before slowly returning to the non-oil growth path once the shock has finished. The shock will be accompanied by both "Dutch disease" and fluctuations in the real exchange rate. Ultimately, the associated jump in investment will move Ghana more quickly along the path of structural transformation.

5.1 The model

To analyse Ghana's investment in domestic assets we use a model of structural transformation with three sectors: agriculture, traded manufacturing and non-traded services. This follows Acemoglu and Guerrieri [2008] but adds an agricultural sector to capture the full extent of structural transformation, and opens the economy to trade in M goods.. Growth in each sector is exogenous, though each sector differs in labour and capital intensity. As the economy grows and capital accumulates, output increases in the capital-intensive, high-growth manufacturing sector. As capital continues to grow, the marginal product of labour in the manufacturing sector continues to rise, and labour starts to be released to the slower-growth services sector, as manufacturing and services are gross complements. We also allow foreign borrowing and impose a debt premium similar to that discussed in Section 3.1.This model allows us to match the structure of the Ghanaian economy and determine the appropriate paths of capital and labour in a poor structurally transforming country.

Consider an economy consisting of three sectors agriculture (A), the traded sector (M) and the non-traded sector (S). Each sector's TFP grows at a different exogenous rate g_A, g_M and g_S respectively. Production in each sector is Cobb-Douglas, with labour share 1, α_M and α_S respectively.The M and S sectors are combined into a final non-agricultural good using a CES aggregation function, $Y_t = (\gamma Y_{S,t}^{\frac{\varepsilon-1}{\epsilon}} + (1-\gamma) M_t^{\frac{\varepsilon-1}{\varepsilon}})^{\frac{\varepsilon}{\varepsilon-1}}$, with constant elasticity of substitution ε and share parameter γ. In each period the economy is potentially endowed with a windfall of O_t units of natural resource which are sold abroad at the exogenous prices $p_{O,t}$. We assume that the M sector is traded, and that there is international borrowing and lending of the M good.[1] We impose a debt premium on borrowing, $R(D_t) = R^* + \phi(e^{D_t/(A_S^{1/\alpha_S}(g_s^{1/\alpha_s})^t) - \bar{D}} - 1)$, where D_t is the debt stock. Notice that debt levels are normalized by trend growth, to capture the fact that larger economies are able to borrow more. Including a debt premium is also an effective way to close a small open economy model[2] and results in an important shift away from the permanent income hypothesis. Since debt is costly to hold above steady state levels, countries only use debt temporarily to smooth consumption.

Finally, the period utility function, $U(Y_{A,t}, C_t)$, is adopted from Gollin et al. [2002] and given below. Preferences for A are non-homothetic as consumers become satiated with agricultural products when $Y_{A,t} = \bar{A}$. This setup ensures a structural transformation from agriculture to non-agriculture. The full system of equations for the model is given in Appendix 7.5.

$$U(Y_{A,t}, C_t) = \begin{cases} \bar{A} + \left[\frac{C_t^{1-\sigma}-1}{1-\sigma}\right] & \text{if } Y_{A,t} > \bar{a} \\ Y_{A,t} & \text{if } Y_{A,t} \leq \bar{A}. \end{cases} \tag{8}$$

The model is solved by working with transformed, de-trended variables in a similar fashion to Acemoglu and Guerrieri [2008]. To transform the above problem we make two assumptions that determine the trend growth of the economy and then normalise consumption, debt and capital by this trend growth. The first assumption is that the service

[1]The implication of the assumption that borrowing can only take place in the traded sector is that investment and hence capital are partially home produced, so that an endowment of oil will not be absorbed as fast, as when both types of goods could be imported from abroad.

[2]See, for instance, Schmitt-Grohe and Uribe [2003].

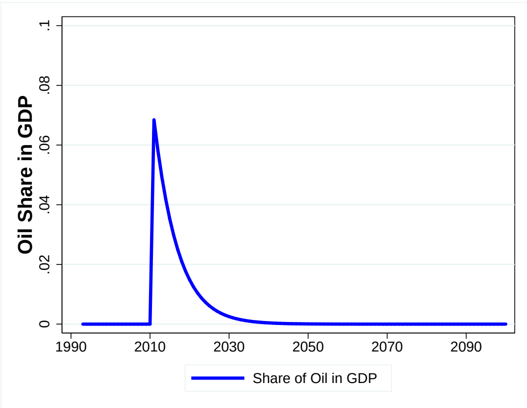
sector is more labour-intensive, $\alpha_S > \alpha_M$. This simplifies the analysis without loss of generality and is confirmed in the calibration. The second assumption is that the augmented rate of technological progress in services is less than manufacturing, and that S and M are gross complements, $g_S^{1/\alpha_S} < g_M^{1/\alpha_M}$ and $\varepsilon < 1$ (see Acemoglu and Guerrieri [2008]). This ensures that the labour-intensive sector S is asymptotically dominant, and thus will determine the long-run growth rate of the economy. We then normalise consumption, bonds and capital by trend growth to define $c_t = C_t/A_S^{1/\alpha_s}(g_s^{1/\alpha_s})^t$, $d_t = D_t/A_S^{1/\alpha_s}(g_s^{1/\alpha_s})^t$ and $k_t = K_t/A_S^{1/\alpha_s}(g_s^{1/\alpha_s})^t$. Given these normalizations, the de-trended model can be solved with a simple multiple shooting algorithm. The model is then calibrated to match quantitatively the structural transformation of the Ghanaian economy, described in Appendix 7.6.

5.2 The effects of an anticipated oil shock

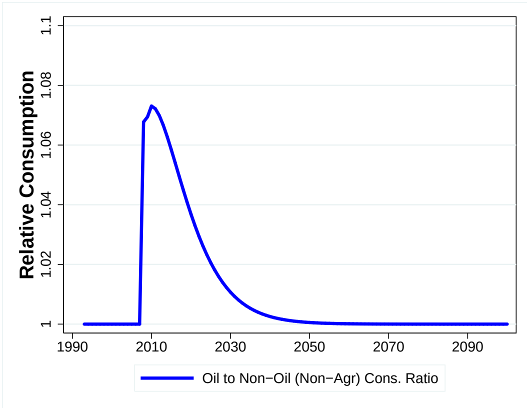
In the presence of an anticipated oil shock, domestic capital should be consumed before, and quickly accumulated during the shock, before slowly returning to the non-oil growth path once the shock has finished. The macroeconomic impact of the oil windfall will decline as the economy grows. Agents will smooth the effects of the shock using the capital stock and, to a lesser extent, debt. The windfall will be accompanied by "Dutch disease": a shift of labour and capital from the traded to the non-traded sector. However, the traded sector will shrink naturally as the economy grows, so the oil windfall simply brings forward its decline. There will also be a temporary depreciation and appreciation of the exchange rate, though these effects are small. Ultimately, the jump in investment during the shock will move Ghana more quickly along the path of structural transformation.

The macroeconomic impact of the oil windfall will decline as the economy grows. The value of the oil windfall, relative to the price of traded goods, is assumed to decline at a constant rate of 8.7% a year - as implied by Figure 2. However, the value of the windfall as a share of GDP declines faster due to growth in TFP, as illustrated in Figure 10a. The faster an economy grows, the shorter the impact of oil will be. Since our model generates an endogenous growth process (unlike many business cycles models), it better captures the transitory importance of oil in an economy undergoing the growth process.

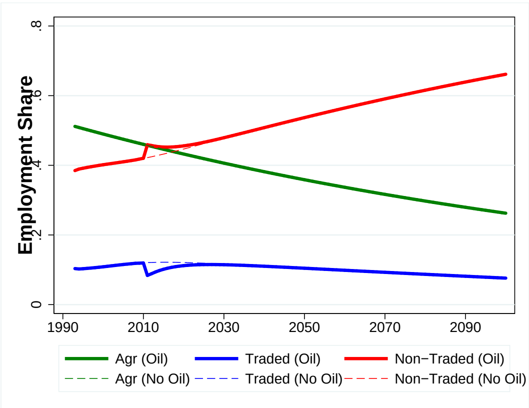
In the presence of an anticipated oil shock, agents will use the capital stock and debt to help smooth out non-agricultural consumption. We study an oil shock that begins in 2011, but is anticipated from 2008. Figure 10b shows that agents smooth consumption as soon as news of the oil find arrives, with consumption jumping approximately 7% against the non-oil economy. Consumption smoothing is largely accomplished by lower investment rates and de-investment of existing capital. Figure 10e demonstrates that, as soon the oil discovery is announced, the stock of capital falls by 5% relative to a non-oil economy. The change in capital stock is driven by a downward jump of the investment rate as shown in Figure 11. Debt also plays a role in smoothing consumption, however it is relatively minor. Figure 12 shows that changes to both the level of debt and the current account due to the oil windfall are small. This is a result of both the small size of the windfall, and the cost of borrowing above the trend level of debt. During the oil shock, investment jumps and debt is quickly repaid. As oil income declines over time, investment rates drop and capital stock returns to what it would have been without oil.



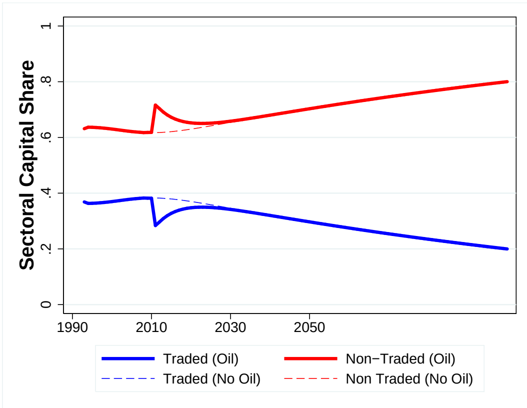
(a) Share of Oil in GDP



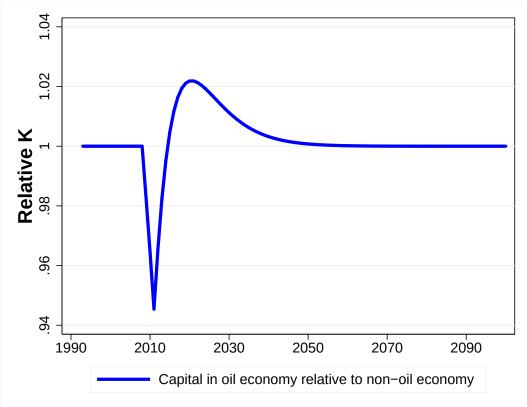
(b) Non-agr. cons. in oil rel to non-oil case



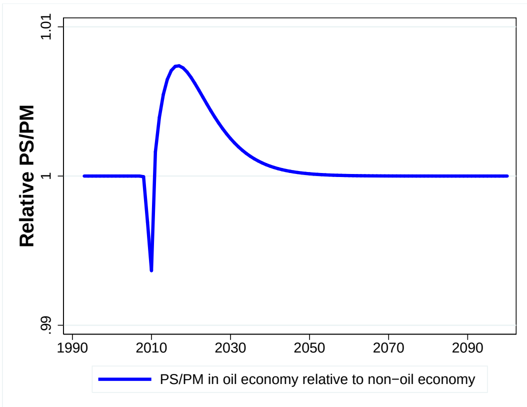
(c) Sectoral Employment



(d) Sectoral Capital Shares

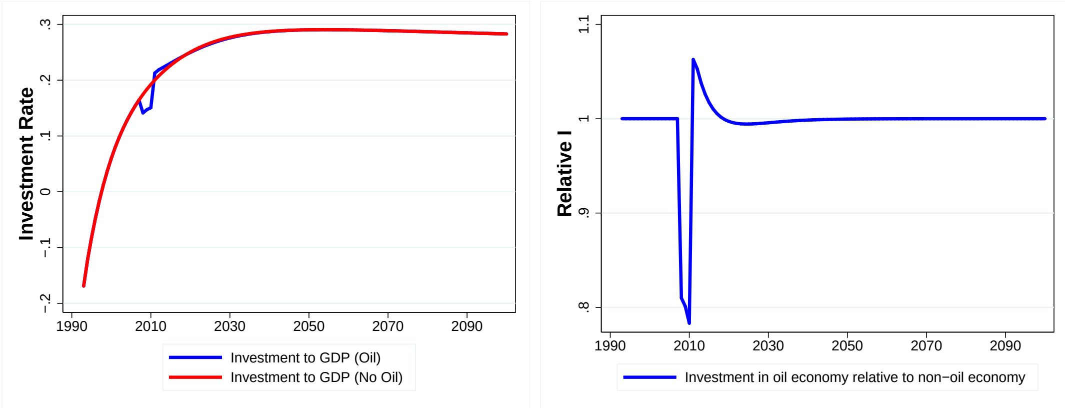


(e) Capital stock in oil rel. to non-oil case



(f) Non-traded goods price, in oil rel. to non-oil case

Figure 10: Consequence of Oil Shock in Ghana (With International Borrowing)



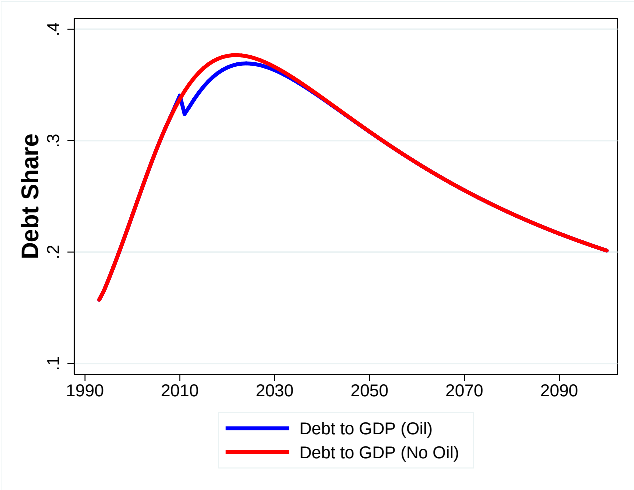
(a) Investment Rate

(b) Relative Investment

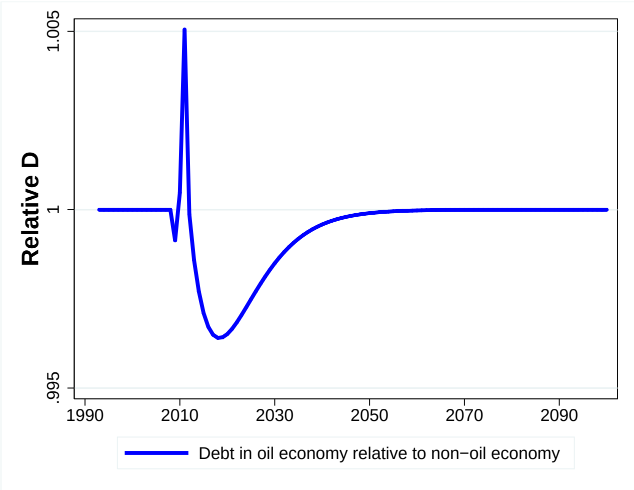
Figure 11: Evolution of Investment

The oil windfall is also accompanied by standard labor and capital reallocation effects, commonly known as "Dutch disease". We see a reallocation of approximately 4 percentage points of labor from the traded to the non-traded sector in response to the higher demand for non-traded goods. We also see a much larger reallocation of capital from the traded to the non-traded sector of approximately 10 percentage points. Over time, as the value of oil (relative to GDP) declines, labor shares and capital shares return to their non-oil paths. Interestingly enough, even once the oil has ran out, the employment share in the traded sector is not going to be as large as when the oil was found due to the process of structural transformation. As the economy gets richer, the traded sector naturally shrinks - the oil find simply brings forward the decline of the traded sectors.

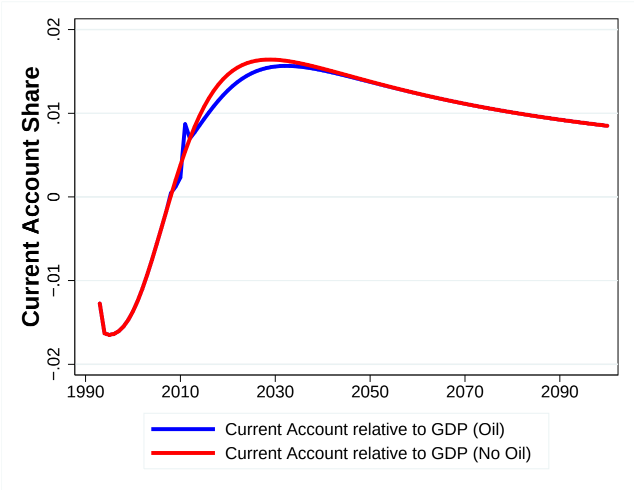
Finally, before the oil shock there is a real depreciation, followed by a temporary appreciation during the shock, though both of these are small. Figure 10f shows that there is first a 0.5 percentage point dip in the price of non-traded goods, followed by a 0.75 of a percentage point rise. The prices of non-traded goods thus roughly follow the path of capital accumulation. As the quantity of capital decreases initiallly, labor becomes relatively abundant. Since non-traded goods are relatively more labor intensive, the price of the labor intensive, non-traded output falls. As capital accumulation increases, labor becomes relatively scarce and the price of labor intensive non-traded good increases. What is interesting, is the small extent to which prices move. This is partly due to the small initial size of the windfall, the growth of the Ghanaian economy which renders the windfall even smaller and the relatively small differences in labor intensity across sectors.



(a) Debt to GDP Share



(b) Relative Debt (oil to non oil economy)



(c) Current Account relative to GDP

Figure 12: Evolution of Debt and the Current Account.

6 Conclusion

This paper addresses the question of how Ghana should best harness the revenues from its recent oil windfall. We show that the windfall should first be used to alleviate capital scarcity by reducing holdings of foreign debt. This will help to reduce credit spreads, in turn stimulating private and public investment and raising wages. The remainder of the windfall should primarily be used to invest in domestic capital, to stimulate growth and move Ghana along the path of structural transformation. However, some funds should temporarily be parked in foreign assets due to likely absorption constraints in the non-traded sectors.

The paper was structured in two main sections. In the first we addressed the question of to what extent Ghana should spend or save the windfall. Using calibrations based on the Ghanaian economy we took the permanent income rule as a benchmark and assessed the relative magnitude of a range of spending options. On balance we found that spending could be brought forward against the permanent income rule, if spending is focused on promoting growth through investment. As Ghana's recently passed Petroleum Revenue Management Act, 2011, suggests such a spending profile we find it broadly appropriate. Further work may look to integrate each of these spending rules into a larger collective model, and estimate parameters directly using Ghanaian data. This would provide a more detailed description of the relative merits of each rule and of the optimal spending path.

In the second section we addressed the question of how Ghana's oil windfall should be spent. In doing so we focused on investment and considered three options. The first was alleviating Ghana's capital scarcity. Building on work by van der Ploeg and Venables [2011] that uses a debt-elastic interest rate, we argue that if the stock of foreign debt is raising Ghana's cost of borrowing, it should focus on reducing this debt. This will reduce borrowing costs, and in doing so stimulate private and public investment. The second option was investing in foreign assets through a sovereign wealth fund. We find that this strategy is useful as a temporary way to stabilise oil volatility and smooth the effects of both "Dutch disease" and absorption constraints. However, this should only be pursued once the issues of capital scarcity have been alleviated. The third option was investing in domestic assets. Section 4 used growth accounting to show that Ghana's low growth is largely driven by its small and slow growing capital stock. Section 5 used a three-sector model of structural transformation to show that the optimal spending strategy is to invest heavily in domestic assets during the oil boom. This will move Ghana more quickly along the path of structural transformation. The effects of Dutch disease will largely be subsumed by the broader contraction of the traded sector through structural transformation. Potential extensions to this work may study empirically how much Ghana's stock of debt is affecting capital scarcity. Extensions may also involve a more detailed study of what types of domestic capital should be focused on. This may include examining the likely extent of absorption constraints in Ghana.

More broadly, this paper contributes to the literature on the optimal management of resource windfalls in small developing countries. It has focused on fiscal policy options once the windfall has been received, and thus has not addressed many equally important questions. First are the questions surrounding exploration and extraction, such as contracting between governments and private firms. Second are questions of optimally capturing the resource rents through tax policy. Third, we have not considered the potential short run demand effects of Dutch disease on inflation, and the potential role of monetary policy to flank different types of fiscal policy in Ghana (e.g. Dagher et al., 2010). Finally, we have ignored questions of political economy which are of primary importance in developing countries. In particular, when there are closely contested elections as there regularly are in Ghana, there will be a political bias towards illiquid investment projects and away from sovereign wealth funds, since the latter can be raided by political rivals when they take over office. Also, the recent work on the quality of the delivery of public investment and the data series for an efficiency-adjusted capital stock (Gupta et al., 2011) and the related problem of the difficulties of scaling up public investment programmes in the context of Dutch disease (e.g., Berg et al., 2010) will prove very useful for this purpose. Each of these are areas of active academic engagement, and should be included in any comprehensive analysis of how Ghana should optimally harness its oil windfall.

7 Appendix

7.1 The size of Ghana's oil windfall

Prospect	Field	MMBOE (P90-P50-P10)
DWT/WCTP	Jubilee Phase 1	250-370-590
DWT/WCTP	Jubilee Phase 1a	60-100-215
DWT/WCTP	Jubilee Phase 1b	160-205-260
DWT/WCTP	*Total Jubilee*	*470-675-1065*
DWT	Tweneboa	100-200-650
DWT	Enyenera (formerly Owo)	100-200-550
DWT	Ntomme	20-50-280
DWT	*Total DWT*	*220-450-1480*
WCTP	Teak	50-100-200
WCTP	Mahogany East Area	40-80-200
WCTP	*Total WCTP prospects*	*90-180-400*
WCTP	Odum	?
WCTP	Odum East	?
WCTP	Odum/Banda Updip	?
WCTP	Banda	?
WCTP	Banda West	?
WCTP	Banda Deep	?
WCTP	South Central Channel	?
WCTP	Dahoma Updip	?
DWT	Sapele	?
DWT	Turonian Deep	?
DWT	Wawa	?
DWT/WCTP	*Total Other*	*?-?-1055*
DWT/WCTP	*Total*	*780-1305-4000*

Table 2: Prospective reserves: millions of barrels of oil. (Source: Tullow Oil, 2010)

7.2 Spending Rules: Precautionary savings

The complete system of equations used to solve the dynamic programming problem for precautionary savings are:

$$
\begin{aligned}
C_T &= A_T \frac{r}{1+r} && (9)\\
C_{t-1} &= \bar{C}_t(1+\nu_t)^{-\sigma} \quad \forall t = 1, \ldots T && (10)\\
\nu_t &= \frac{\frac{1}{\sigma}(\frac{1}{\sigma}+1)}{2}\mu_t^2\sigma_P^2 && (11)\\
\mu_t &= \frac{E_{t-1}\sum_{s=t}^{\infty}\frac{P_s Y_s}{(1+r)^{s-t}}}{\bar{L}_t} && (12)\\
\bar{L}_T &= A_T && (13)\\
L_{t-1} &= \frac{\bar{L}_t}{1+r} + C_{t-1} && (14)\\
A_{t-1} &= (A_t - \bar{P}_t Y_t)(1+r)^{-1} + C_{t-1} && (15)\\
A_0 &= P_0 Y_0 && (16)
\end{aligned}
$$

7.3 Growth Accounting: Sectoral Employment and Capital

Since sectoral data is not readily available for Ghana, in this section we show how we can estimate sectoral employment and capital. We assume that output in each sector, s, is produced with the the following production function:

$$Y_s = A_s L_s^{\chi_s} K_s^{1-\chi_s} \tag{17}$$

where, L_s and K_s are the employment and capital used in sector s. If we also assume that the rates of return on capital and labor are equalized across sectors (two arbitrage conditions), then it is easy to show that the above functional form implies that for any two sectors s and s', the following two conditions must hold:

$$\chi_s \frac{P_s^D Y_s}{L_s} = \chi_{s'} \frac{P_{s'}^D Y_{s'}}{L_{s'}} \text{ and } (1-\chi_s)\frac{P_s^D Y_s}{K_s} = (1-\chi_{s'})\frac{P_{s'}^D Y_{s'}}{K_{s'}}, \tag{18}$$

where P_s^D is the domestic producer price of sector s goods. As is emphasized by Caselli [2005], this price will generally differ from the PPP price and it is the price that a domestic investor will care about. Finally, $P_s^D Y_s$ is sector s-es value added (in domestic prices), calculated using UN current price data in local currency units. If there are N sectors, the above expressions provide $2N-2$ distinct equations. Combining these with a labor and capital market clearing conditions:

$$\sum_s L_s = L \text{ and } \sum_s K_s = K, \tag{19}$$

where K and L are aggregate capital stock and employment, we have a system of $2N$ equations in $2N$ unknowns from which we obtain expressions for sector specific capital stock, K_s, and employment L_s for each of the N sectors:

$$L_s = \left(\frac{\chi_s P_s^D Y_s}{\sum_i \chi_i P_i^D Y_i}\right) L \text{ and } K_s = \left(\frac{(1-\chi_s)P_s^D Y_s}{\sum_i (1-\chi_i) P_i^D Y_i}\right) K. \tag{20}$$

Aggregate Labor and Capital We follow Caselli [2005] and use the Penn World Tables (version 7.0) to construct estimates of aggregate capital stock. This is done using the perpetual inventory equation:

$$K_{t+1} = (1 - \delta)K_t + I_t, \tag{21}$$

where I_t is investment and δ is the depreciation rate. Like Caselli [2005], we measure I_t from the PWT 7.0 as real aggregate investment in PPP.[3] As is standard, we compute the initial capital stock K_0 as $I_0/(g + \delta)$, where I_0 is the value of the above investment series in the first period that it is available, and g is the average geometric growth rate for the investment series in the first twenty years the data is available.[4]As is discussed in the literature - and by Caselli [2005] - the choice for initial capital stock is tenuous and stems from the assumption that an economy is on a balanced growth path of a Solow model (with a trend growth rate of g) in the initial year. Finally, I follow Caselli [2005] and set the depreciation rate, δ, to 0.06. The above process gives us sequences of capital stocks derived from PWT data in 2005 International dollars. To make the capital stock comparable to our GDP data (which is in constant and not international dollars), we calculate the capital output ratio and then multiply it by constant price GDP from the UN.

Labor force is backed out from the Penn World Tables (version 7.0) data. In particular, the PWT give real (chained) GDP per worker data (rgdpwok), real (chained) GDP per capita data (rgdpch) and total population data (POP). Thus, the labor force, L can be backed out as $L = POP * rgdpch/rgdpwok$.

Labor Shares The final element needed to calculate the expression in equations 20 are estimates of the labor share, χ_s, for each sector. For Ghana and Nigeria we obtain this data from social accounting matrices provided by the International Food Policy Research Institute [Breisinger et al., 2007]. For Norway and the OECD, we make use of OECD data to calculate the average annual share of employee compensation for each sector in OECD countries for the longest period of time that data is available. We calculate the labor share as the ratio of total compensation of employees (wages and salaries before taxes, as well as employers social contributions) over sectoral value added. Since we will also be performing a growth accounting exercise for Malaysia and since equivalent data is not available, we shall take an average of OECD and Ghanaian labor shares. Table 3 presents the results.

Results: Employment Shares Figure 13 presents the implied employment shares found by the above procedure in agriculture, industry and services. The fit of services, is relatively good in all cases. The model tends to over predict employment in industry and under predict employment in agriculture. Performing a further decomposition of employment in industry in Figure 14, we see that the reasons for this vary by country. In Ghana, the model over predicts employment in mining, utilities and construction. In

[3]So that $I_t \equiv RGDPL \cdot POP \cdot KI$, where $RGDPL$ is real income per capita obtained with the Laspeyres method, POP is the population and KI is the investment share in real income.

[4]Caselli [2005] uses the growth rate between the first available year and 1970. We prefer our method, which should provide better estimates for countries whose investment data series start closer to 1970.

Labor Share	Ghana	Nigeria	Norway	OECD	OECD/Ghana Average
Agriculture	0.92	0.96	0.22	0.26	0.59
Mining and Utilities	0.37	0.05	0.15	0.31	0.34
Manufacturing	0.66	0.53	0.73	0.57	0.62
Construction	0.65	0.02	0.74	0.59	0.62
Services	0.73	0.92	0.62	0.54	0.64
All	0.76	0.43	0.54	0.52	0.64

Table 3: Implied Labor Shares

Nigeria, the model over predicts employment in manufacturing. Despite these presumable flaws in the construction method, since we do not have better long run data (especially for Ghana and Nigeria), we use the data predicted by the model above to construct TFP decompositions at the sectoral level. We do emphasize however, that because of these data limitations the TFP decompositions in the main text have to be taken with a large grain of salt.

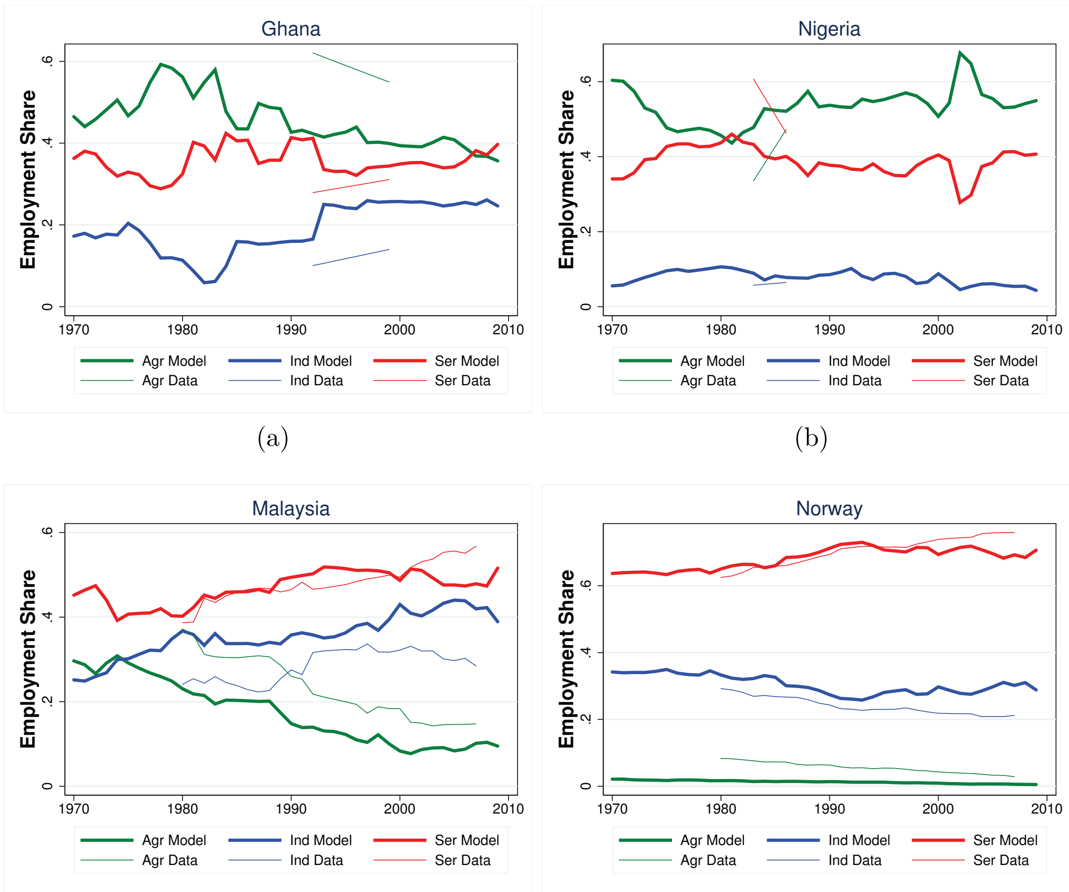
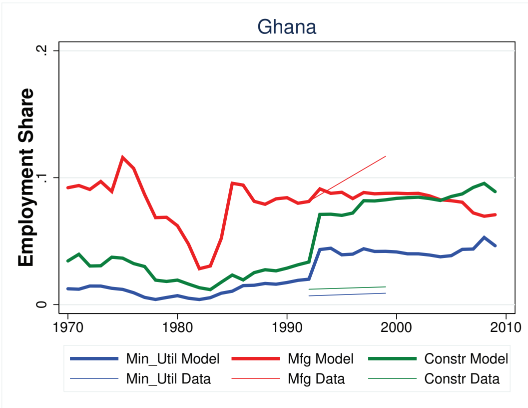


Figure 13: Sectoral Employment Shares in Agriculture, industry and services: Data and Model.



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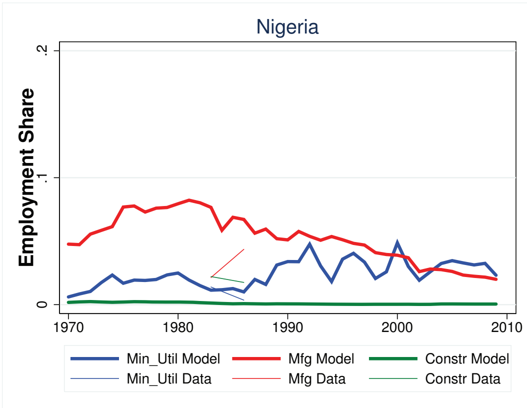

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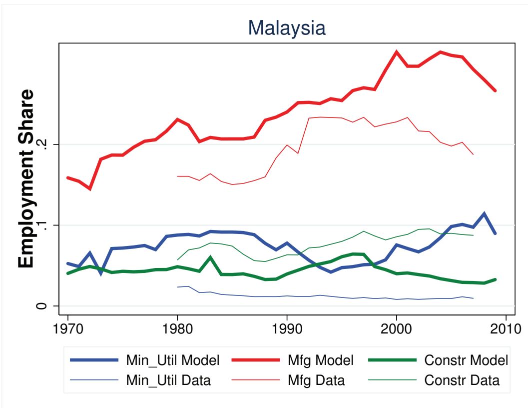

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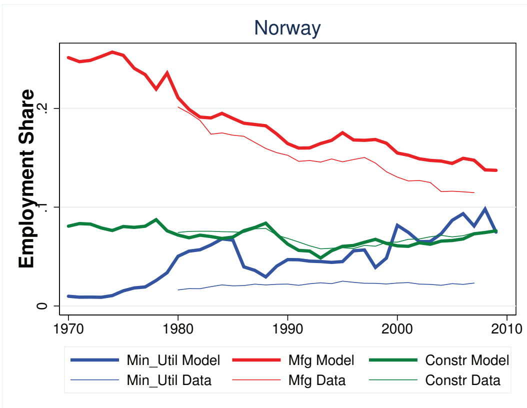
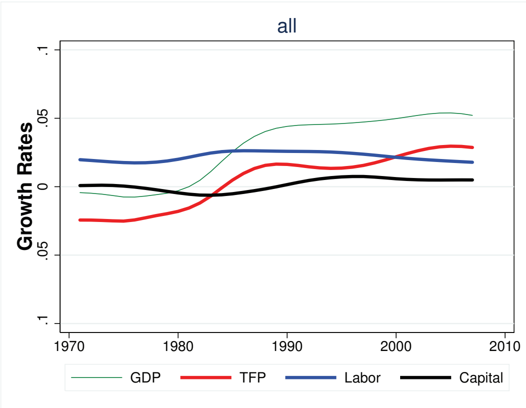


(d)

Figure 14: Sectoral Employment Shares.

7.4 Growth Accounting: Figures

This Appendix provides the results of the growth accounting exercise in Section 4. For these graphs the original sectoral GDP, capital and labor data was smoothed using an HP filter with smoothing parameter set to 100. Finally, recall that the capital stock in this exercise is constructed from investment data using the perpetual inventory method. This method requires an initial guess of capital stock, and is hence sensitive to that initial guess in the first several years. Since the investment data used to construct the capital stock for Malaysia started in 1955 (as opposed to 1950 in all other countries), we present results only from 1975 for Malaysia.



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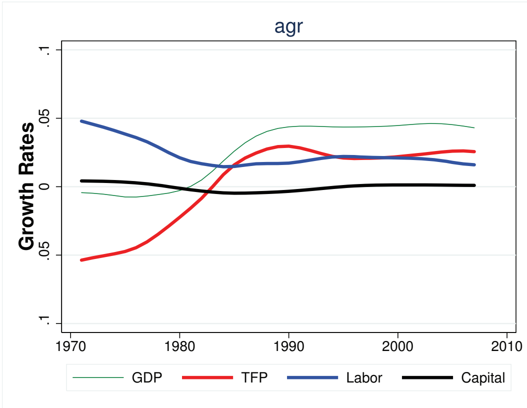

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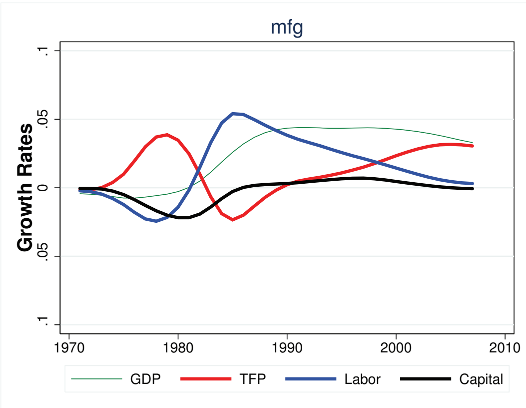

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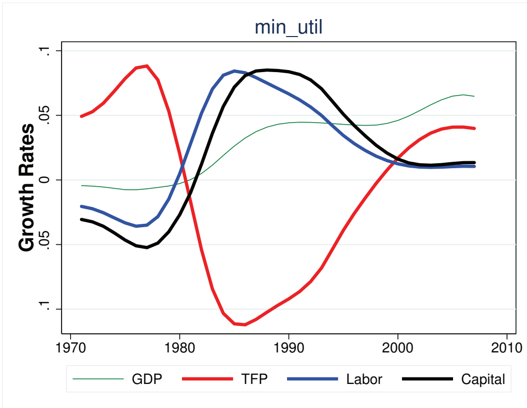

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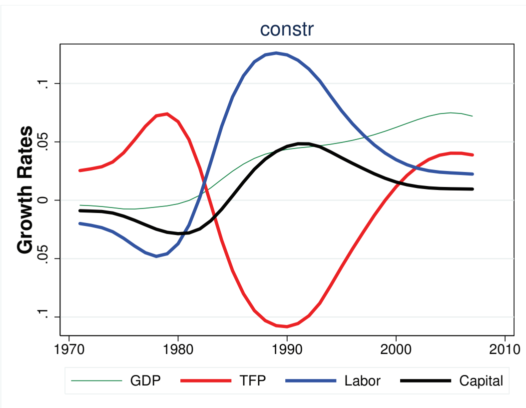

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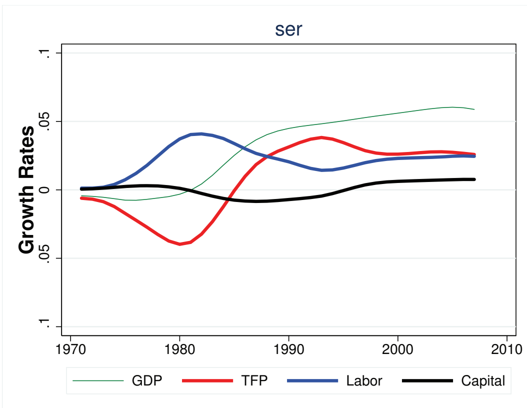


(f)

Figure 15: Ghana Decomposition

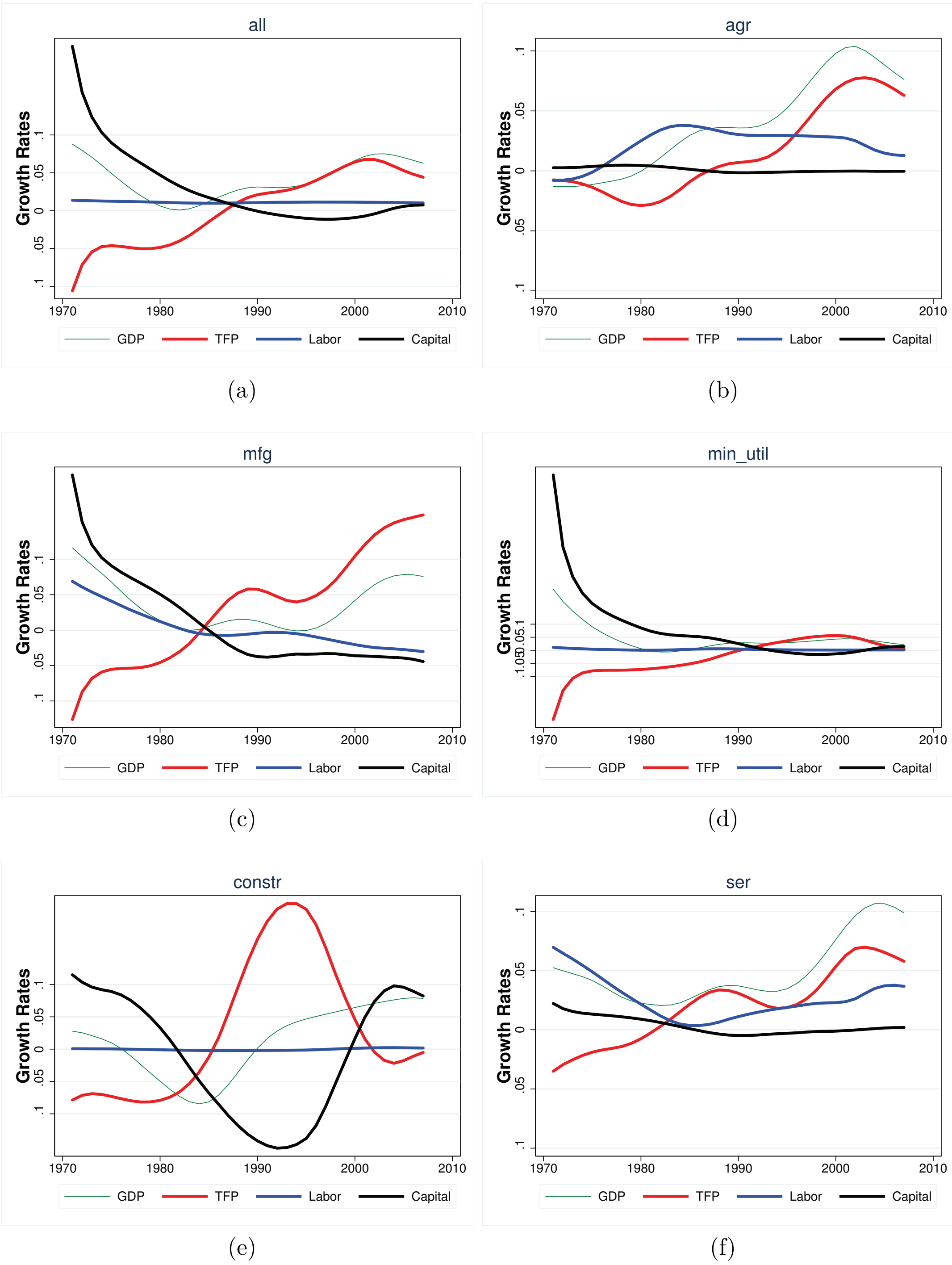
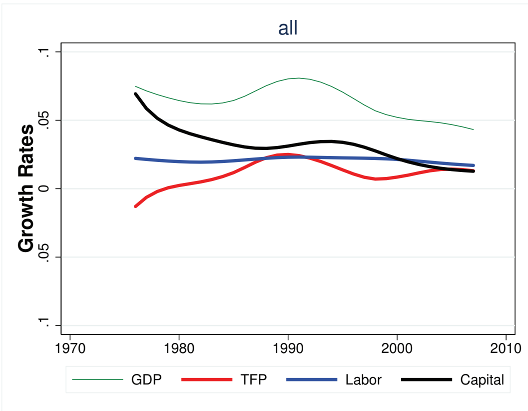


Figure 16: Nigeria Decomposition



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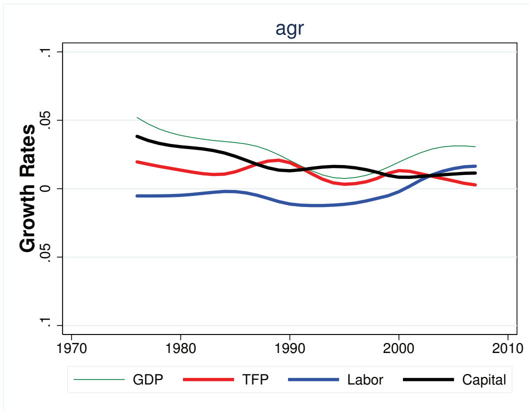

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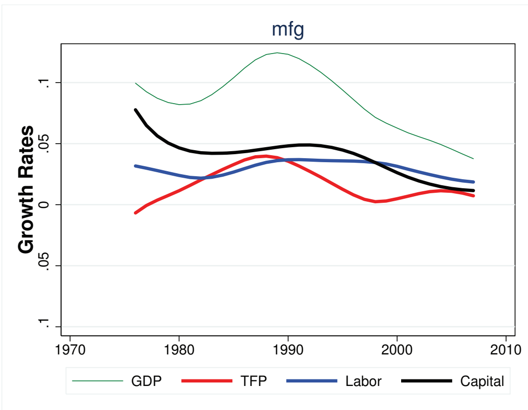

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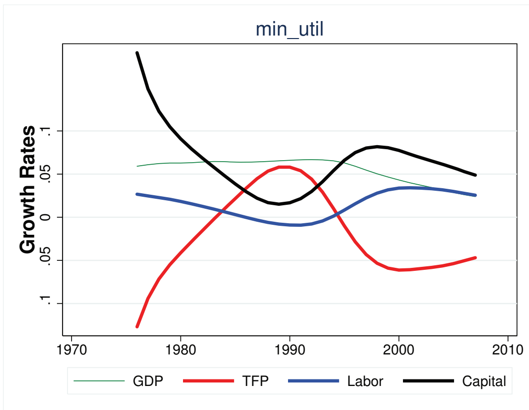

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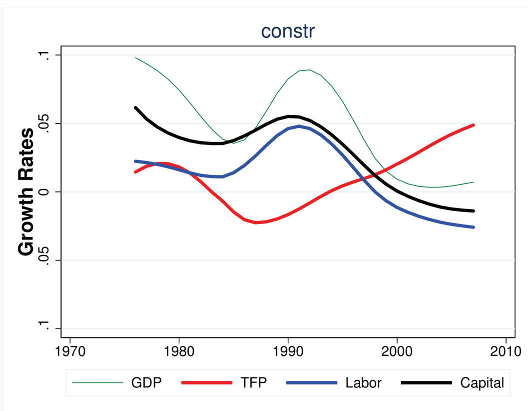

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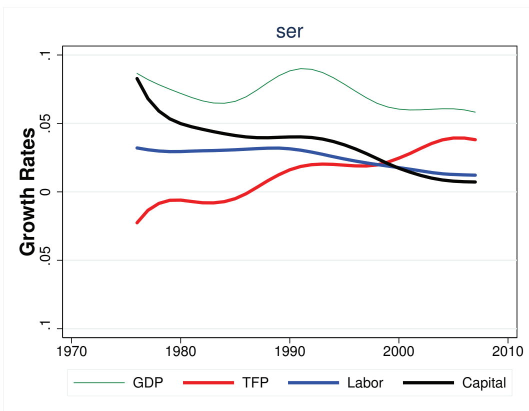

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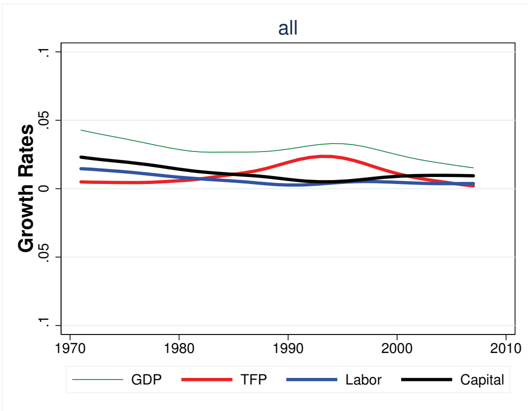
Figure 17: Malaysia Decomposition



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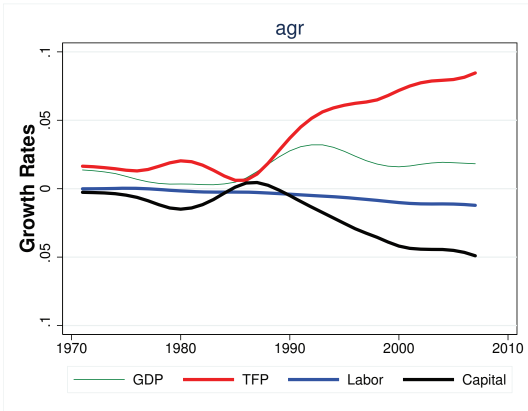

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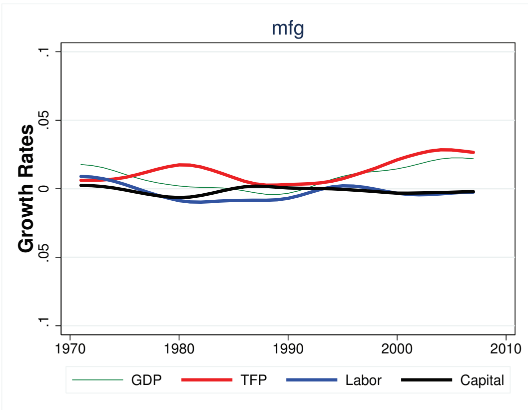

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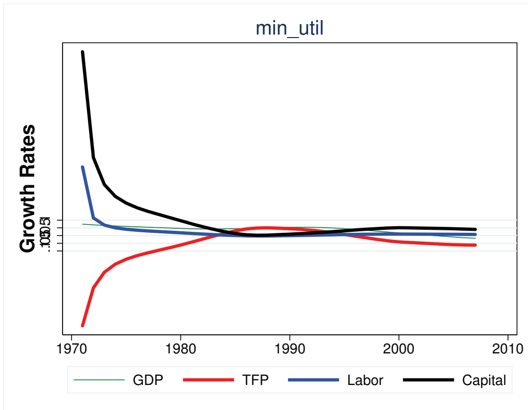

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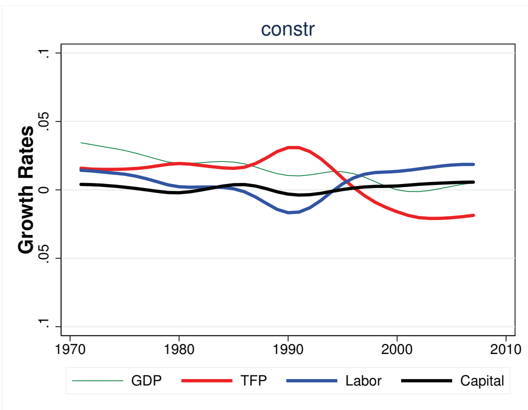

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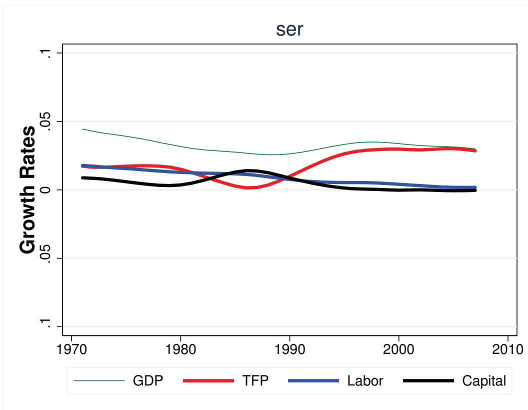


(f)

Figure 18: Norway Decomposition

7.5 Structural Transformation: Model

The full system of equations describing the structural transformation model are:

$$
\begin{aligned}
&\max \sum_{t=0}^{\infty} \beta^t U(Y_{A,t}, C_t) \\
Y_{A,t} &= g_A^t A_A L_{a,t} \\
Y_{S,t} &= g_S^t A_S L_{s,t}^{\alpha_s} K_{s,t}^{1-\alpha_s} \\
Y_{M,t} &= g_M^t A_M L_{m,t}^{\alpha_m} K_{m,t}^{1-\alpha_m} \\
M_t + R(D_t)D_t &= Y_{M,t} + p_{O,t}O_t + D_{t+1} \\
C_t + I_t &= F[Y_{S,t}, M_t] \equiv (\gamma Y_{S,t}^{\frac{\varepsilon-1}{\epsilon}} + (1-\gamma)M_t^{\frac{\varepsilon-1}{\varepsilon}})^{\frac{\varepsilon}{\varepsilon-1}} \\
K_{t+1} &= (1-\delta)K_t + I_t \\
K_t &= K_{m,t} + K_{s,t} \\
1 &= L_{m,t} + L_{s,t} \\
&K_0 given
\end{aligned}
$$

7.6 Structural Transformation: Calibration

The model described above is calibrated to the Ghanaian economy. Ghana underwent a period of significant political upheaval in the early 1990's and regained some form of stability after 1993. As such, we choose to match the data to the years 1993-2007. As we are interested in long run estimates, we smooth this data using an HP filter (with smoothing coefficient of 100). To match our model, we express all quantities in per capita terms. Our first assumption is to split the economy into three sectors: agriculture, traded goods (manufacturing and mining denoted by M), and non-traded goods (services and construction denoted by S). Later we will add a fourth, oil sector, but since oil is discovered in early 2008, in the initial (non-oil calibration) we will abstract from that sector.

Labor Shares First we find the labor shares of the above sectors. The data comes from the SAM matrices from IFPRI data. The labor share in the traded sector is $\alpha_M = 0.53$ and in the non-traded sector the labor share is $\alpha_S = 0.71$ with the rest going to capital. In agriculture, the labor share is 0.72 whilst the land share is 0.2 with the rest going to capital. For simplicity, we simply assume the labor share is one in agriculture. Thus the traded (predominantly manufacturing) sector is the most capital intensive sector and it has a higher capital intensity than the non-traded (predominantly service) sector.

Remaining Parameters The remaining parameters are chosen as follows. First, we set the discount rate and the depreciation rate to standard values of $\beta = 0.98$ and $\delta = 0.06$ (notice that this was also the depreciation rate used to construct capital in the perpetual inventory method). Next, we normalize the initial TFP levels in all sectors to one, i.e.

Parameter	Value	Target
$A_{i,1993}$	1	Normalization
$\bar{A}$	0.51	Agr employment 1993
g_A	1.006	Agr employment 2007
g_M	1.063	Change in ps/pm, 1993-2007
g_S	1.049	GDP growth, 1993-2007
γ	0.77	NT employment, 1993
ε	0.62	NT employment, 2007
δ	0.06	Standard
β	0.98	Standard
σ	0.84	Long run US interest rate
α_S	0.71	NT labor share
α_M	0.53	T labor share

Table 4: Calibrated Parameters

$A_A = A_M = A_S = 1$. This amounts to simply choosing units. The simplicity of the agricultural sector then allows us to choose $\bar{a} = 0.512$ and $g_A = 1.006$ to match the employment share in agriculture in Ghana in 1993 and 2007 of 51.17% and 46.89% of the labor force respectively. The initial capital stock is chosen so that the initial capital to output ratio in the model is equal to that in the data in 1993, approximately 3.5. The remaining parameters $\{\sigma, g_S, g_M, \gamma, \varepsilon\}$ are chosen to match: an annual (asymptotic) interest rate of $R^* = 8\%$ as in Acemoglu and Guerrieri [2008], the average GDP growth rate of Ghana between 1993 and 2007 (measured as a constant 2005 price sum of sectoral value added) of 2.2%, the average annual change in the price of non-traded to traded goods between 1993 and 2007 of 0.4% and the employment share in the non-traded sector in 1993 and 2007 of 37% and 41% respectively.

Next, we explain the above choices. We know from the above that in the long run (given sectoral labor shares) the growth rate of aggregate output is determined by the TFP growth rate of the non-traded sector, g_S. Given this growth rate, from the Euler equation we can show that in the limit $\sigma = \frac{\alpha_S log(\beta(1+\bar{R}))}{g_S}$, where $\bar{R}$ is the annual (asymptotic) interest rate. The growth rate of the traded sector, g_M, fundamentally determines how fast output in the traded sector is growing relative to output in the non traded sector and hence the change in the price of non-manufacturing goods to manufacturing goods (This can be seen very clearly in the case when there is no capital in the model. Then, the price of non-traded to traded goods is given by: $\frac{p_{S,t}}{p_{m,t}} = \frac{A_M g_M^t}{A_S g_S^t}$).

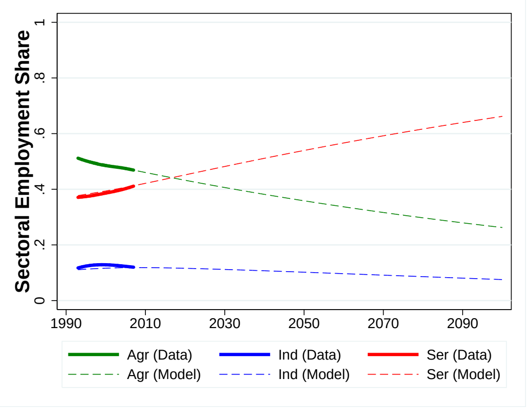
To calibrate the interest rate and debt premium we assume that $R^* = \frac{1}{\beta}$. From **?**, we assume that $\phi = 1.9$. Lastly, we choose initial bond holding and the parameter $\bar{D}$ to match the level of debt to GDP ratio in 2003[5] of approximately 25% of GDP and a long run debt to non-traded GDP ratio of approximately 10%. This results in $D_0 = 0.5$ and $\bar{D} = 0.52$.

Finally, γ determines the relative weight of non-traded goods and hence how large the share of employment is for those goods, whilst ε determines how much sectoral employment (and capital) reallocation takes place for a given change in the relative size of output

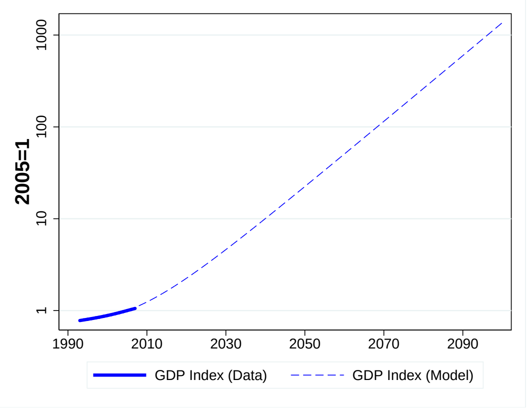
[5]We choose this date rather than 1993, since most of Ghana's debt was written off in 2003.

of sectors. The calibrated parameters are presented in table 4. We show the fit of the model for sectoral employment shares, capital output ratio and real GDP in Figure 19.

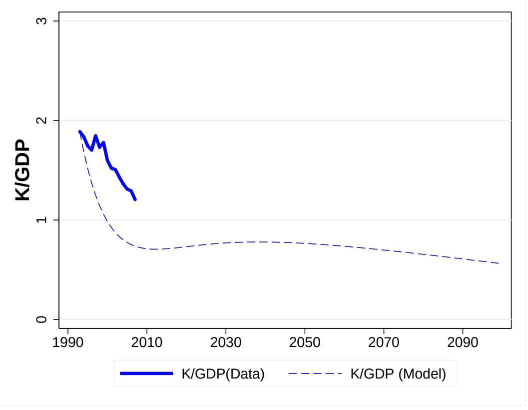
Oil shock To analyse the effects of an anticipated oil shock we set $p_{O,2011}O_{2011} = 0.48$, so that the ratio of the value of endowment of oil relative to nominal GDP in 2011 is approximately 6.9%. We then assume that the value of oil windfall (relative to the price of traded goods) declines at a constant rate of 8.7% a year - the rate implied by Figure 2



(a) Employment Shares



(b) GDP Index



(c) Capital to GDP ratio

Figure 19: Model and Data for GDP, employment shares and capital output ratio.

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