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Labor productivity and energy use in a three sector model: An application to Egypt

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Abstract

This paper presents a model of a developing economy with three sectors---a modern sector producing manufactures and services, a traditional sector producing agricultural goods, and a third sector providing energy. Modern and energy sector are assumed to be demand--constrained; the agricultural sector is supply--constrained. Simulation exercises confirm insights of existing theory on structural heterogeneity: A price--clearing agricultural sector can impose an inflationary barrier on growth. Further, emphasis is placed on the sources of productivity growth. Specifically, higher energy intensity rather than increases in energy productivity enable labor productivity growth, with the attendant complications for 'green growth.'

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Abstract

This paper presents a model of a developing economy with three sectors—a modern sector producing manufactures and services, a traditional sector producing agricultural goods, and a third sector providing energy. Modern and energy sector are assumed to be demand–constrained; the agricultural sector is supply–constrained. Simulation exercises confirm insights of existing theory on structural heterogeneity: A price–clearing agricultural sector can impose an inflationary barrier on growth. Further, emphasis is placed on the sources of productivity growth. Specifically, higher energy intensity rather than increases in energy productivity enable labor productivity growth, with the attendant complications for 'green growth.'

1 Introduction

The science of climate change is clear. In order to avoid further temperature increases, decisive policy action is needed to quickly lower greenhouse gas emissions (GHG). IPCC (2007) documents the likely dire consequences of inaction.

Economic research on the impact of climate change and the policies to address it has focused on the distribution of costs of mitigation across generations. Stern (2007) and Nordhaus (2008) are only two of the most influential papers, and exemplify the approach taken. In both, containing future temperature increases costs today's consumption, but increases future consumption. A heated debate ensued on how strongly to discount future generation welfare. However, Foley (2008) argued that these studies ask the wrong question. Investment in mitigation capital would cost consumption only if the world economy today were on its efficient production frontier; because of the unpriced externality, however, it is not. Investment in mitigation capital then increases consumption of both current and future generations, and financing it through borrowing ensures that the burden falls where the benefits do, namely on future generations. Rezai et al. (2009) put forth simulations of a

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simplified model similar in structure to Nordhaus (2008), but correcting for these problems and confirming insights of Foley (2008).

These studies assume full employment and take the path of labor productivity growth as given. The question asked is what investment in mitigation (and conventional) capital is necessary to sustain labor productivity growth. Taylor (2008) takes a different approach. He investigates the linkages between energy productivity, labor productivity and global warming. Energy productivity, output per unit of energy Y/E, is of course a measure of mitigation. Labor productivity growth is the sum of the growth rates of energy productivity and energy intensity, or the ratio of energy per unit of labor E/L. Historically, rising labor productivity was made possible by increases in energy intensity. The challenge climate change poses is to render future labor productivity increases rather the result of energy productivity increases.

The topic of this study is a first step to investigate if and how that might be possible in a developing country. The defining characteristic of many developing countries is structural heterogeneity—the existence of modern production activities side by side with informal, traditional activities (Prebisch (1959); Polanyi Levitt (2005)). The fundamental policy challenge for developing countries is to provide productive employment opportunities for often still fast growing populations and to raise labor productivity. If GDP growth is strong enough, transfer of labor from low productivity to high productivity activities can support a virtuous circle of development and growth (Kaldor (1978); Ocampo (2005)). Generating employment in modern high productivity activities is difficult enough. It can be further complicated for several reasons, some of which have been raised for decades in the field of development economics.

First, a surge in labor productivity in modern activities can reduce demand for labor, and hence increase the share of workers in informal activities (Rada (2010)). Second, growth of modern activity employment, rural-urban migration and other global factors can lead to upward pressure on agricultural prices (Lewis (1954); Harris and Todaro (1970); Kalecki (1976)). The resulting decrease in modern sector real wages in terms of necessary agricultural goods can choke off an expansion, especially when external demand is weak or export capacities are underdeveloped (Taylor (1983)). Third, energy supply bottlenecks can stall capital deepening, as could a global agreement on energy emissions reductions. The challenge to increase labor productivity would then be still more exacting (Ocampo et al. (2009); UN–DESA (2009)).

All three issues have regained prominence in the ongoing debate on macroeconomic development policies. Despite strong growth performances, several so-called success stories show mixed employment pictures. China and India are only the two largest developing countries where jobless growth in the wake of the global downturn at the turn of the century appears to have taken hold. In both countries, the share of informal sector employment in total employment is rising. High commodity prices, and specifically high prices of food and staples continue to threaten livelihoods and depress real incomes in the Global South, even if they have receded from their highs in the developed world. And last but not least, stable and sufficient energy supply and distribution in developing countries is often lacking, and in some cases available only in foreign-dominated extractive resource industries. Increasing energy supply and energy-related infrastructure is of crucial importance for development prospects, and the technological, knowledge-related and cost impediments to quickly adopt high productivity designs are often considerable. High emission energy provision is then the only feasible option.

In this paper, we discuss a simple three sector model that augments a fairly standard dual economy model with an energy–providing sector. Our intent is to investigate the linkages and bottlenecks between these three sectors. The crucial questions asked are, first, what the implications of the supply–constraint in agriculture are for the macro–economy; and, second, what macroeconomic relationship exists between labor productivity and energy use. The time horizon of the model is the medium run. This first step therefore does not address explicitly climatological issues—damage and mitigation—and the resulting (long run) nexus between climate change and the economy.

We begin below with a discussion of structural change and economic performance in Egypt. The following section 3 presents the model. Section 4 presents simulation results and discussion. Section 5 concludes.

2 Structural change and economic performance in Egypt

Development requires structural transformation towards high-productivity, high value-added activities. Manufacturing in particular has the potential to deliver increasing returns to scale and overall productivity growth through spillovers and dynamic linkages. Agricultural and primary activities are usually subject to decreasing returns and therefore can present a drag on productivity growth and growth in general. However, industrialization and structural transformation is impossible without an expansion of output and productivity in the agricultural sector. Provision of affordable foodstuffs is crucial to alleviate poverty. Further, inflation of food prices has negative effects on external competitiveness.

In this section we examine indicators on structural transformation and economic performance of the Egyptian economy for the last four decades. We follow it up by a discussion of structural features of the economy based on a 1996/7 SAM.

[**Figure 1–4 about here**]

Figure 1 on structural change in Egypt confirms the trend towards services and manufacturing one expects to see for a developing economy. Agriculture and primary activities have shrunk from 30 per cent of GDP in 1970s to 15 per cent by 2000s while manufacturing and services gained 5 and 9 percentage points respectively over the period. However, a closer examination of growth dynamics based on a simple decomposition of GDP growth by sectors reveals that manufacturing and agriculture's contribution to growth has steadily increased over time. See Figure 2.[1] The service sector's contribution to growth, on the other hand, has declined between the 1980s and 2000s despite the rise in the sector's weight in the overall economy. Slow growth of labor productivity in services is one reason, that the new services jobs tend to be low-productivity and possibly informal is another. Since the 1970s overall economic growth has as well benefited significantly less from mining activities. In this case, the cause has to be seen in large fluctuations of oil prices, as documented by, for example, UNDP (2009).

Figure 3 shows the shares of main sources of final demand. Household expenditures make up the largest share of demand followed by gross fixed capital formation (GFCF). Net exports have been negative for most years prior to the 2000s. We can also decompose economic growth by sources of demand. In Figure 4 household consumption and gross investment appear as the main drivers of economic growth. Government spending shows a minor contribution, and net exports acted as a drag on growth in the 1970s. The positive contribution of net exports to growth since the 1980s has been fairly small.

For the simulation exercises we use a Social Accounting Matrix (SAM) from El-Said et al. (2001) with a base year of 1996/7. We aggregate the SAM, shown in Table 1 below, to three sectors and three households. The three sectors are the t–sector, which includes industry and services; the n–sector, which includes agriculture, and the e–sector, which provides energy.[2] The traditional sector in our framework includes all agricultural and husbandry activities except food processing, which here is considered part of the industry. Energy covers petroleum–related and electricity producing activities.

[**Tables 1–3 about here**]

We aggregate the ten households of the SAM in El-Said et al. (2001) into modern and

[1]Aggregate value added is calculated by summing value added across sectors, $X = \sum_{i=1}^{n} X_i$. Total differentiation of this expression with respect to time allows us to write the growth rate of value added as a weighted average of sectoral growth rates in value-added, $\hat{X} = \sum_{i=1}^{n} \theta_i \hat{X}_i$, where θ_i is each sector's share in overall value-added.

[2]The terminology here follows the time–tested *traded,non–traded* distinction. While our n–sector, in accordance with the facts on the ground in Egypt does import, it does not feature exports. Throughout the paper, we will use the labels t–sector,industry and n–sector,agriculture,traditional interchangeably. The label *modern* activities refers to t and e–sector production, since e–sector activities are assumed to be large–scale operations.

traditional households using the source of income as a criterion. Traditional households, for example, receive the income of all factors of production—labor, capital and land—from agricultural and husbandry activities. We label them N–households. In the modern t and e–sectors, we distinguish between labor and capital incomes and assume wage-earning and profit–earning households.[3] We label wage–earners the T–households, and profit–earners the C–households. (T–households receive wage income from both the industry and energy sector, as do C–households for profits.) The numbers in Table 2 show that capital income going to the traditional sector represents about 8 percent of total profits in the economy, while traditional labor receives 15 percent of economy-wide wages. Together with income from land, agricultural activities captured 18 percent of the Egyptian national income in 1996/7.

Final demand consists of household consumption, government spending, exports and gross fixed capital formation. In this paper, we make several simplifying assumptions—none of which fundamentally change the model. We assume that capitalist households do not consume. They are as well the only households that save; government spends only on the modern good; exports consist of modern goods and oil; and industry provides the only investment good.

We divide final consumption of modern, traditional and energy goods into consumption by traditional and modern households respectively using the following methodology. We first calculate the weights of traditional and modern households' incomes in total household income using dissagregated data on types of households' incomes. These weights are then used to divide final household consumption into consumption of traditional and modern good by traditional and modern households. For example consumption of agricultural or traditional goods by the traditional household is calculated as:

$$C_N^N = C_N \left(\frac{w_N}{\sum_j y_j} + \frac{\pi_N}{\sum_j y_j} + \frac{rent}{\sum_j y_j} \right) \tag{2.1}$$

where C_N is total consumption of good N by the household sector, w and π are wages and profits, y_j is the type of income j, and N, T are notations used for the traditional or n-sector and modern or t-sector sector respectively.

Table 2 summarizes a few general indicators of the Egyptian economy's structure. In 1996/7 industries and services contributed 78 per cent of gross value–added compared to 16 per cent and 6 per cent by agriculture and energy, respectively. The bulk of final demand or 57 per cent went to consumption by the household sector. As expected, demand distribution by type of goods favored manufactures and services. Households spent 82 per

[3]Wage-earning households do receive transfers of profits from businesses. For simplicitly, we abstract from these; meaning that part of profit income is suppressed in the SAM.

cent of their budget on t–sector product, 17 per cent on n–sector product, and the rest on energy consumption. Unlike most of the previous years, Egypt had a slight trade balance surplus in 1996/7 of almost 2 per cent of GDP. Gross fixed capital formation was relatively solid and represented 17 percent of GDP.

Table 3 provides the output multiplier matrix—the Leontief–inverse. It allows us a more in-depth analysis of the structural linkages and final demand effects. The modern sector has the largest impact on the economy through its overall multiplier of 1.65, implying that a unit increase in final demand for t–sector product leads to an overall increase in gross output of 1.65. The relevant figures for the traditional and energy sectors are 1.42 and 1.30. As expected, the sectors' own multipliers—the diagonal elements of the two matrices—are larger than one suggesting a significant impact of final demand in each sector on its own output.

How about effects across sectors? Both the traditional and energy sector appear to be more dependent on industries and services. A unit increase in the demand for agricultural goods creates a demand for modern sector's product of 0.21 units, while a rise in the consumption of energy leads to a demand of 0.25 units for the t–sector good. At the same time output in the n–sector gains 0.11 units following a rise of one unit in modern sector's final demand. Energy, on the other hand, does not benefit much from a rise in final demand in either the modern or the traditional sectors. See the third row of Table 3. This suggests a relatively low energy intensity of economic activities in the Egyptian economy.

3 The model

The characteristic feature of the model is that the modern t and e–sectors are quantity–clearing, hence demand–constrained, and the agricultural n–sector is price–clearing or supply–constrained.

Industry and services—the t–sector—are structurally similar to industry and services in advanced economies. Large firms with significant market shares produce with excess capacity, enjoy pricing power, and satisfy current demand X_t by varying their rates of utilization. Higher rates of utilization necessitate hiring; $\hat{L}_t > 0$.[4] The growth rate of employment, however, is smaller than the growth rate of value added Y_t; in the short run due to labor hoarding, and in the medium run due to Kaldor–Verdoorn effects. Along these well–known lines, labor productivity growth has the same sign as output growth.

Agriculture—the n–sector—is fundamentally different than industry, or even agriculture in an advanced economy. With a given technology and limited fertile land, output X_n is pre–determined, and does not vary with changing levels of labor supply, L_n. However, labor

[4] A *hat* over a variable, such as $\hat{L}_t > 0$, denotes the proportional growth rate of L_t.

productivity is endogenous, since a demand expansion in, say, the t–sector leads to hiring there, and a reduction of surplus labor here. Further, given output X_n, the price P_n ensures that sectoral excess demand is zero.

Energy provision—the e–sector—is modeled principally like the t–sector. An important difference is that there are neither investment nor government expenditures on e–sector product. Otherwise, the sector's firms are assumed to be large, have significant market share, excess capacity and pricing power; hence, quantity–clearing. This structure is reasonable in the short and medium run. In the long run, conventional fossil–based energy provision might well be supply–constrained and price–clearing, but we will leave that topic for future inquiry and focus for now on the medium run linkages between industrialization, food prices, and energy demand.

Nominal wages in both t and e–sector are fixed at a conventional level.[5] Since both prices P_t and P_e rise with an expansion, as does labor productivity $\xi_t = Y_t/L_t$ in the t–sector, macroeconomic distributive adjustment shows *forced saving*: an expansion is financed by redistribution towards (high–)saving profit–earning households. The nominal agricultural wage rises with market receipts per unit and average productivity. Food price inflation then feeds into intermediate costs and aggregate inflation, and threatens to halt the expansion.

3.1 Output and employment

Having broadly laid out the model's structure, we can proceed to present some more detail. Let us begin with determination of outputs. In the t–sector, real output X_t is the sum of intermediate demands, consumption C_t, investment I_t, government expenditures G_t and exports E_t:

$$X_t = \sum_{i}^{3} a_{ti} X_i + C_t + G_t + I_t + E_t. \tag{3.1}$$

Total consumption of t–sector product decomposes by sources of demand, $C_t = C_t^T + C_t^N$, where subscripts denote the type of product, and (capitalized) superscripts the origin of demand for that product. Note the aggregation scheme: T–households earn (after–tax) wage income from t and e–sectors and consume all of it; N–households earn (after–tax) wage income from the n–sector and consume all of it; C–households earn (after–tax) profit income from t and e–sectors and save all of it.

[5] Conventional wage levels w_t and w_e are currently calibrated to unity in the base year data. These could be extended to include a fixed premium on the agricultural wage w_n.

Analogous to equation (3.1), e–sector output is demand–determined,

$$X_e = \sum_i^3 a_{ei} X_i + C_e^T + E_e, \tag{3.2}$$

with the difference that n–sector households do not consume (significant amounts of) energy, so that $C_e^N = 0$. In contrast to t and e–sector, the level of n–sector output is capacity–constrained, and just proportional to inherited capital:

$$X_n = \gamma K_n = \bar{X}_n. \tag{3.3}$$

Value added in the three sectors is proportional to real outputs. We can write the share of domestic value added in supply as

$$\mu_j = \frac{Y_j}{X_j} = \left(1 - \sum_i^3 a_{ij} - t_j^X - f_j e\right), \tag{3.4}$$

where t_j^X is a production tax net of subsidies, $f_j = M_j / X_j$ is the sectoral import propensity and e is the nominal exchange rate, quoted as the domestic currency price of a unit of foreign currency.

Export and import demand *can* be responsive to price changes; in standard fashion export and import functions are

$$M_j = \phi_j^0 \rho^{-\phi_j^1} X_j \tag{3.5}$$

$$E_j = \epsilon_j^0 \rho^{\epsilon_j^1} W_j, \tag{3.6}$$

where $\rho = \frac{eP_M}{P_y}$ is the real exchange rate with P_M a weighted price index of imports, and P_y the GDP–deflator. W_j represents world demand for j–sector product; $W_n = 0$. As discussed below, price elasticities of import demand ϕ_j^1 and export demand ϵ_j^1 can vary substantially across sectors.

Investment and government expenditures on t–sector product are exogenous. Consumption is determined by a standard Linear Expenditure System (LES). Recall that only wage earners consume; we discuss profit income in a moment. Modern wage–earning households—denoted by the superscript T—are comprised of those working in the t and e–sectors. Their disposable income is $Y_d^T = (1-\pi_t)(1-t_t^T)P_t Y_t + (1-\pi_e)(1-t_e^T)P_e Y_e$, where $\pi_i = 1 - \frac{w_i L_i}{P_i Y_i}$ for $i = t, e$ is the sectoral capital share, and t_i^T is the (net) tax rate on sectoral wage income. T–households demand all three goods, and consume a minimum "floor" amount of n–sector product, C_F^T. We list the equations here for completeness.

$$\begin{aligned} C_t^T &= c_t^T \frac{Y_d^T - P_n C_F^T}{P_t} && (3.7) \\ C_e^T &= c_e^T \frac{Y_d^T - P_n C_F^T}{P_e} && (3.8) \\ C_n^T &= (c_t^T + c_e^T) C_F^T + (1 - c_t^T - c_e^T) \frac{Y_d^T}{P_n}. && (3.9) \end{aligned}$$

Analogously, n–sector households disposable income is $Y_d^N = (1 - t^N) P_n Y_n$, and their floor consumption of n–sector product is C_F^N:

$$\begin{aligned} C_t^N &= c_t^N \frac{Y_d^N - P_n C_F^N}{P_t} && (3.10) \\ C_n^N &= c_t^N C_F^N + (1 - c_t^N) Y_d^N. && (3.11) \end{aligned}$$

Fixed real n–sector income implies that consumption demand for n–sector product from these households is fixed, as well. It follows that a rise of intermediate demand for X_n can be satisfied only if modern households shift away from consumption of food. As will be seen in the discussion of simulation results below, high levels of floor consumption can significantly constrain the system.

Profit income is the sum of profits generated in t and n–sectors. We denote profit–earning households with the superscript C. Their income is $Y^C = \pi_t P_t Y_t + \pi_e P_e Y_e$, and their savings—the sole source of private savings—is equal to a constant fraction s_π of Y^C. Profit income is taxed at the rates t_t^C and t_e^C in the two sectors, respectively.

Finally, let us consider the labor market. Employment in industry and energy rises with demand. As rates of capacity utilization increase, labor demand increases. We define the following relationship

$$L_i = \frac{Y_i}{\xi_i} \tag{3.12}$$

for $i = t, e$ and with ξ_i equal to sectoral labor productivity—assumed constant for the energy providing sector, but endogenous and pro–cyclical in industry. (Since labor productivity plays a crucial role in the determination of the distribution of income, we discuss it in the next section.) The n–sector, however, must absorb all surplus labor:

$$L_n = L - L_t - L_e, \tag{3.13}$$

where L is the constant labor force. An important implication is that there is no unemployment, but only disguised *under*employment in the agricultural sector.

3.2 Prices and distribution

The model features three sectoral output prices (P_t, P_n, P_e), three nominal wage rates (w_t, w_n, w_e), and a set of two profit rates (r_t, r_e) and two corresponding sectoral profit shares (π_t, π_e).

Let us begin with prices of e and t–sector output. Prices are cost–determined, and depend on the mark–up power of firms. Defining $\nu = (1-\pi_i)\mu_i + \sum_{j,j\neq i}^{3} a_{ji} + f_i e$, we can write the output price as a weighted average of all cost components—domestic intermediates, imported inputs and nominal unit labor costs $\frac{w_i}{\xi_i}$—marked up on depending on the degree of monopoly:

$$P_i = \sum_{j,j\neq i}^{3} \frac{a_{ji}}{\nu} P_j + \frac{\mu_i}{\nu}\frac{w_i}{\xi_i} + \frac{f_i}{\nu} e P_i^*. \tag{3.14}$$

The price of n–sector output responds to excess demand, but must as well take cost factors into account. In terms of the SAM, and with given $\bar{X}_n$, P_n clears n–sector row and column. We can write

$$P_n = \frac{\left(\sum_{j,j\neq n}^{3} a_{jn} P_j + f_n e P_n^*\right) X_n + w_n L_n}{\sum_{i,i\neq n}^{3} a_{ni} X_i + C_n - t_n^X X_n}, \tag{3.15}$$

which appears complicated, but essentially implies that the price of n–sector product responds positively to own–cost factors, $\frac{\partial P_n}{\partial w_n} > 0$, and responds positively to demand expansion in either t or e–sectors, $\frac{\partial P_n}{\partial X_{t,e}} > 0$. The latter is due to the fact that demand and the resulting income expansion in the modern sectors increase demand for agricultural output as intermediate and consumption good. Only if P_n rises do household shift away from food consumption, so that increased intermediate demand can be satisfied.

In the n–sector, the nominal wage varies to clear the income–value added identity, so that

$$w_n = \frac{P_n Y_n}{L_n} = P_n \xi_n, \tag{3.16}$$

which of course implies that the real agricultural wage grows at the rate of n–sector labor productivity growth.

Nominal wages in t and e–sectors are exogenous, but profit rates vary with the distribution of income and economic activity. The two sectoral profit rates are allowed to differ—since the model describes the short to medium run, and sectoral capital stocks are assumed fixed, sectoral profit rates can differ. Since the e–sector uses accumulated t–sector output as capital, the rate of profit must be adjusted for the relative price. From the definition of the capital share, the profit rates can then be written as

$$r_t = \pi_t \frac{Y_t}{K_t} \text{ and} \tag{3.17}$$

$$r_e = \pi_e \frac{P_e Y_e}{P_t K_e}. \tag{3.18}$$

The functional distribution of income in t and e–sectors is

$$\pi_i = 1 - \frac{w_i L_i}{P_i Y_i} = 1 - \frac{\omega_i}{\xi_i} \tag{3.19}$$

for $i = t, e$, and where $\omega_i = \frac{w_i}{P_i}$ is the sectoral real wage and ξ_i sectoral labor productivity. Since prices in all three sectors are endogenous, the distribution of income is, too—as are sectoral mark–up rates $\tau_i = f[\pi_i]$, with $\frac{\partial \tau}{\partial \pi} > 0$.

In the t–sector, further, labor productivity ξ_t is endogenous. Following the literature on the Kaldor–Verdoorn Law, we assume that labor productivity increases with demand. In order to explicitly introduce the link to energy use, we include as well energy intensity $\frac{E_t}{L_t}$ in the productivity rule:

$$\xi_t = \delta_t^0 \left(\frac{Y_t}{K_t}\right)^{\delta_t^1} \left(\frac{E_t}{L_t}\right)^{\delta_t^2}. \tag{3.20}$$

Lastly, we have to aggregate. The overall profit share π is just total profit income as a share of aggregate GDP, $P_y Y$. The GDP–deflator P_y is calculated as a Fisher–index of the three sectoral prices.[6] The real exchange rate index ρ is the ratio of the (import–)weighted average of import prices in domestic currency to P_y.

4 Simulation results and discussion

In this section, we discuss simulation results. Six different scenarios are considered: investment demand expansion, government expenditure increase and a rise in world demand represent demand shocks; an exchange rate depreciation and a wage increase in both t– and n–sector represent price shocks. The results are summarized in Tables 4–7, the first of which shows overview statistics, and the second statistics on energy demand, productivity and intensity. Tables 6 and 7 show in more detailed statistics on (sectoral) prices and distribution, and (sectoral) allocation of output, labor and product demands, respectively.

Before delving into the numbers, let us briefly consider the baseline calibration. First, we assume that imports in the agricultural and energy sector do not respond to real exchange

[6] The Fisher–index is the square root of the product of Laspeyres and Paasche indexes, with base year quantities and post–shock equilibrium quantities as weights, respectively.

rate changes, meaning $\phi_n^1 = \phi_e^1 = 0$. With Egypt's reliance on food and oil imports in mind, this seems not to be an overly restrictive short–run assumption. Further, price elasticities of import and export demand for t–sector goods are more responsive to price changes; $\phi_t^1 = -0.6$ and $\epsilon_t^1 = 0.6$. The export price elasticity of energy demand is lower at $\epsilon_e^1 = 0.2$, since the rest of the world is as well dependent on energy provision independent of its price. Other behavioral parameters concern the labor productivity rule in the t–sector and the linear expenditure system. The former features two elasticities, as introduced above. $\delta_t^1 = 0.35$ is the (short–run) Kaldor–Verdoorn elasticity, and $\delta_t^2 = 0.2$ describes the response of t–sector labor productivity to increases in energy intensity, E_t/L_t. Engel elasticities of the linear expenditure system depend on budget shares of the base year SAM data and the assumed floor consumption of n–sector product. (Recall that floor consumption of t and e–sector product is zero.) We assume $CFT/C_n^T = 0.2$, and $CFN/C_n^N = 0.6$, so that only one fifth of n–sector demand from T–households is invariable to changes in their real income, but three fifth of n–sector demand from N–households.

In the following subsections, we discuss the three demand shocks together, followed by the three price shocks. Lastly, we separately examine issues pertaining to energy demand, productivity and intensity.

4.1 Demand shocks: The basic storyline

We can first consider the investment shock in more detail. In this scenario, (exogenous) real investment demand in the t–sector (I_t) is increased by ten per cent relative to the base year. The upper part of Table 4 shows net lending flows relative to GDP of the private and public sector, and net borrowing relative to GDP of the foreign sector.[7] The first column shows the base year ratio in percentage points, and the following columns the ratios resulting from the shocks applied.

[Tables 4–7 about here]

In response to the investment shock, the private balance swings by a bit more than six tenth of one percentage point relative to GDP, from a surplus to a deficit. The expansion increases revenues, so that the government's surplus increases by almost a fifth of a percentage point relative to GDP. The new investment is financed from abroad. The current account worsens by half a percentage point relative to GDP, but remains in surplus.

The lower sections of Table 4, and Tables 5–7, corroborate this first impression. The demand expansion in the t–sector leads to growth of output in that sector, and the accompa-

[7]Private and public balance are reported as *leakage less injection* ($S - I, T - G$) and the foreign balance as *injection less leakage* ($E - M$) because we are accustomed to think in terms of the resulting signs.

nying (slower) growth of labor demand. Labor demand can be satisfied at the conventional wage w_t out of existing labor surplus in the n–sector. Structural change is set in motion; the t–sector employment share rises by a third of one percentage point. With nominal wage levels fixed, but prices and productivity endogenous and pro–cyclical, distribution changes in favor of capital. The overall profit share rises by roughly one percentage point. Clearly, investment is financed not only through lower foreign lending, but as well through domestic forced saving—redistribution towards high saving households enables the expansion.

Following the labor transfer from the n–sector to the t–sector, average productivity in agricultural activities rises. Since (intermediate) demand for n–sector output rises as well, the price P_n increases to balance demand and fixed supply. The nominal wage grows with inflation and the rise in productivity; the real wage w_n/P_n grows at the rate of labor productivity growth—1.12 per cent in this case. (See Table 5.)

Overall, inflation is driven by the spike in P_n. See Table 6. The food–to–manufactures price ratio jumps. The rise in food prices is sufficient to propel aggregate inflation ($\hat{P}_y$) above two per cent, and that despite a relatively small output weight. This inflation leads to some real appreciation and results in a decline of net real exports.[8]

Changes in consumption demands play an essential role in the adjustment to the shock. See Table 7. Specifically, consumption demand for n–sector product has to fall in order to free up resources for increased intermediate input demands from the other two—expanding—sectors. Since the N–household's real income in terms of the food price does not change, its consumption demand C_n^N for n–sector product remains the same. However, the rise in the food–to–manufactures price ratio outweighs the increase in real income of the t–sector household, reducing its consumption demand C_n^T for n–sector product. Conversely, the rise in the price ratio P_n/P_t allows an increase in t–sector product consumption of the N–household, so that C_t^N rises.[9]

A ten per cent increase in government expenditures G_t on t–sector product in the second scenario shows a similar pattern. The demand increase leads to an expansion, the expansion leads to labor transfer. Labor transfer implies productivity growth in agricultural activities, which together with inflation induced by the rise in demand leads to nominal (and real) wage inflation, $\hat{w}_n > \hat{P}_n$. Aggregate (product and consumption) real wages fall, and the profit share rises.

[8]The growth rates of real imports reported in the lower part of Table 7 are import flows valued at foreign prices in domestic currency, and deflated by the sector's domestic output price. As mentioned above, $\phi_n^1 = \phi_e^1 = 0$, and $\hat{X}_n = 0$.

[9]Indeed, the fall in C_n^T has to be sufficiently large to enable the expansion in t and e–sector production. High floor consumption levels of n–sector product by t–sector households leads to a strangling bottleneck: If C_n^T can not adjust, the burden falls on Y_t—the investment expansion leads to inflation, *lower output* of industry, and a more unequal distribution of income.

Changes of these variables are smaller by about a third than in the investment scenario solely because the ten per cent increase in G_t represents only about two thirds of the ten per cent autonomous investment increase. However, there is an important difference between the two scenarios. With government expenditure expansion, public rather than private balances deteriorate. Despite rising tax revenues—in nominal and real terms—the government's surplus is reduced by about a full percentage point of GDP. The private balance relative to GDP improves by two thirds of a percentage point, and the foreign sector's deficit shrinks by the remaining one third of a percentage point.

Similarly, rising world demand on the one hand leads to the same pattern of expansion, structural change, inflation and forced saving, and on the other differs significantly in its macroeconomic effects. In this scenario, world demand for Egypt's exports rises by ten per cent: external demand for manufactures E_t and energy E_e is shocked upward by ten per cent. The eventual increase in real exports is slightly smaller, since at a fixed nominal exchange rate domestic inflation leads to some inflation and real appreciation. (See the bottom part of Table 7.) Increased production in the two exporting sectors necessitates labor transfer. As above, price and productivity increases lead to higher agricultural real wages, but overall increasing inequality. Macroeconomically, rising world demand leads to a deterioration only of the foreign sector's balances. Private and public balance improve, by a sizable one and a half points of GDP and a third of a point of GDP, respectively.

4.2 Contractionary devaluation; contractionary wage increase

A nominal depreciation ($\hat{e} > 0$) of ten per cent has much smaller effects on macroeconomic balances. Size and sign of the output effects of exchange deprecation depend of course on the (model–specific) Marshall–Lerner condition. In our case, a simple trade weighted average of the applied trade elasticities barely exceeds unity. However, price flexibility and the particular base year data further constrain this condition.[10] As calibrated, the exchange depreciation is contractionary.

What exactly happens? Aggregate GDP contracts, so does value added in industry. Since that implies lower labor demand, the n–sector (re–)absorbs surplus labor. Correspondingly, labor productivity decreases in this sector, and in the aggregate. In the t–sector, labor productivity shows a smaller decrease. The decrease is *small* due to rising energy intensity. Labor demand is more flexible than energy input requirements, and the resulting increase in E_t/L_t buffers the demand–induced productivity contraction. Despite the decrease in GDP (and productivity), prices rise. Higher import costs trigger this limited

[10] Since n–sector production is supply constrained, inflation resulting from increased demand spills over into the the real exchange rate and limits the expansionary impact the depreciation. In that sense, it might be more appropriate to talk of a (model–specific) Bickerdike–Robinson–Metzler condition.

inflation. As a result, the functional distribution of income turns against labor. As mentioned before, changes in macroeconomic balance are limited. As shares of GDP, changes for all three institutional sectors are smaller than one tenth of one percentage point.

Let us now consider wage policies.[11] A nominal wage shock ($\hat{w}_t > 0$) of ten per cent in the t–sector has significant effects on private, public and foreign balance. Private balance swings into deficit, a swing of four fifth of a percentage point of GDP; public balance worsens by about three fifth of a percentage point of GDP. The foreign sector reduces its net borrowing by the sum, about seven fifth of a percentage point of GDP; meaning net exports fall significantly.

Indeed, the real exchange rate appreciates by more than ten per cent. Nominal wage inflation, which feeds into t sector prices, plays a role here. The biggest chunk of *aggregate* nominal wage inflation, however, stems from increases in P_n. What causes this significant inflation of n–sector product prices? n–sector production requires t–sector intermediate input. $\hat{P}_t > 0$ leads to cost–push inflation in the n–sector; but above and beyond that the rise in wage income puts consumption demand pressure on n–sector output. To balance this, $\hat{P}_n \gg 0$, and real consumption demand C_n^T by t–sector households falls.

Importantly, exogenous investment and trade elasticities (low enough to establish devaluation as contractionary) in a one sector model imply wage–led demand. In a two (and here three) sector model with a supply constrained sector, even these conditions do not guarantee positive correlation between growth of GDP and the macroeconomic wage share. Inflation necessary to balance the n–sector feeds into aggregate price statistics, and reduces the product and especially the (food) consumption real wage. Pro–cyclical productivity does the rest.[12]

This relationship appears to exist across all scenarios: The n–sector supply constraint limits beneficial effects of (urban) incomes policies, and demand management could imply a worsening of the income distribution.

4.3 The subplot: Energy demand, productivity and intensity

What, all the while, happens in the energy sector? Table 5 summarizes aggregate and sectoral detail on energy demand, productivity and intensity. *Energy producivity* refers to value added per unit of energy, and *energy intensity* to energy per unit of labor. The sum of the growth rates of energy productiocity and energy intensity is (approximately) identically

[11] Due to the relatively small size of the e–sector wage bill, wage increases in this sector have overall limited effects, albeit with the same signs as the increase in w_t. We focus here on the increase in w_t.

[12] Thinking in terms of a distributive and demand curve in wage share and activity–space, the distributive regime is always downward sloping—exogenous nominal wages in the t–sector bind overall wages. Demand, however, *increases* in the wage share, but the price changes lead to shifts of—likely fairly flat and steep, respectively—curves that overwhelm the slope coefficients.

equal to the growth rate of labor productivity. Where, in our simple three sector model, do aggregate labor productivity increases stem from—increases in the productivity or intensity of energy?

The answer to this question depends in part on how we define *energy*. First, and in contrast to many other studies, we do not specify the physical energy content of the energy sector's output. We simplify by considering only the (real) value of that output X_e, and its price P_e.[13] Further, aggregate *energy* can be viewed as value added of the e–sector. Alternatively, we might look at aggregate energy absorption—in other words, real output less exports, $X_e - E_e$. The rationale is simply that $X_e - E_e$ is the total energy output used domestically for production as well as T–household's consumption.

The top part of Table 5 shows both measures. Both, of course, sum to aggregate labor productivity growth. The signs, however, differ in important ways. Energy productivity in terms of e–sector value added contributes positively to labor productivity growth in the case of a domestic demand shock, as does higher energy intensity. A world demand shock leads to falling energy productivity, since (net) export growth in sector leads to faster growth of e–sector value added than aggregate GDP. Concomitantly, energy intensity sharply rises, to add to about one per cent growth of labor productivity.

Exchange depreciation does not trigger sufficient export growth ($\hat{E}_e$), but increases the sectoral import bill, since $\hat{f}_e = 0$ with $\phi_e^1 = 0$. The result is that the domestic content of energy supply contracts ($\hat{m}_e < 0$)—and contracts faster than overall GDP, which leads to rising energy productivity and falling energy intensity. The absorption measure shows more consistent signs. Energy productivity in terms of energy used domestically falls across all six scenarios. Energy intensity in terms of energy used domestically rises across all six scenarios. The sectoral data in the lower half of Table 5 provides further detail. Importantly, it is industry where aggregate outcomes are determined.

5 Conclusions

This paper explores medium run sectoral dynamics of the Egyptian economy based on a 1996/7 SAM. Several results are noteworthy. Demand–driven expansion and structural change are limited by inflationary pressures coming from the supply–constrained agricultural sector. Forced saving and adjustments in the trade balance play the equilibrating role at the macro level. Interestingly, the government's budget balance benefits from private or external demand expansion through a mechanism reminiscent of the inflation tax. Positive

[13] Specification of physical energy content becomes necessary when pollution mitigation is included in the model, since greenhouse gas (GHG) emissions of energy provision than matter. As discussed in the introduction, this paper is primarily concerned with the linkages and bottlenecks between these three stylized sectors of a developing economy.

shocks in macro prices such as the exchange rate and the nominal wage in the t–sector lead to a worst–case scenario for policy makers. Output declines and inflation shoots up. Low trade elasticities and demand-pull inflation limits the effectiveness of a nominal exchange rate depreciation. Cost–push and demand–pull inflation combine to reverse output growth when nominal wages increase.

Across all scenarios, energy intensity rises when energy consumption is measured as domestic absorption. The growth rate of energy productivity, on the other hand, is consistently negative. These outcomes confirm stylized facts observed for other economies—see Ocampo et al. (2009), but their sources are more complicated in the case of Egypt. First, changes in the energy trade balance drive changes in domestic energy absorption (or value added for that matter). Second, demand for labor is more flexible than energy input requirements with firms substituting energy for labor. We suspect these two peculiarities to be behind the rise in energy intensity even when output contracts as is the case with a currency depreciation or a rise in the nominal wage. The value added approach on the other hand suggests energy intensity to behave pro–cyclically. Simulation results confirm predictions one would expect from structuralist theories of development. However, further analytical and numerical work on energy intensity and productivity is necessary to untangle these preliminary insights and how they relate to the idiosyncracies of the Egyptian economy.

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Tables and Figures

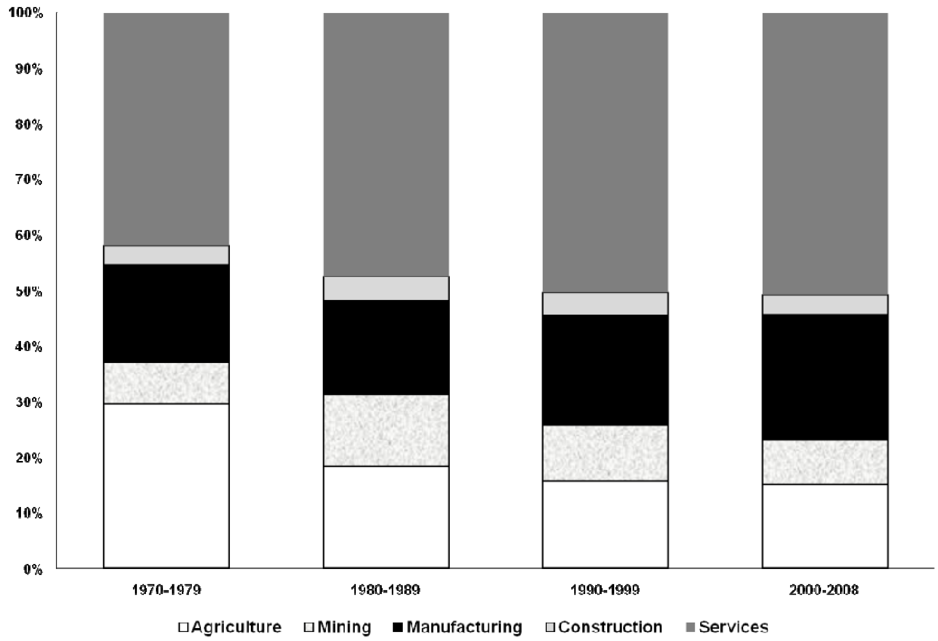

Figure 1: Sectoral shares in aggregate output, Egypt 1970 – 2008.
Source: UN SNA and author's calculation.

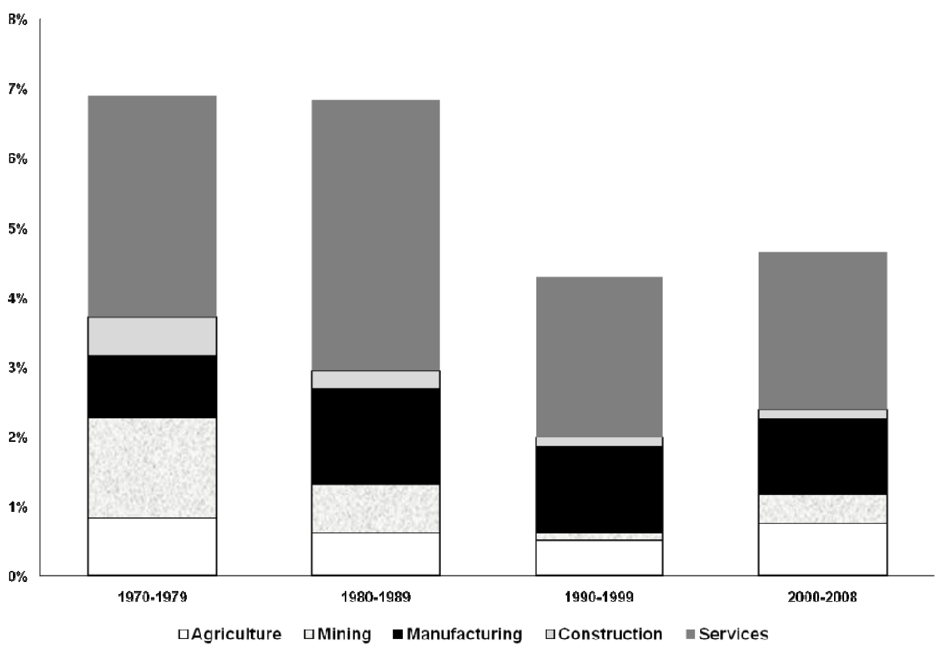

Figure 2: Sectoral contributions to aggregate output growth, Egypt 1970 – 2008.
Source: UN SNA and author's calculation.

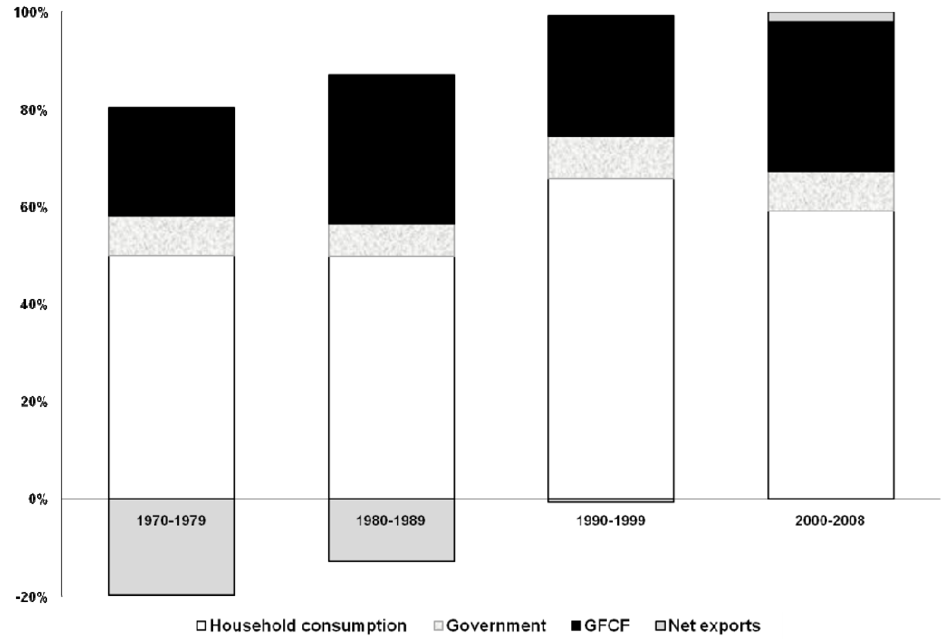

Figure 3: Shares of aggregate demand by institutional sectors, Egypt 1970 – 2008.
Source: UN SNA and author's calculation.

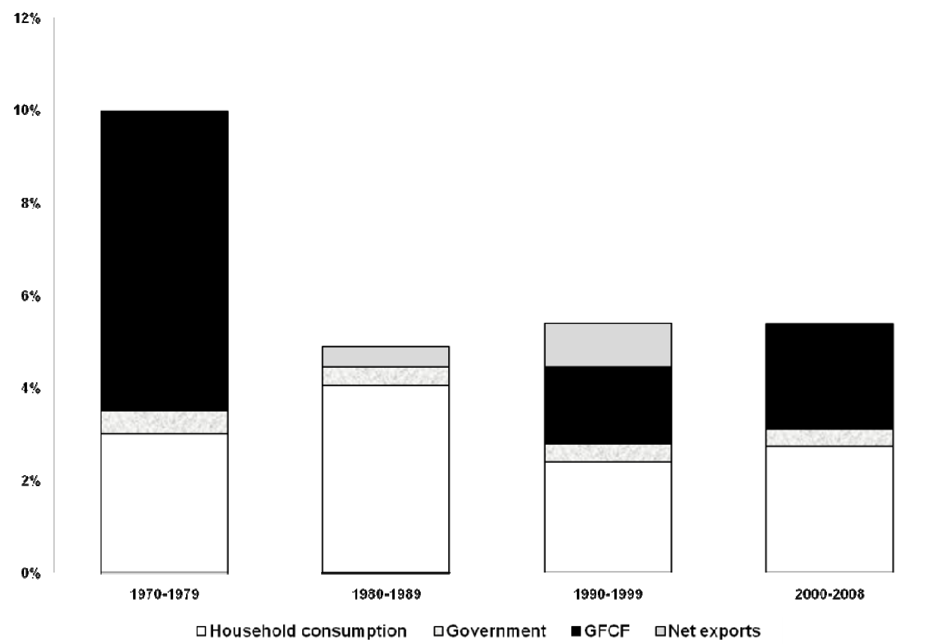

Figure 4: Contributions to growth of aggregate demand by institutional sectors, Egypt 1970 – 2008.
Source: UN SNA and author's calculation.

	Costs			Consumption			Gov	Foreign	Inv	Sum
	T	N	E	T	C	N				
T	131.6	9.2	5.6	117.4		40.2	29.6	54.9	45.2	434
N	25.7	11.3	0.0	23.7		8.1				69
E	12.1	0.1	0.4	3.4				13.1		29
Wages	154.0	51.7	1.8							207
Profits	42.2		15.6							58
Government	17.7	-9.4	0.0	11.2	11.4	3.4				34
Foreign	50.5	5.9	5.7							62
Flows of funds					46.3		4.7	-5.9	-45.2	0
Sum	434	69	29	156	58	52	34	62	0	

Table 1: Social Accounting Matrix (SAM) for Egypt 1996/1997

Indicator	
Modern Sector (% of GVA)	0.78
Traditional sector (% of GVA)	0.15
Energy sector (% of GVA)	0.06
GFCF (% of GVA)	0.17
Current account balance/GDP	0.02
Household consumption of modern good	0.82
Household consumption of traditional good	0.17
Household consumption of energy	0.02
Capital income of the traditional sector (percentage of total capital income)	0.08
Wage income of the traditional sector (percentage of total wage income)	0.15
Overall traditional income of total income (wages, profits and land incomes)	0.18

Table 2: Macroeconomic indicators based on SAM (Table 1)

	T	N	E
T	1.49	0.21	0.26
N	0.11	1.21	0.02
E	0.04	0.01	1.02
Multiplier	**1.65**	**1.42**	**1.30**

Table 3: Leontief inverse matrix

	base	1 It	2 Gt	3 e0	4 e	5 wt	6 we
Macroeconomic balance: Shares to GDP							
(S-I)/GDP	0.43	-0.23	1.10	1.93	0.39	-0.35	0.42
(T-G)/GDP	1.79	1.96	0.79	2.05	1.77	1.20	1.78
CA/GDP	2.22	1.73	1.90	3.98	2.16	0.85	2.20
	0.00	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Shares: Change in percentage points							
Lt/L	0.74	0.33	0.22	0.41	-0.26	-0.54	-0.01
Yt/Y	0.74	0.15	0.10	-0.04	0.20	-0.16	0.00
pi	0.22	1.00	0.66	1.47	0.06	-1.56	-0.02
Growth rates							
Y		0.61	0.40	1.04	-0.66	-0.62	-0.01
Lt		0.45	0.30	0.55	-0.35	-0.73	-0.01
Py		2.44	1.58	3.13	0.40	12.75	0.14
Pn/Pt		3.88	2.51	5.01	0.65	21.00	0.22
w/Py		-0.68	-0.44	-0.85	-0.74	1.37	0.02
w/Pn		-3.68	-2.42	-4.65	-1.26	-12.04	-0.17
r		8.38	5.49	10.64	0.53	-4.79	0.36
RER		-2.38	-1.56	-3.04	9.56	-11.31	-0.14
Y/E		0.40	0.26	-3.58	1.64	-0.45	0.00
E/L		0.21	0.14	4.79	-2.26	-0.17	0.00
Y/L		0.61	0.40	1.04	-0.66	-0.62	-0.01

Table 4: Simulation results – Macroeconomic statistics

	base	1 It	2 Gt	3 e0	4 e	5 wt	6 we
ENERGY							
Aggregate: e-Sector value added							
Y/Ye	*(Growth*	0.40	0.26	-3.58	1.64	-0.45	0.00
Ye/L	*rates)*	0.21	0.14	4.79	-2.26	-0.17	0.00
Aggregate: e-Sector absorption							
Y/Ae		-0.17	-0.11	-0.04	-1.08	-2.22	-0.03
Ae/L		0.78	0.51	1.08	0.43	1.64	0.02
Intermediate energy use							
E(e)		0.21	0.14	4.79	1.06	-0.17	0.00
E(n)		0.00	0.00	0.00	0.00	0.00	0.00
E(t)		1.19	0.78	1.48	0.69	1.10	0.01
Energy productivity							
Ye/E(e)		0.00	0.00	0.00	-3.28	0.00	0.00
Yn/E(n)		0.00	0.00	0.00	-1.14	0.00	0.00
Yt/E(t)		-0.37	-0.24	-0.48	-1.06	-1.92	-0.02
Energy intensity							
E(e)/L(e)		0.00	0.00	0.00	3.40	0.00	0.00
E(n)/L(n)		1.37	0.90	1.85	-1.12	-2.13	-0.02
E(t)/L(t)		0.73	0.48	0.92	1.04	1.84	0.02

Table 5: Simulation results – Energy demand, intensity and productivity

		1	2	3	4	5	6
		It	**Gt**	**e0**	**e**	**wt**	**we**
PRICES							
Pn	*(Growth*	5.62	3.64	7.24	0.94	29.93	0.33
Pt	*rates)*	1.74	1.13	2.24	0.28	8.93	0.10
Pe		0.87	0.56	1.12	0.14	4.47	0.05
Py		2.44	1.58	3.13	0.40	12.75	0.14
rt		8.38	5.49	10.64	0.53	-4.79	0.36
re		-0.55	-0.36	3.78	-2.39	-3.80	-1.18
we		0.00	0.00	0.00	0.00	0.00	10.00
wn		7.07	4.58	9.22	-1.33	27.17	0.30
wt		0.00	0.00	0.00	0.00	10.00	0.00
e		0.00	0.00	0.00	10.00	0.00	0.00
RER		-2.38	-1.56	-3.04	9.56	-11.31	-0.14
DISTRIBUTION							
Functional distribution of income							
pi (0.22)	*(Percen-*	1.00	0.66	1.47	0.06	-1.56	-0.02
pit (0.21)	*tage*	1.61	1.06	2.05	0.20	-0.86	0.08
pie (0.90)	*points)*	0.09	0.06	0.11	0.01	0.43	-1.01
Wages							
wt/Pt	*(Growth*	-1.71	-1.12	-2.19	-0.28	0.98	-0.10
wn/Pn	*rates)*	1.37	0.90	1.85	-2.25	-2.13	-0.02
wt/Pn		-5.32	-3.51	-6.75	-0.93	-15.34	-0.32
wn		7.07	4.58	9.22	-1.33	27.17	0.30
w		1.74	1.13	2.26	-0.34	14.29	0.16
w/Py		-0.68	-0.44	-0.85	-0.74	1.37	0.02
w/Pn		-3.68	-2.42	-4.65	-1.26	-12.04	-0.17
Labor productivity							
xie	*(Growth*	0.00	0.00	0.00	0.00	0.00	0.00
xin	*rates)*	1.37	0.90	1.85	-2.25	-2.13	-0.02
xit		0.36	0.23	0.44	-0.03	-0.11	0.00
Y/L		0.61	0.40	1.04	-0.66	-0.62	-0.01

Table 6: Simulation results – Prices and distribution

		1	2	3	4	5	6
	base	**It**	**Gt**	**e0**	**e**	**wt**	**we**
QUANTITIES							
Sectoral weights: Percentage points							
Le-Weight	0.01	0.00	0.00	0.04	-0.02	0.00	0.00
Ln-Weight	0.25	-0.34	-0.22	-0.45	0.28	0.54	0.01
Lt-Weight	0.74	0.33	0.22	0.41	-0.26	-0.54	-0.01
Ye-Weight	0.07	-0.03	-0.02	0.24	-0.11	0.03	0.00
Yn-Weight	0.19	-0.12	-0.08	-0.20	-0.10	0.12	0.00
Yt-Weight	0.74	0.15	0.10	-0.04	0.20	-0.16	0.00
Value added: Growth rates							
Y		0.61	0.40	1.04	-0.66	-0.62	-0.01
Ye		0.21	0.14	4.79	-2.26	-0.17	0.00
Yn		0.00	0.00	0.00	-1.14	0.00	0.00
Yt		0.81	0.53	1.00	-0.39	-0.84	-0.01
Output: Growth rates							
Xe		0.21	0.14	4.79	1.06	-0.17	0.00
Xn		0.00	0.00	0.00	0.00	0.00	0.00
Xt		1.19	0.78	1.48	0.69	1.10	0.01
Final demands: Growth rates							
CeT		-0.59	-0.38	-0.73	-0.56	3.75	0.05
CnN		0.00	0.00	0.00	-0.51	0.00	0.00
CnT		-4.05	-2.67	-5.12	-1.08	-13.27	-0.18
CtN		3.81	2.48	4.90	-0.63	19.28	0.22
CtT		-1.44	-0.94	-1.82	-0.70	-0.50	0.00
It		10.00	0.00	0.00	0.00	0.00	0.00
Gt		0.00	10.00	0.00	0.00	0.00	0.00
Trade: Growth rates							
Et		-1.43	-0.94	7.98	5.63	-6.95	-0.09
Ee		-0.48	-0.31	9.32	1.84	-2.37	-0.03
Me		-0.65	-0.42	3.63	11.02	-4.44	-0.05
Mn		-5.32	-3.51	-6.75	8.98	-23.04	-0.32
Mt		0.90	0.60	1.12	4.55	-0.26	0.00

Table 7: Simulation results – Quantities