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A Macroeconomic Analysis of Energy Subsidies in a Small Open Economy

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Abstract

We construct a dynamic general equilibrium model to analyze the effects of large energy subsidies in a small open economy. The model includes domestic energy production and consumption, trade in energy at world market prices, as well as private and public sector production. The model is calibrated to Egypt and used to study reforms such as reductions in energy subsidies with corresponding reductions in various tax instruments, or increases in infrastructure investment. We calculate the new steady states, transition paths to the new steady state and the size of the associated welfare losses or gains. In response to a 15 percent cut in energy subsidies, GDP may fall as less energy is used in production. Excess energy is exported and capital imports fall. Welfare in consumption equivalent terms can rise by up to 0.6 percent of GDP. Gains in output can be realized only if the government re-invests into infrastructure.

JEL Classification: E21, E63, H55, J26, J45

Keywords: Energy subsidies, fiscal policy reform, public sector reform, growth

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"To understand the effects of subsidies and taxes on an energy sector and on consumption in a given country requires establishing a complete picture of the market in which it operates and of the various policies — past and present — that have applied to it." (IEA 2010c, page. 11)

1 Introduction

A report by the International Energy Agency (IEA) in 2010 identified 37 countries that together account for 95 percent of global subsidized fossil-fuel consumption and found that total fuel consumption subsidies were about \$557 billion in 2008, a stark increase from \$342 billion in 2007 (IEA (2010a), IEA (2010b)). Countries with the highest subsidies for energy turn out to be smaller, oil producing countries like Iran (\$101 billion in subsidies in 2008, a third of GDP), Saudi Arabia, Venezuela, and Egypt (compare figure 1). The underpricing of energy can lead to excess consumption of energy that together with the need to finance these subsidies can have adverse economic effects, both intra- and intertemporally. Energy subsidies may therefore have large adverse effects on capital accumulation, economic growth, and hence welfare, especially for future generations. The IEA estimates that many countries forgo faster growth by subsidizing energy. Figure 2 shows estimates of growth effects triggered by cutting energy subsidies in various countries reported in IEA (2010c). Since 2008 many major oil subsidizing countries have started to bring their prices in line with world market prices, among them are China, Russia, India and Indonesia.

Many of the concerns about the inefficiency of energy subsidies have focused on environmental aspects and green house gas (GHG) emissions in particular. The IEA (2010c) estimates that a world-wide reduction of fuel subsidies could decrease GHG emissions in the long run by around 10 percent. There are relatively few studies of the short-term and long-term macroeconomic effects of reductions in energy subsidies. These effects are complex and require an explicit dynamic general equilibrium modeling approach. There are many interrelated effects. 1. Phasing out energy subsidies alters the price of energy relative to other consumption goods and hence not only the quantity demanded for energy but also the demand for other goods. 2. The degree of complementarity/substitutability between these consumption goods together with the expectations of the time path for the phase out influences savings behavior and thus capital accumulation of households. 3. Changing energy subsidies influences use of energy in production. Whether energy is a complement or a substitute to other factors of production influences total output and marginal products of all factors of production. 4. Changes in factor payments influence household income and thus consumption and savings behavior. 5. Phasing out energy subsidies allows for other changes in the government budget such as changes in tax rates or other government expenditures, which in turn will influence firm and household behavior. 6. All of these effects are impacted by the degree of openness of the economy.

We use a dynamic general equilibrium model to sort out these effects and to analyze how cuts in energy subsidies to households and/or firms can affect a small open, energy exporting, economy. In order to obtain quantitative results the usual practice is to calibrate models to a particular economy. We calibrate the model to Egypt since fossil fuel consumption subsidies in Egypt are among the largest in the world (see figure 1).

At the outset of this enterprise it is useful to take stock of the particular fiscal policy situation in Egypt. Energy extraction and production play a crucial role in the Egyptian economy. The energy sector accounts for about 20 percent of total GDP. Of course this number is subject to considerable fluctuations given the observed large variation in world energy prices and the finiteness of energy stocks underground. Associated with the energy sector is a large and important system of subsidies. These types of subsidies are not limited to the energy sector but extend also to food and other commodities. Total commodity subsidies account for close to 7 percent of GDP, with energy subsidies making up around 77 percent of all commodity subsidies, which is about 5.4 percent of GDP. Said and Leigh (2006) find in a sample of poor countries that average explicit fuel subsidies amount to 2.4 percent of GDP. The large subsidies in Egypt thus merit scholarly attention. In addition, the size of the public sector in production in Egypt is large whether measured in terms of output, investment or employment relative to the respective total. Public sector employment is around 25 percent of total employment and public investment has in the past exceeded private investment. This large public involvement is especially pronounced in the petroleum sector where both the public investment and public employment shares have reached over 65 percent.

Our dynamic model incorporates overlapping generations of heterogeneous households, a public sector, and an energy sector. In addition, we distinguish between low and high income earners. We consider a small open economy model where capital and energy are traded at given world market prices. Since we leave the world market prices for energy constant, our findings are not directly comparable to estimates by the IEA that try to factor in decreases in "global" cuts of energy subsidies (see figure 2).

We first calibrate parameters using data from Egypt and solve the model for a steady state equilibrium. We then impose cuts to energy subsidies to households and firms and solve for the new, post-reform, steady state where the government can use the freed up funds to either lower taxes or boost infrastructure investments. We then compare economic aggregates across the two steady states. We find that decreases in energy subsidies can cause output to decrease. The cuts to energy subsidies for producers lower the rate of return to physical capital so that less physical capital is used in production. This allows the economy to lower its imports of physical capital. The entire economy shrinks and energy that was previously consumed by domestic households and used in domestic production of goods and services will simply be exported at fixed world market prices.

This somewhat surprising result demonstrates that without developing an alternative energy sector or more efficient usage of energy in the final goods production sector, cuts in energy subsidies in developing or emerging economies like Egypt can have adverse effects on growth. These "negative" results are overturned when the freed up revenue is used to finance more investment in infrastructure, rather than tax cuts. Similar to Berg et al. (2012) we find that increasing public investment in infrastructure as a response to cuts in fuel subsidies can increase output, consumption and welfare. We calculate various welfare measures using solutions obtained from calculating the transition path from the old to the new steady state. This also allows us to distinguish the welfare effects of young vs. old, rich vs. poor, and private vs. public sector workers. In all of our experiments consumption and therefore welfare increase as the economy approaches the new steady state. Long run welfare gains of the policy reform can amount to 0.6 percent of GDP or 1 percent of pre-reform consumption. These welfare gains are obtained despite declines of GDP. These are quantitative results we obtain when we decrease energy subsidies to households and firms simultaneously. We also study cuts to energy subsidies for households only and for firms only. In these cases we obtain broadly similar results.

Literature. At least since the 1990s have formal dynamic general equilibrium models been used to study the influence of fiscal policy on capital accumulation, economic growth, long run levels of income, and welfare. Examples of this literature include Barro (1990), Saint-Paul (1992), Glomm and Ravikumar (1997), Turnovsky (2000), Blankenau and Simpson (2004) and many others. Calibrated versions of these types of models have been used to asses the quantitative effects of particular fiscal policy reforms on economic growth. Most of these calibration exercises are done in the context of the US economy. These papers include Lucas (1990), Glomm and Ravikumar (1998) and many others. In these models a typical result is that the effect of tax reform on growth can be very small as in Lucas (1990), for example, while growth effects of changes in public expenditures on infrastructure and public education, to name just a few, can be larger. See for example Baier and Glomm (2001).

There is now a small literature on the connection between energy consumption, pollution, energy prices and macroeconomic variables such as economic growth. Brock and Taylor (2010), for example, combine technological progress in an environmental abatement technology with a standard version of the Solow growth model and are able to generate the environmental Kuznets curve as an equilibrium outcome. Smulders and de Nooij (2003) study the connection between energy conservation policies and long-run economic growth. Moon and Sonn (1996) use a growth model to investigate the connection between energy expenditures and economic growth. Peretto (2009) shows that the connection between energy taxes and economic growth depends upon the precise interplay of the demand elasticities for energy and technological progress.

Similar to Peretto (2009) a part of the literature on the double dividend hypothesis of green taxes investigates the connection between energy taxes/subsidies and capital accumulation. Glomm, Kawaguchi and Sepulveda (2008) use a calibrated version of a growth model to study the complementary use of energy and physical capital in production to obtain predictions concerning energy taxes/subsidies and transitional economic growth.

The papers closest to the present one are Pereira and Pereira (2011a) and Pereira and Pereira (2011b) who study a growth model with an energy sector that is calibrated to data from Portugal to investigate the connection between energy prices and macroeconomic variables as well as Plante (2011) who studies the impact of energy subsidies in oil importing developing countries. One fundamental difference between their papers and ours is that they study an oil importing economy while we focus on Egypt, which is a net exporter of oil. Other papers that have studied issues surrounding fuel subsidies are Coady and Newhouse (2006), Baig and Ntamatungiro (2007) and Coady and Tyson (2010). Del Granado and Gillingham (2010) study household expenditure patterns and focus on the distributional consequences of changes in fuel subsidies. The focus of our paper here is more dynamic with an emphasis on capital accumulation and growth.

The paper is organized as follows. The next section describes the model. In section 3 we calibrate the model to Egypt and in section 4 we conduct policy experiments. Section 5 provides a discussion of the results and concludes. The appendix contains all tables and figures. A separate technical appendix, available upon request from the authors, contains the details for all the model solutions and the welfare calculations.

2 The model

2.1 Heterogeneity

There is a large number of individuals who live for J periods in an overlapping generations economy. The economy is open so that many prices (i.e. interest rates and the price of energy) are exogenous. We do not allow for labor migration. Each period accounts for $\frac{70}{J}$ years, with working life beginning at age 20 and life ending for sure at age 90. Workers are born with an innate ability that determines their income. This income type cannot be changed. In addition, workers can either work in the public sector (civil servants etc.) or in the private sector. We denote the income type as variable *income* and the working sector as variable $sector \in \{Private, Government\}$. The agent is then characterized by age, income type, and working sector. We summarize this information in state vector $\theta = \{income, sector\}$. Here and in the rest of the paper the subscripts P and G denote private sector workers and public sector workers respectively. When we need to distinguish between the sectors we fix the sector variable to one of the sectors and use the following state vector notation $\theta_P = \{income, sector = Private\}$ and $\theta_G = \{income, sector = Government\}$.

2.2 Demographics

Agents have a random life time. At each age, agents face a mortality shock with a given survival probability π_j. Population grows exogenously at net rate n. We assume stable demographic patterns so that, similar to Huggett (1996), age j agents make up a constant fraction $\mu_{j,t}$ of the entire population at any point in time t. Variable $\mu_j(\theta)$ denotes the mass of age j agents with characteristic θ. We normalize the population in each time period to one so that aggregate variables correspond to per capita values. It then has to hold that $\sum_{j=1}^{J}\sum_{\theta}\mu_{j,t}(\theta)=1$. The relative size of each age cohort $\mu_{j,t}=\sum_{\theta}\mu_{j,t}(\theta)$ is recursively defined as

$$\mu_{j,t}=\frac{\pi_j}{(1+n)}\mu_{j-1,t}.$$

Similarly, the cohort size of agents dying each period (conditional on survival up to the previous period) can be defined recursively as

$$\upsilon_{j,t}=\frac{1-\pi_j}{(1+n)}\mu_{j-1,t}.$$

In the following we will drop the calendar time subscript t whenever possible to not clutter the notation.

2.3 Human capital

Agents are endowed with one unit of time each period and they provide $(1-l_j)$ units of time to the labor market with age dependent efficiency $e_j(\theta)$. Effective labor (or human capital) at each age is given by $h_j(\theta)=(1-l_j)\,e_j(\theta)$. This varies over the life-cycle following the typical hump-shaped pattern.

2.4 Preferences and technology

Within each period of their lives agents value a numeraire consumption good c, energy m_C, and leisure l according to the period utility function

$$u(c,l,m_C).$$

This function has the standard properties of monotonicity and quasi-concavity. Utility is discounted at the rate β.

Physical capital depreciates at rate δ each period and can be used in the production of the final consumption good and the production of energy, so that

$$K=K_P+K_M,$$

where K_P is physical capital used in the production of final consumption goods and services and K_M is physical capital used in the production of energy.

Final consumption and services are produced from four inputs, a public good G, physical capital stock K_P, effective labor (human capital) in the private sector H_P, and energy M_P according to the production function

$$Y = F_P\left(G,\ K_P,\ H_P,\ M_P\right).$$

This production function is homogenous of degree one in K_P, H_P, and M_P. The public good in the production function can be thought of as the stock of public infrastructure such as roads. This public good is made available to all firms at a zero price. Specifications of the technology similar to this one have been used by Barro (1990), Turnovsky (1999) and others. Total factor productivity grows exogenously at rate g .

The intermediate good (energy) is produced using capital K_M and human capital H_M according to

$$M = F_M\left(K_M, H_M\right).$$

Profits of energy production, if any, are redistributed to the government.

The government uses effective labor (human capital) of civil servants H_G and public capital K_G to produce infrastructure capital according to

$$G = F_G\left(K_G, H_G\right). \tag{1}$$

This production function is characterized by the properties of monotonicity, concavity, and homogeneity of degree one. This set-up allows us to not only study the costs of public sector compensation including pension benefits but also the benefits of public sector employment.

Public capital evolves according to

$$K_{G,t+1} = \frac{1}{(1+n)(1+g)}\left(\left(1-\delta_G\right)K_{G,t} + I_{G,t}\right), \tag{2}$$

where we detrend capital with the exogenous population growth rate and the exogenous technological growth rate. Public capital depreciates at rate δ_G in each period and $I_{G,t}$ is investment in the public capital in period t.

2.5 Labor markets and government

Labor markets. We assume that workers cannot migrate, so that labor markets are closed. At the beginning of their life, workers are selected into employment in either the public or private sector. We assume that for all cohorts in all time periods public sector wages exceed those in the private sector by factor $\xi^W > 1$ in order to mimic the more generous public sector compensation scheme. Hence all workers prefer public sector jobs to jobs in the private sector. We maintain the assumption that all workers of a given age and type are equally productive regardless of whether they work in the public or private sector. All workers will retire at age J_1 irrespective of the sector they are working in. We think of this as the standard retirement age, i.e. age 60.

Government expenditures. The government finances investment in public capital $I_G = \Delta_G \times GDP$, where Δ_G is the fraction of GDP allocated to public investments.[1] The remainder of government expenditure is government consumption C_G. We let $C_G = \Delta_{C_G} Y$. Government consumption is assumed to be unproductive.

The government uses public capital and hires labor to produce public goods. The fraction of civil servants is fixed exogenously at N^G as a matter of government policy. The total wage bill of currently employed civil servants is

$$Wage_G = \sum_{\theta_G} \sum_{j=1}^{J_1} w_G h_j \left(\theta_G\right) \mu_j \left(\theta_G\right).$$

The wages of civil servants are set by the government using a markup $\xi^W > 1$ over private sector wages so that $w_G = \xi^W \times w_P$. Private sector wages are determined by the market.

The government runs two separate pension programs, one for public sector workers and one for private sector workers. All workers of both sectors are required to participate in the pension program and consequently have to pay a social security tax τ_{SS}^P and τ_{SS}^G. When workers retire they stop paying labor taxes and social security taxes and are eligible to draw pension benefits. We summarize the payout formula to private sector retirees as

$$Pen_j \left(\theta_P\right) = \Psi_P \times \frac{1}{J_1} \sum_{j=1}^{J_1} w_{P,t-J_1+j} \times h_{j,t-J_1+j} \left(\theta_P, j\right), \tag{3}$$

and the payout formula to public sector retirees as

$$Pen_j \left(\theta_G\right) = \Psi_G \times \frac{1}{J_1} \sum_{j=1}^{J_1} w_{G,t-J_1+j} \times h_{j,t-J_1+j} \left(\theta_G, j\right). \tag{4}$$

Note that the payout formula is a function of the workers average earnings, where Ψ_P and Ψ_G stands for the pension replacement rate in the private and public sector respectively.

In addition, the pension scheme for public sector workers differs from the scheme for private sector workers in contribution rates and benefit payments. The total pension payouts for private sector retirees and for public sector retirees are given by

$$Pen_P = \overbrace{\sum_{\theta_P} \sum_{j=J_1+1}^{J} Pen_j \left(\theta_P\right) \mu_j \left(\theta_P\right)}^{\text{total pensions private sector workers}}$$

and

$$Pen_G = \overbrace{\sum_{\theta_G} \sum_{j=J_1+1}^{J} Pen_j \left(\theta_G\right) \mu_j \left(\theta_G\right)}^{\text{total pensions public sector workers}}.$$

[1] GDP in the model is defined as the sum of private sector output Y and private consumption of energy $p_M M_C$.

Government income. The government collects labor income taxes from all workers in the private and public sector at the rates τ_L^P and τ_L^G as well as social security taxes τ_{SS}^P and τ_{SS}^G. Accidental bequests are taxed at τ_{Beq}. The government also taxes consumption at rate τ_C, fuel consumed by households at rate τ_{Mc}, and fuel used in firm production at rate τ_{M_P}. In addition, the government collects a tax on capital t_K. The total tax revenue is given by

$$
\begin{aligned}
Tax \quad = \quad & \overbrace{\left(\tau_L + \tau_{SS}^P\right) \sum\nolimits_{\theta_P} \sum\nolimits_{j=1}^{J_1} w_P h_j \left(\theta_P\right) \mu_j \left(\theta_P\right)}^{\text{labor and soc. sec. income tax from the private sector}} \\
& + \overbrace{\left(\tau_L + \tau_{SS}^G\right) \sum\nolimits_{\theta_G} \sum\nolimits_{j=1}^{J_1} w_G h_j \left(\theta_G\right) \mu_j \left(\theta_G\right)}^{\text{labor and soc. sec. income tax from the public sector}} \\
& + \overbrace{\tau_{Beq} \sum\nolimits_{\theta} \sum\nolimits_{j=1}^{J} a_j \left(\theta\right) \upsilon_j \left(\theta\right)}^{\text{tax on bequests}} \\
& + \overbrace{\tau_K \times \left(q - \delta\right) K}^{\text{capital tax}} \; + \quad \overbrace{\tau_K \times r \times B}^{\text{tax on bonds' interest}} \\
& + \overbrace{\tau_C \sum\nolimits_{\theta} \sum\nolimits_{j=1}^{J} c_j \left(\theta\right) \mu_j \left(\theta\right)}^{\text{consumption tax}} \\
& + \overbrace{\tau_{M_c} \sum\nolimits_{\theta} \sum\nolimits_{j=1}^{J} \bar{p}_M m_{C,j} \left(\theta\right) \mu_j \left(\theta\right)}^{\text{fuel tax/subsidy from HH}} \\
& + \overbrace{\tau_{M_P} \sum\nolimits_{\theta} \sum\nolimits_{j=1}^{J} \bar{p}_M m_{P,j} \left(\theta\right) \mu_j \left(\theta\right)}^{\text{fuel tax/subsidy from firms}},
\end{aligned}
$$

where $\bar{p}_M$ is the world market price of fuel and q is the cost of capital. The government can borrow a fraction $\Delta_{B,t}$ of GDP each period t. These bonds are denoted $B_{t+1} = \Delta_{B,t} Y_t$, where $\Delta_{B,t}$ is set exogenously. Newly issued bonds have to be detrended with the exogenous technological growth rate g and the exogenous population growth rate n.[2] The government also collects all profits from the energy sector, $EProfit$. The government budget constraint can be expressed as

$$
R_t B_t + C_{G,t} + I_{G,t} + I_{E,t} + Wage_{G,t} + Pen_{P,t} + Pen_{G,t} = Tax_t + (1+g)(1+n) B_{t+1} + EProfit_t. \tag{5}
$$

2.6 Household problem

In general, households in the private and the government sector have similar maximization problems. Households decide their consumption of final goods and energy as well as

[2] Fuster, Imrohoroglu and Imrohoroglu (2005) use similar exogenous growth rates.

leisure $\{c_j(\theta), l_j(\theta), m_{C,j}(\theta)\}_{j=1}^{J}$ as a function of their income type and their sector of employment as summarized in state vector θ. The household problem can be recursively formulated as

$$\begin{aligned} & V(a_j(\theta), \theta) = \\ & \max_{\{a_j(\theta), c_j(\theta), m_{C,j}(\theta), l_j(\theta)\}} \{u(c_j(\theta), l_j(\theta), m_{c,m}(\theta)) + \beta \pi_j V'(a_{j+1}(\theta), \theta)\} \\ & s.t. \end{aligned} \tag{6}$$

$$\begin{cases} \begin{array}{c} (1+\tau_C) c_j(\theta) + (1+\tau_{M_c}) \bar{p}_M m_{C,j}(\theta) + (1+g) a_{j+1}(\theta) \\ = R a_j(\theta) + (1-\tau_L-\tau_{SS})(1-l_j(\theta)) e_j(\theta) w_t + (1-\tau_{Beq}) T_{Beq} \end{array} & \text{if } j \leq J_1, \\ \\ \begin{array}{c} (1+\tau_C) c_j(\theta) + (1+\tau_{M_c}) \bar{p}_M m_{C,j}(\theta) + (1+g) a_{j+1+1}(\theta) \\ = R a_j(\theta) + (1-\tau_{Beq}) T_{Beq} + Pen_j(\theta) \end{array} & \text{if } J_1 < j, \end{cases}$$

$$\begin{aligned} 0 &\leq a_j(\theta), \\ 0 &< l_j(\theta) \leq 1, \end{aligned}$$

where $j = \{1, 2, ..., J\}$, $w_t = \{w_P \text{ or } w_G\}$ is the individual wage rate which is sector specific, and T_{Beq} are transfers of accidental bequests that are taxed at rate τ_{Beq}. Notice that household assets are required to be non negative, i.e. households are not allowed to borrow.

2.7 Firm problems

Capital and energy can be bought at world market at prices $\bar{q} = \bar{q}_P = \bar{q}_M$ and $\bar{p}_M$ respectively. The final goods producing firm solves the problem

$$\max_{(H_P, K_P, M_p)} \{F_P(G_t, K_P, H_P, M_P) - \bar{q}_P K_P - w_P H_P - (1+\tau_{M_P}) \bar{p}_M M_P\},$$

given $(w_P, \bar{q}_P, \bar{p}_M, G)$. The fuel producing firm solves the problem

$$\max_{(K_M, H_M)} \{\bar{p}_M F_M(K_M, H_M) - \bar{q}_M K_M - w_M H_M\},$$

given $(\bar{p}_M, \bar{q}_M, w_M)$. We graphically summarize the main features of the model in figure 3.

2.8 Definition of equilibrium

We model all markets as competitive so that all households and firms take all prices as given. Given the government policy

$$\left\{\tau_{L,t}, \tau^{P}_{SS}, \tau^{G}_{SS}, \tau_{B,t}, \tau_{K,t}, \tau_{M_c,t}, \tau_{M_P,t}, \Delta_{B,t}, \Delta_{G,t}, \Delta_{C_G,t}, \xi^{W}_{t}, \Psi_{Pt}, \Psi_{G,t}\right\}_{t=0}^{\infty}$$

and the exogenously given prices

$$\{\bar{q}_{P,t}, \bar{q}_{M,t}, \bar{p}_{M,t}\}_{t=0}^{\infty},$$

a competitive equilibrium is a collection of sequences of decisions of privately and publicly employed households $\{l_{j,t}(\theta), c_{j,t}(\theta), m_{c,j,t}(\theta), a_{j+1,t+1}(\theta)\}_{t=0}^{\infty}$, sequences of aggregate stocks of private physical capital and private human capital $\{K_{P,t}, K_{M,t}, H_{P,t}, H_{M,t}\}_{t=0}^{\infty}$, sequences of aggregate stocks of public physical capital and public human capital $\{K_{G,t}, H_{G,t}\}_{t=0}^{\infty}$, sequences of factor prices $\{w_{P,t}, w_{M,t}, w_{G,t}\}_{t=0}^{\infty}$ such that

(i) the sequence $\{c_{j,t}(\theta), l_{j,t}(\theta), m_{c,j,t}(\theta), a_{j+1,t+1}(\theta)\}_{t=0}^{\infty}$ solves the household maximization problem (6),

(ii) domestic capital demand, wages, domestic fuel prices, and the after tax interest rate are determined by

$$\begin{aligned}
\bar{q}_{P,t} &= \frac{\partial F_P(G_t,\ K_{P,t},\ H_{P,t},\ M_{P,t})}{\partial K_{P,t}}, \\
w_{P,t} &= \frac{\partial F_P(G_t,\ K_{P,t},\ H_{P,t},\ M_{P,t})}{\partial H_{P,t}}, \\
\bar{q}_{M,t} &= \frac{\bar{p}_{M,t}\partial F_M(K_{M,t}, H_{M,t})}{\partial K_{M,t}} \\
w_{M,t} &= \frac{p_{M,t}\partial F_M(K_{M,t}H_{M,t})}{\partial H_{M,t}}, \\
w_{M,t} &= w_{P,t}, \\
w_{G,t} &= \xi^{W} w_{P,t}, \\
\bar{q} &= \bar{q}_{P,t} = \bar{q}_{M,t}, \\
R_t &= 1 + (1-\tau_{K,t})(\bar{q}_t - \delta) = 1 + (1-\tau_{K,t})\bar{r}_t,
\end{aligned}$$

(iii) aggregate variables are given by

$$A_t = \sum_{\theta} \sum_{j=1}^{J} a_{j,t}(\theta)\, \mu_{j,t}(\theta) + \overbrace{\sum_{\theta} \sum_{j=1}^{J} a_{j,t}(\theta)\, \upsilon_{j,t}(\theta)}^{\text{accidental bequests}},$$

$$\Delta K = \overbrace{(A_t - B_t)}^{\text{domestic capital supply}} - \overbrace{(K_{P,t} + K_{M,t})}^{\text{domestic capital demand}}, \text{ (net exports of capital)}$$

$$\bar{p}_{M,t} \Delta M = \bar{p}_{M,t} \left(\overbrace{F_M(K_{M,t})}^{\text{domestic energy supply}} - \overbrace{(M_c + M_p)}^{\text{domestic energy demand}} \right) > 0, \text{ (net exports of energy)}$$

$$H_t = H_{P,t} + H_{M,t} = \sum_{\theta_P} \sum_{j=1}^{J} \overbrace{(1 - l_{j,t}(\theta_P))\, e_{j,t}(\theta_P)}^{h_{j,t}(\theta_P)} \mu_{j,t}(\theta_P),$$

$$H_t^G = \sum_{\theta_G} \sum_{j=1}^{J_1} \overbrace{(1 - l_{j,t}(\theta_G))\, e_{j,t}(\theta_G)}^{h_{j,t}(\theta_G)} \mu_{j,t}(\theta_G),$$

$$S_t = \sum_{\theta} \sum_{j=1}^{J} a_{j+1,t+1}(\theta)\, \mu_{j,t}(\theta),$$

$$C_t = \sum_{\theta} \sum_{j=1}^{J} c_{j,t}(\theta)\, \mu_{j,t}(\theta),$$

$$M_{c,t} = \sum_{\theta} \sum_{j=1}^{J} m_{c,j,t}(\theta)\, \mu_{j,t}(\theta),$$

(iv) commodity markets clear[3]

$$C_t + (1+g) S_t + I_{G,t} + C_{G,t} = Y_t + (1 - \delta_P) K_t + (1+n)(1+g) B_t + Beq_t + EProfit_t,$$

(v) taxed accidental bequests are returned in lump sum transfers to surviving agents

$$T_{B,t} = \frac{\sum_{\theta_P} \sum_{j=1}^{J} a_{j,t}(\theta_P)\, \upsilon_{j,t}(\theta_P) + \sum_{\theta_G} \sum_{j=1}^{J} a_{j,t}(\theta_G)\, \upsilon_{j,t}(\theta_G)}{\sum_{\theta} \sum_{j=1}^{J} \mu_{j,t}(\theta)},$$

(vi) and the government budget constraint (5) holds.

[3]Since the public good G is an input into private sector production of Y, the public sector wage bill is already contained in the measure of Y. For simplicity we do not take net exports into account when expressing policy parameters as percentage of GDP.

In addition, the aggregate S_t already incorporates the exogenous population growth rates via the population weight μ. We therefore only have to detrend with the exogenous technological growth rate g.

3 Calibration

We solve the model for steady states using a numerical algorithm similar to Auerbach and Kotlikoff (1987). This algorithm solves a complicated set of non-linear equations using an iterative technique commonly referred to as the Gauss-Seidl method. The algorithm starts with a guess of various endogenous variables and treats them as exogenous. Then, after solving all household and firm maximization problems and imposing the budget constraints and market clearing conditions, the algorithm solves for a new set of endogenous variables. If the new set of endogenous variables equals the original guesses, a solution to the system has been found and the algorithm stops. Otherwise, we take linear combinations of the guessed variables and the new solutions for the variables and start all over. Once the algorithm converges to a steady state, we compare the model's outcome to moments in the data for Egypt. We use a similar algorithm to solve for transitions between two equilibrium allocations that result from changes in policy variables. We check for uniqueness of equilibrium by trying various starting points for the algorithm.[4]

We first calibrate a closed economy version to get prices for energy and capital. We then fix these prices and adjust the total factor productivity of the energy sector to match energy export and capital import figures from Egypt in 2008. We present the parameter values that are used in the baseline model in table 1. Policy parameters are summarized in table 2 and matched data moments are presented in table 3. We next describe briefly how we calibrated the model.

3.1 Heterogeneity

We calibrate the OLG model with $J = 14$ periods to Egyptian data. Thus, each model period corresponds to 5 years. Agents become economically active at age 20 and die for sure at age 90. We differentiate among two income types (rich and poor) and two sector types (private and public), which is summarized in state vector

$$\theta = \{income = \{low,\ high\},\ sector = \{Private, Government\}\}.$$

3.2 Demographics

We use population fractions by age group from the *African Statistical Yearbook* (2005). The annual population growth rate was $n = 1.8$ percent in 2006 according to the United

[4]There is no formal proof of uniqueness available for this type of Auerbach-Kotlikoff models (see Kotlikoff, Smetters and Walliser (2001)). Laitner (1984) provides a proof of uniqueness for a linearized version of the original Auerbach-Kotlikoff model.

Our solution algorithm is locally stable. That is for changes in initial conditions (guesses of initial prices R and w) the algorithm converges to the same steady state. We have no proof of global convergence. It has been our experience that higher order dynamics in multi period OLG models with bonds can lead to multiple steady states. In such cases we were able to rule out Pareto inferior steady states (e.g. steady states that result in negative interest rates). Compare also Colucci (2003) who shows the existence of at least two steady states in a very simple multi period OLG model.

Nations World Population Prospects.[5] We then choose the survival probabilities so that the model matches the size of the different age groups.

3.3 Human capital

Income profiles are calculated using

$$wh_j(\theta) = w \times e_j(\theta) \times (1 - l_j(\theta)).$$

We distinguish between low and high skilled workers, where we define high skilled workers as workers with a post-secondary degree or a university degree. We pick the profiles $e_j(\theta)$ so that high skilled agents earn wage incomes that are twice as high as wage incomes of low skilled agents. The efficiency profile exhibits the typical hump-shaped pattern over the life cycle.

According to Worldbank (2008) the skill decomposition in the public sector is 70 percent low skilled workers (i.e. highest degree is vocational high school) and 30 percent high skilled workers (i.e. post-secondary and university and above). The skill decomposition in Egypt overall is roughly 50 percent low skilled and 50 percent high skilled according to Worldbank (2009). Given the size of the public sector, the private sector skill decomposition results in 43 percent low skilled and 57 percent high skilled workers.

In addition we assume that public sector workers are 20 percent less productive on average across both skill groups. However, the public sector income-age profile is higher reflecting the more generous compensation (wages and pensions) in the public sector.

3.4 Preferences and technology

Preferences are represented by the following utility function:

$$u(c_j(\theta), l_j(\theta), m_{C,j}(\theta)) = \frac{\left(\Theta \times \left(c_j(\theta)^{\gamma} l_j(\theta)^{1-\gamma}\right)^{\rho} + (1-\Theta) \times \varrho \times (m_{C,j}(\theta))^{\rho}\right)^{\frac{1-\sigma}{\rho}}}{1-\sigma},$$

where c and l is consumption and leisure respectively and m_C is energy consumed by the household, and $0 < \gamma < 1$, $\sigma > 0$, $0 < \Theta$, $\varrho < 1$, and $\rho > 0$. Parameter γ measures the relative weight of consumption versus leisure. The elasticity of substitution between consumption and leisure on the one hand and energy m_c is $\frac{1}{1-\rho}$. Parameter Θ measures the importance of consumption and leisure relative to energy. Parameter ϱ is a scale factor that determines the importance of energy consumption, and σ is the coefficient of relative risk aversion. Parameter $\Theta = 0.96$ and $\varrho = 0.2$, both are chosen the primarily match the household demand for energy.

[5] Awad and Zohry (2005) find that the population growth rate was about 1.9 percent for the earlier period from 1990 to 2005.

The elasticity of substitution between consumption and energy is $\frac{1}{1-\rho} = 0.8$ so that $\rho = -0.25$. Consumption and energy are therefore complements. The consumption preference parameter $\gamma = 0.28$ is chosen to get labor supply to be around $30-35$ hours a week for agents in their prime working age from 25 to 55. Both, the time preference parameter $\beta = 1.022$ and the inverse of the intertemporal elasticity of substitution $\sigma = 2.2$ are chosen to match the capital output ratio.[6] Consequently, in our model the resulting capital output ratio is equal to 2.9.

Final goods production. The production function for the final good is

$$F_P\left(G,\ K_P,\ H_P,\ M_P\right) = A_1 G^{\alpha_1} K_P^{\alpha_2} H_P^{\alpha_3} M_P^{\alpha_4},$$

where $\alpha_i \in (0,1)$ for $i = 1, ..., 4,\ \alpha_2 + \alpha_3 + \alpha_4 = 1$ and $A_1 > 0$. Total factor productivity A_1 is normalized to one. The exogenous technological rate of growth is 1 percent (Worldbank communication). The estimates for α_1, the productivity parameter of the public good in the final goods production function, for the U.S. cluster around 0 when panel data techniques are used (e.g. Hulten and Schwab (1991) and Holtz-Eakin (1994)) and they cluster around 0.2 when GMM is used to estimate Euler equations (e.g. Lynde and Richmond (1993) and Ai and Cassou (1995)). Calderon and Serven (2003) estimate this parameter to be around 0.15 and 0.20. For a cross-section of low income countries Hulten (1996) obtains an estimate for α_1 of 0.10. We use $\alpha_1 = 0.09$, which is a conservative estimate in order to not overstate our results.

The capital share of GDP is relatively high in Egypt so we chose $\alpha_2 = 0.52$. Since this is a small open economy model where capital and energy can be traded at world market prices, the model also results in capital imports of 7.4 percent of GDP. Worldbank sources report estimates that range between 5.46 to 6.6 percent of GDP on average between 2005 to 2008. We set the capital depreciation rate to 10 percent per year. Parameter $\alpha_3 = 0.39$ together with the preference parameter for leisure $(1-\gamma)$ determines average hours worked. We pick $\alpha_{4,}$ the share of energy in production to be equal 0.08. We chose this parameter to match the size of the energy sector in Egypt. The size of the energy production sector is jointly determined by parameters α_4 (domestic industry demand for energy), Θ (household demand for energy), and A_2 (energy supply) which we describe next.

Energy production. The energy production function is

$$F_M\left(K_M, H_M\right) = A_2 K_M^{\eta_{21}} H_M^{\eta_{22}},$$

where $A_2 > 0$ and $\eta_{21,}\eta_{22,} \in (0,1)$ and $\eta_{21} + \eta_{22} \leq 1$. If the production function exhibits constant returns to scale this will result in zero profits. If we have decreasing returns

[6] It is clear that in a general equilibrium model every parameter affects all equilibrium variables. Here we associate parameters with those equilibrium variables that they affect the most directly quantitatively.

to scale, profits π_M will be redistributed to the government. We chose $\eta_{21} = 0.66$ and $\eta_{22} = 0.12$ so that firms make a profit of 4.6 percent of GDP. According to the Worldbank profits from the energy sector are around 3 percent (Worldbank communication). In the model all profits from the energy sector are collected by the government. Total factor productivity A_2 is chosen to match the size of the energy sector and also the size of energy exports. In the model, energy exports amount to 5.4 percent of GDP compared to empirical estimates between 5.8 percent of GDP (Worldbank communication).

Public good production. The production function for the public good is

$$F_G(K_G, H_G) = A_3 K_G^{\eta_3} (\omega_h H_G)^{(1-\eta_3)},$$

where $A_3 > 0$ and $\eta_3 \in (0, 1)$. The fraction of civil servants contributing to the production of the public good is denoted $\omega_h \in (0, 1)$. The remaining civil servants produce government consumption that is not explicitly modeled. Total factor productivity $A_3 = 1.05$ is chosen to match the size of the public goods sector. We have little information about the parameters of the production technology of the public good. We view the choice of $\eta_3 = 0.6$ and $\omega_h = 0.4$ as our benchmark and we perform sensitivity analysis on these parameters. We find that our qualitative and quantitative results are relatively robust to changes in η_3 and ω_h. Capital K_G depreciates at 10 percent per year.

3.5 Labor markets and government

Labor markets. In the model we assume that all agents retire at age 60, or $J_1 = 8$. The total number of periods in a life is $J = 14$ which corresponds to age 90. The government policy parameters are summarized in table 2.

Government expenditures. Based on Worldbank (2009) public sector employment as fraction of total employment is approximately 25 percent. In addition, public sector workers earn on average up to 10 percent higher wages than private sector workers. Since this number is calculated factoring in income of informal sector workers, we pick a slightly more moderate markup factor of public wages of 5 percent so that $\xi^W = 1.05$ to not overstate wages in the public sector.

According to Gupta et al. (2009), 90 percent of the labor force is covered by the pension program. In order to not overstate the replacement rates in the private sector we decided to match the size of the pension programs (public and private) as percent of GDP as well as the government revenue from payroll taxes paying for pensions.[7]

[7] Pension replacement rates in the public sector are 80 percent on average. Replacement rates in the private sector are higher. Estimates for replacement rates are as high as 150 percent of average lifetime salary (see Gupta et al. (2009)). These high replacement rates in the private sector are the result of averaging. There are large groups of workers working in the private sector who have very low income and some of these workers are informal sector workers. However, we do not distinguish informal vs. formal sector workers in our model. The private sector replacement rates in our model are therefore much lower and chosen to match aggregate private sector pension payments.

This allows us to not only match the size of pension programs but also their relative deficit/surplus. In 2007 the pension system in Egypt ran a deficit of 0.8 percent of GDP according to Gupta et al. (2009), where the private sector pensions contributed a deficit of 0.9 percent of GDP and public sector pension plans ran a surplus of roughly 0.1 percent of GDP. We therefore end up using replacement rates of $\Psi_P = 0.35$ and $\Psi_P = 0.99$ as well as payroll taxes of $\tau_{SS}^P = 2.8$ percent and $\tau_{SS}^G = 16.6$ percent.[8]

Government income. In addition the government raises labor taxes, consumption taxes, taxes on bequests, and taxes on profits (in the model this is approximated using capital taxes[9]) to finance public sector workers, government consumption, investments into public capital, and service of its debt. Capital taxes in Egypt are zero. However, tax revenues raised from corporate profits are three times the size of revenues raised from labor income taxes. If one excludes taxes collected from Suez Canal profits, the tax revenue raised on company profits is still twice the size of labor income tax revenue. In our model we use capital taxes as a proxy for taxes on profits and choose the capital tax rate so that revenue streams from taxes on profits are matched.

We set the tax rates so that revenue streams from the various taxes are matched to data from Worldbank (2009). Table 3 presents the details. According to Worldbank (2009) total tax and non-tax revenues as fraction of GDP are about 28 percent, half from personal and corporate income tax, the remainder from sales and excise taxes. This revenue figure includes profits from oil exports and Suez canal fees so that estimates for tax revenue itself are probably between 15 and 20 percent. The model is calibrated to generate tax revenues of 22.3 percent of GDP.

The size of the energy subsidies is 5.29 percent of GDP according to Worldbank (2009). We choose subsidy rates for households of $\tau_{M_C} = 30$ percent and $\tau_{M_P} = 30$ percent which result in energy subsidies of 4.6 percent in the model.

The government issues new bonds in the amount of $\Delta_B = 12$ percent of GDP in every model period which results in a steady state government debt level of 65 percent of GDP (Worldbank (2009) states 65 percent as well).

We calibrate investments into a public capital that is needed to produce a public good (e.g. roads etc.) to be $\Delta_G = 2$ percent of GDP in order to match the size of the public good production as a share of GDP (27 percent according to Worldbank (2009). In our model the government share in production is 29.2 percent of GDP, 8.4 percent from public goods production (produced by a public capital and public sector workers) and 20.7 percent from energy production (produced by physical capital and human capital employed in the energy sector at competitive wages). Profits from the energy sector are redistributed to the government.

[8]The statutory contribution rates are between $21 - 24$ percent for salaried employees and between $14 - 16$ percent for workers (Worldbank (2009)).

[9]Capital taxes in the model are raised on asset returns of households and not on capital stock in the production sector.

4 Policy experiments and results

In our experiment we decrease the energy price subsidy by 15 percent and let either consumption taxes (τ_C), labor taxes (τ_L), capital/profit taxes (τ_K) , or investments into the public capital (Δ_G) adjust to clear the government budget constraint in reaction to the simulated 15 percent change of the respective status quo variable. The policy changes are unanticipated by all agents and result in either decreases of τ_C, $\tau_{L,}$ and τ_K or increases of infrastructure investments Δ_G.

4.1 Decrease in energy subsidies for both consumers and producers

Energy is heavily subsidized in Egypt and the total energy subsidy amounts to roughly 5.29 percent of GDP. In this section we simulate a decrease in the subsidy rate by 15 percent. Steady state results are presented in table 4. The first column in table 4 is the normalized benchmark regime before the policy change. We normalized all level variables to 100 to allow for simple comparisons between the pre-reform equilibrium and the new post-reform equilibrium after reform has become fully effective.

Since energy subsidies drop, the government responds with either tax decreases or increases in infrastructure investments. See column two for post reform steady state results with an adjustment of labor taxes τ_L, column three for post-reform steady state results with an adjustment in consumption taxes τ_C, column four for post-reform steady state results with an adjustment in capital tax rates τ_K, and column five for post-reform steady state results when infrastructure investments Δ_G adjust to accommodate the drop in energy subsidies.

Steady state analysis with an adjustment in labor taxes. A drop in the subsidy rate increases both, the price of energy used for the production of final goods and services as well as the price of energy consumed by households. This cut does not have much of an effect on the domestic production of energy though, as energy can always be traded at fixed world market prices, so that the value of domestic energy production $p_M M$ stays relatively stable. However, labor taxes can now adjust downwards from 5 to 2.9 percent to accommodate the decrease in energy subsidies. This generates an income effect that triggers various changes in a household's consumption and savings portfolio.

First, we observe an increase in domestic capital accumulation K of 2.3 percent due to income effects (see second column in table 4). This increase in domestic capital accumulation allows Egypt to decrease its imports of physical capital by 18 percent as now more domestically accumulated capital (via household savings) becomes available. The drop in the labor tax rate provides a direct source of extra income to working households so that they can increase their consumption level C by 1.2 percent.

Despite the lower tax rates, growth effects of output cannot be realized. The reason is that Egypt is a small open economy that has access to international capital markets.

Since physical capital K_P and energy M_P are complements in the production function for the final consumption good, cutting the energy subsidies causes a decrease in the return for physical capital, so that physical capital used in domestic production K_P decreases by about 1.1 percent. This allows for a decrease of physical capital imports by 18 percent. All in all domestic output of final goods and services drops by about 1.1 percent.

Transition dynamics with an adjustment in labor taxes. Figure 4 depicts the transition paths for a select number of market aggregates. We see that after an initial jump, most variables converge to the new steady state in a smooth manner. The lower labor taxes directly generate additional income for working households which translates into higher consumption of the numeraire good C (panel 7, in figure 4). Household energy consumption, on the other hand, drops immediately due to the cuts in subsidies (panel 8, in figure 4). Whether this results in welfare gains or welfare losses depends on the relative importance of the final consumption good C and household energy consumption of M_c in the households' preferences but also on the extra income generated for each households. Since in this case labor taxes can be lowered after the government cuts its expenditures on subsidies, working households will gain directly from this reform. Retired households, on the other hand, will not be able to obtain any additional tax breaks.

We provide the following welfare measures over the transition path in figure 5. Panel [1] expresses welfare gains/losses in terms of compensating consumption units that are expressed as a fixed percentage of life-time consumption. We provide these measures for each generation separately. Generation 0 is the first generation born right after the reform has been implemented. Generations to the left of zero were born up to 13 periods before the reform and generations to the right of zero are born after the reform. Compensating consumption units are given to households born in the new steady state in order to make them indifferent between the pre-reform equilibrium and the post-reform equilibrium. Negative values in this graph indicate welfare gains, positive values are welfare losses.

Comparing the welfare graphs in figure 5 we immediately see that retired households will not gain from the reform, whereas working households are identified as winners from the reform. Generation zero roughly gains 0.5 percent of consumption in each of its 14 life periods. In other words, if we took away half a percent of period consumption in each period from generation zero, then generation zero would be indifferent (in terms of utility) between the pre-reform and post-reform steady states. We see that the retired generation does not gain at all, the working generation before the reform starts to have welfare gains up to 0.5 percent of consumption, whereas generations born about 15 periods after the reform can fully benefit from the lower tax rate and realize gains of almost 1 percent of per period consumption. There is not any significant difference between the low and high income groups in terms of welfare gains. The second panel shows an almost identical situation for public sector workers. This makes sense as public sector workers are not treated any different by the reform.

Finally, we would like to measure welfare gains for each period after the reform, aggregated over all generations that are alive in said period. We express the aggregate compensating consumption units of all alive generations per period as a fraction of GDP in that period to give a better indication about the size of the overall welfare effect. We find that the small welfare losses of the retired generations are more than compensated by welfare gains of the working generations, so that the reform creates an immediate aggregate welfare gain at the end of the period of its implementation. These welfare gains start growing to about 0.6 percent of GDP as the economy sets into the new equilibrium.

Steady state analysis with an adjustment in consumption taxes. We next let consumption taxes adjust (decrease) to accommodate the drop in energy subsidies and find that consumption taxes decrease from roughly 16.6 percent to 14.7 percent (column 3 in table 4). The first difference to the previous experiment is that now all generations can benefit from lower taxes, not just the working generations. This has a direct impact on the welfare results, which we will discuss shortly.

The lower consumption tax triggers a strong substitution effect, so that households switch their consumption from energy $p_M M_C$ to the final consumption good C. We find that aggregate consumption C increases by 0.6 percent. Similarly, we find that household consumption of energy $p_M M_C$ drops by almost 6 percent. Because domestic demand for energy decreases, more energy is now exported at the fixed world market price. As energy use in domestic production M_p decreases by over 7 percent (column three in table 4), energy exports increase by 21 percent to roughly 6.6 percent of GDP(up from 5.4).

Simultaneously, the domestic production sector of final goods and services experiences a drop in output of almost 2 percent of GDP as it now uses less energy. Negative income effects from decreases in output also affect the savings rate of the households, so that physical capital accumulation decreases and steady state capital K drops by more 1 percent. The economy therefore increases its imports of physical capital by 1.4 percent.

Transition dynamics with an adjustment in consumption taxes. The transition dynamics point to welfare increases that stem from increases in consumption C of the final good (see figure 6 for transition results of market aggregates and figure 7 for welfare results). This extra consumption is made possible by cuts in the sales tax but also by increases in energy exports. It is apparent that these welfare gains are realized for both, working and retired generations, contrary to the earlier result derived from a labor tax adjustment. The compensating consumption that can be achieved in the long run is around 0.3 percent of per period consumption for private and public sector workers. The welfare gains, in terms of percent increases, are slightly larger for the high income group. Welfare gains expressed as fraction of GDP are around 0.2 percent and therefore much smaller than in the previous experiment.

In terms of implementability of these reforms, it will obviously be easier to find a majority of voters for the second reform (using consumption taxes) as the intergenerational conflict can be avoided.

Steady state analysis with an adjustment in capital taxes. Capital taxes decrease from 15 percent to 7.2 percent as they accommodate the subsidy cuts. We observe the largest effect on capital accumulation in this case as the after tax return to capital is directly increased. We find that steady state capital K increases by 10.6 percent (see fourth column in table 4). Egypt therefore decreases its current capital import by almost 77 percent. In addition, less energy is used in the production process due to the lack of the subsidies so that output drops significantly. The additional capital that was accumulated by households is used to decrease the imports but does not increase the level of physical capital used in the domestic production process. This level, K_P, actually drops slightly. Despite the drop in output Y, aggregate consumption C again increases.

Steady state analysis with an adjustment in investment in public capital. Lower energy subsidies leave funds for infrastructure investments, assuming that the government holds tax rates at their pre-reform levels. Infrastructure investments can therefore increase from 2 to 2.7 percent of GDP (see column five in table 4).

The extra infrastructure investments increase the production of the public good G by 22.5 percent. Since G enters the final goods production function, the marginal returns to physical capital inputs K_P increase, so that the domestically used level of physical capital increases by 2.76 percent. Returns to energy used in the production of the final good would equally increase, however, the factor energy itself has now become more expensive, so that overall less energy is used in domestic production, i.e. $p_M M_P$ decreases by 3.5 percent. All these effects combined will increase GDP by 2.5 percent. The additional income generated allows households to consume more final consumption goods and services (C increases by 2.5 percent).

4.2 Sensitivity analysis

4.2.1 Decrease in energy subsidies of various sizes

Labor tax case. We next implement cuts of energy subsidies of various sizes and let either labor taxes or infrastructure investments adjust to clear the government budget constraint. Table 5 reports the results for a decrease in the labor tax and table 6 contains similar results for increases in infrastructure investments. The cuts in energy subsidies are again implemented for both, consumers and producers. The first column shows again normalized, pre-reform steady state aggregates. Column 2 to 7 report steady state results for energy cuts of 25, 30, 45, 60, 75, and 90 percent.

From table 5 we see that the results for market aggregates are monotone when gradually cutting energy subsidies by 15 percent up to 90. The most severe cut of 90 percent decreases steady state output Y by 5.5 percent, despite a 10 percent increase in domestic capital accumulation K (savings). Cutting subsidies to such a large extent allows Egypt to almost double its energy exports (92.3 percent increase). Aggregate consumption levels do rise by up to 4.8 percent.

Infrastructure investments. Table 6 indicates that infrastructure investments can be increased from 2 to 5.8 percent. This increase is also responsible for a 7 percent increase in the domestic savings rate. Despite the fact that energy usage in the final goods production decreases by almost 33 percent, the additional physical capital in production K_P, as well as the additionally available public good (G almost doubles) will increase output by 7.6 percent. This is the largest output gain that we found in any of the experiments (see column 7 in table 6). Finally, steady state consumption levels C increase by 6.8 percent.

4.2.2 Decrease in energy subsidies for consumers vs. producers

We next analyze the difference in cutting the subsidy for consumers vs. producers. If we cut energy subsidies to households by 15 percent and leave the energy subsidies for firms in place, we find that energy consumption of households $p_M M_C$ decreases by up to 4.4 percent whereas energy consumption of producers $p_M M_P$ stays stable. Table 7 reports the results when we let either consumption taxes (τ_C), labor taxes (τ_L), capital/profit taxes (τ_K), or investments into the public capital (Δ_G) adjust to clear the government budget. Column one is the benchmark economy normalized to 100 when the respective variable is a level variable. The effects are typically smaller than in table 4 where subsidies to both firms and households are cut simultaneously.

We next cut energy subsidies to firms by 15 percent and leave the energy subsidies for households in place. Table 8 reports the steady state results for this case. Column one is again the benchmark economy normalized to 100 when the respective variable is a level variable. In this case we find the opposite effect on the energy consumption patterns. Household consumption of energy $p_M M_C$ remains relatively stable, since household subsidies remain in place, whereas energy usage by firms $p_M M_P$ decreases by up to 8.4 percent.

In terms of output we immediately see that 15 percent cuts in energy subsidies to producers will decrease steady state output by up to 2.4 percent, whereas a similar cut of energy subsidies to households will barely decrease output. In addition, we find that cuts to energy subsidies for producers allow for more drastic adjustments in the policy variables (i.e. taxes or infrastructure investments) which in turn will trigger larger substitution and income effects. The welfare effects are larger in the case of cuts to energy subsidies for producers, as in this case consumers are able to maintain their level of consumption of energy in addition to the increase of consumption levels of the final good.

5 Conclusion

We have constructed a dynamic general equilibrium model, calibrated it to Egypt and used it to study the effects of a decrease of energy subsidies. The overall findings that emerge from this analysis are: a 15 percent reduction of energy subsidies to households and firms can either lead to decreases of GDP by 3 percent or increases of GDP by a similar amount. The expansionary or contractionary effect is mainly determined by the government policy that reacts to the subsidy cut and clears the government budget constraint. If infrastructure investments are increased after the subsidy cut, then growth effects can be realized. If subsidy cuts are handed back to households via lower taxes, no such growth effects will result as households simply consume the extra income and excess energy is exported at fixed world market prices. More severe cuts of energy subsidies amplify all effects monotonically.

Overall we find that welfare gains for most generations along the transition path can be realized. Only in the case with lower labor taxes in reaction to the subsidy cuts do we observe welfare losses by generations that are already retired when the reform takes place. These cohorts are not able to benefit from the lower taxes. We also find that energy cuts to producers lead to more direct growth effects. In addition, positive welfare effects are also larger as consumers do not suffer from higher (unsubsidized) energy prices and are therefore able to maintain their prior levels of energy consumption.

There are a few modeling choices we have made. First, we have not modeled explicitly the international trade side and the question of how these fiscal policy reforms would influence the trade balance. We have abstracted from explicitly modeling the formal and informal sector. These policy reforms undoubtedly would impact workers in the informal sector differentially since they would be excluded from some forms of taxation.

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6 Appendix

6.1 Tables and Figures

Parameters	Model:	Observation/Source:
Preferences		
Discount factor	$\beta = 1.022$	To match $\frac{K}{Y}$ and R
Inverse of intertemp. elast. of subst.	$\sigma = 2.2$	To match $\frac{K}{Y}$ and R
Weight on consumption	$\gamma = 0.28$	To match average hours worked.
Weight on c and l	$\Theta = 0.96$	
Weight on m_C	$\varrho = 0.2$	
Elasticity of substitution between c and m_C is $\frac{1}{1-\rho}$	$\rho = -0.25$	c and m_C are complements
Private Production:		
TFP	$A_1 = 1$	Normalization
Productivity of public good G	$\alpha_1 = 0.09$	
Capital productivity	$\alpha_2 = 0.39$	Worldbank communication
Human capital productivity	$\alpha_3 = 0.53$	
Intermediate good productivity	$\alpha_4 = 0.08$	
Capital depreciation	$\delta = 10\%$	
Long run growth rate	$g = 1\%$	Worldbank communication
Intermediate Good Production:		
TFP for intermediate good	$A_2 = 0.8$	To match size of Energy sector
	$\eta_{21} = 0.66$	Positive profit in energy sector
	$\eta_{22} = 0.12$	Match size of energy sector workforce
Public Production:		
TFP for public good production	$A_3 = 1.05$	To match public sector size
	$\eta_3 = 0.6$	Sensitivity analysis
Productive civil servants	$\omega_h = 40\%$	Sensitivity analysis
Public capital depreciation	$\delta_G = 10\%$	To match public sector size
Human Capital:		
Efficiency profile	$e_j(\theta)$	To match size of public good sector and hours worked
Efficiency profile low vs. high skilled	2 : 1	
Distribution low vs. high skilled, public	70% / 30%	Worldbank (2008)
population growth rate	$n = 1.8\%$	UN World Population Prospects

Table 1: Model parameters

	Model:	Observation/Source:
Labor Allocation:		
fraction of civil servants	$N^G = 25\%$	Worldbank (2009)
private sector employees	$N^P = 75\%$	Worldbank (2009)
Expenditures:		
Public wages markup	$\xi^W = 1.05$	Worldbank (2009)
Replacement rates (generosity of pensions)	$\Psi_P = 35\%$ $\Psi_G = 99\%$	to match pension sizes
Investment in public good (in % of private sector output)	$\Delta_G = 2\%$	Worldbank communication
Residual gov't consumption (in % of private sector output)	$\Delta_{C_G} = 0\%$	Residual (thrown into ocean), to match labor tax revenue
Government bonds (in % of private sector output)	$\Delta_B = 12\%$	To match debt level of 65% of GDP, Worldbank communication
Taxes:		
Labor tax rate; private	$\tau_L^P = 5\%$	Adjusts endogenously
Labor tax rate; public	$\tau_L^G = 5\%$	Adjusts endogenously
Consumption tax rate	$\tau_C = 16.6\%$	To match consumption tax share in tax revenue
Capital/profit tax rate	$\tau_K = 15\%$	To match capital/profit tax share in tax revenue
Energy tax HH	$\tau_{M_C} = -30\%$	To match subsidy, 5.39% of GDP
Energy tax firms	$\tau_{M_P} = -30\%$	To match subsidy, 5.39% of GDP
Tax on bequests	$\tau_{Beq} = 20\%$	To match tax revenue of labor tax
Social security tax-private	$\tau_{SS}^P = 2.8\%$	To match pension deficit -0.9% of GDP
Social security tax-public	$\tau_{SS}^G = 16.6\%$	To match pension deficit $+0.1\%$ of GDP

Table 2: Policy parameters

Moments	Model:	Data:	Observation/Source:
Capital output ratio: $\frac{K}{Y}$	2.9	3.1	Worldbank communication
Annual interest rate: r	5.0%	3%	Worldbank communication
Public sector share of GDP: $\frac{G+\bar{p}_M M}{Y}$	29.2%	27%	Worldbank communication, 17% from energy, 10% from public good.
Hours worked/week:	34.9	$30-35$	Worldbank communication
Hours worked/week, private:	35.7	$30-35$	Worldbank communication
Hours worked/week, public:	32.5	$30-35$	Worldbank communication
Public good production: $\frac{G}{Y}$	8.4%	10%	Worldbank communication
Energy prod. in % of GDP	20.7%	17%	Worldbank (2009)
Energy profits in % of GDP	4.6%	3%	Worldbank communication
Energy exports in % of GDP	5.4%	5.8%	Worldbank communication
Capital imports in % of GDP	-7.4%	$-5.4-6.6\%$	Worldbank communication average in past 3 years
Government Size: (all in % of GDP)			
Total tax revenue	22.3%	$15-20\%$	Worldbank (2009) 25% from income, 25% from profits, 50% from sales/excise taxes
Energy subsidy	4.6%	5.29%	Worldbank (2009)
Labor tax revenue	3.3%	1.7%	Worldbank (2009)
Consumption tax revenue	9.8%	7.5%	Worldbank (2009)
Capital/profit tax revenue	3.6%	3.4%	Worldbank (2009)
Soc.Sec.Rev.:private sector	1.5%	1.1%	Gupta et al. (2009)
Soc.Sec.Rev.:public sector	1.6%	1.6%	Gupta et al. (2009)
Bequest tax revenue	2.5%	N/A	to match size of tax revenue
Expenditures: (all in % of GDP)			
Wage bill public sector	12.0%	8%	Worldbank (2009)
Private pensions	2.3%	2%	Gupta et al. (2009)
Public pension	1.5%	1.5%	Gupta et al. (2009)
Debt	65%	65%	Worldbank (2009)
Pension Deficit: (all in % of GDP)			
Total pension deficit	-0.7%	-0.8%	Gupta et al. (2009)
Pension balance priv. sector	-0.8%	-0.9%	Gupta et al. (2009)
Pension balance pub. sector	$+0.1\%$	$+0.1\%$	Gupta et al. (2009)

Table 3: Model generated moments that match Egyptian data

	Benchmark	τ_L	τ_C	τ_K	Δ_G
GDP	100.000	98.808	98.697	96.878	102.513
Output Y	100.000	98.933	98.899	96.915	102.760
Capital K	100.000	102.332	99.002	110.595	102.542
Capital in fuel K_M	100.000	100.573	100.586	100.751	98.642
Capital in final K_P	100.000	98.933	98.899	96.915	102.760
Human capital private H_P	100.000	100.053	100.044	98.435	100.027
Human capital public H_G	100.000	100.215	100.050	98.425	100.031
Public good G	100.000	99.368	99.236	97.494	122.513
Consumption C	100.000	101.176	100.564	101.124	102.524
Energy production $p_M * M$	100.000	100.573	100.586	100.751	98.642
Energy consumption $p_M * M_C$	100.000	96.099	94.336	96.097	97.188
Energy used in prod. $p_M * M_P$	100.000	92.957	92.926	91.061	96.553
Exp: Capital (imp. if neg.)	-100.000	-82.056	-101.405	-23.890	-96.450
Exp: Energy (imp. if neg.)	100.000	119.664	121.228	124.189	104.059
Energy Profit	100.000	100.573	100.586	100.751	98.642
Wages w	100.000	98.957	98.935	98.638	102.539
After tax interest rate r in %	5.096	5.096	5.096	5.096	5.096
Labor tax τ_L in %	5.005	2.956	5.000	5.000	5.000
Consumption tax τ_C in %	16.563	16.563	14.652	16.563	16.563
Capital tax τ_K in %	15.000	15.000	15.000	7.224	15.000
Infrastruc. Inv. Δ_G in %	2.000	2.000	2.000	2.000	2.733
Energy subsidy	100.000	79.785	79.333	78.638	82.226
K/GDP	2.936	3.040	2.945	3.351	2.937
Energy production/GDP in %	20.756	21.127	21.153	21.585	19.975
Cap. exp./GDP (imp.if neg.) %	-7.435	-6.174	-7.636	-1.834	-6.994
Energy exp./GDP (imp.if neg.) %	5.397	6.536	6.629	6.918	5.482
Energy profits/GDP in %	6.986	7.111	7.120	7.266	6.724
Energy susidies/GDP in %	4.608	3.721	3.704	3.740	3.696
Debt to GDP ratio in %	64.997	64.997	64.997	64.997	64.997
Hours worked:	34.929	34.944	34.947	34.462	34.940
Hours worked private	35.734	35.736	35.752	35.260	35.745
Hours worked public	32.516	32.567	32.534	32.067	32.527

Table 4: **Experiment:** Decrease energy subsidies for both, **households and producers** by 15%. Column one presents the benchmark economy. We then let consumption taxes (column 2), labor taxes (column 3), capital taxes (column 4), or infrastructure investments (column 5) adjust to clear the government budget constraint.

	Benchmark	$\tau_L : 15$	$\tau_L : 30$	$\tau_L : 45$	$\tau_L : 60$	$\tau_L : 75$	$\tau_L : 90$
GDP	100.000	98.808	97.693	96.648	95.666	94.740	93.866
Output Y	100.000	98.933	97.935	96.998	96.117	95.285	94.499
Capital K	100.000	102.332	104.385	106.174	107.743	109.127	110.350
Capital in fuel K_M	100.000	100.573	101.117	101.633	102.126	102.596	103.047
Capital in final K_P	100.000	98.933	97.935	96.998	96.117	95.285	94.499
Human capital private H_P	100.000	100.053	100.102	100.147	100.189	100.229	100.267
Human capital public H_G	100.000	100.215	100.404	100.573	100.725	100.863	100.989
Public good G	100.000	99.368	98.768	98.199	97.658	97.144	96.653
Consumption C	100.000	101.176	102.178	103.026	103.746	104.360	104.882
Energy production $p_M * M$	100.000	100.573	101.117	101.633	102.126	102.596	103.047
Energy consumption $p_M * M_C$	100.000	96.099	92.475	89.097	85.946	83.004	80.253
Energy used in prod. $p_M * M_P$	100.000	92.957	86.778	81.316	76.457	72.108	68.195
Exp: Capital (imp. if neg.)	-100.000	-82.056	-66.032	-51.816	-39.116	-27.711	-17.437
Exp: Energy (imp. if neg.)	100.000	119.664	137.240	153.058	167.376	180.404	192.317
Energy Profit	100.000	100.573	101.117	101.633	102.126	102.596	103.047
Wages w	100.000	98.957	97.984	97.073	96.217	95.410	94.647
After tax interest rate r in %	5.096	5.096	5.096	5.096	5.096	5.096	5.096
Labor tax τ_L in %	5.005	2.956	1.093	-0.602	-2.153	-3.579	-4.894
Consumption tax τ_C in %	16.563	16.563	16.563	16.563	16.563	16.563	16.563
Capital tax τ_K in %	15.000	15.000	15.000	15.000	15.000	15.000	15.000
Infrastruc. Inv. Δ_G in %	2.000	2.000	2.000	2.000	2.000	2.000	2.000
Energy subsidy	100.000	79.785	61.897	45.960	31.679	18.814	7.168
K/GDP	2.936	3.040	3.137	3.225	3.306	3.382	3.451
Energy production/GDP in %	20.756	21.127	21.483	21.827	22.157	22.477	22.786
Cap. exp./GDP (imp.if neg.) %	-7.435	-6.174	-5.025	-3.986	-3.040	-2.175	-1.381
Energy exp./GDP (imp.if neg.) %	5.397	6.536	7.582	8.547	9.442	10.277	11.057
Energy profits/GDP in %	6.986	7.111	7.231	7.347	7.458	7.566	7.670
Energy susidies/GDP in %	4.608	3.721	2.919	2.191	1.526	0.915	0.352
Debt to GDP ratio in %	64.997	64.997	64.997	64.997	64.997	64.997	64.997
Hours worked:	34.929	34.944	34.956	34.969	34.981	34.992	35.004
Hours worked private	35.734	35.736	35.738	35.741	35.745	35.749	35.754
Hours worked public	32.516	32.567	32.611	32.652	32.688	32.722	32.753

Table 5: **Experiment:** Decrease energy subsidies for both, **households and firms** by 15%,30%,45%,60%,75%,and 90%. Column one presents the benchmark economy. We then let labor taxes adjust to clear the government budget constraint.

	Benchmark	$\Delta_G : 15$	$\Delta_G : 30$	$\Delta_G : 45$	$\Delta_G : 60$	$\Delta_G : 75$	$\Delta_G : 90$
GDP	100.000	102.501	104.109	105.141	105.795	106.190	106.403
Output Y	100.000	102.748	104.578	105.810	106.643	107.201	107.561
Capital K	100.000	102.539	104.239	105.384	106.161	106.680	107.016
Capital in fuel K_M	100.000	98.647	97.780	97.213	96.840	96.597	96.446
Capital in final K_P	100.000	102.748	104.578	105.810	106.643	107.201	107.561
Human capital private H_P	100.000	100.027	100.055	100.084	100.113	100.141	100.169
Human capital public H_G	100.000	100.032	100.063	100.096	100.129	100.161	100.193
Public good G	100.000	122.434	141.891	158.709	173.346	186.179	197.515
Consumption C	100.000	102.519	104.177	105.277	106.006	106.478	106.768
Energy production $p_M * M$	100.000	98.647	97.780	97.213	96.840	96.597	96.446
Energy consumption $p_M * M_C$	100.000	97.184	94.010	90.745	87.528	84.424	81.464
Energy used in prod. $p_M * M_P$	100.000	96.542	92.664	88.703	84.830	81.125	77.621
Exp: Capital (imp. if neg.)	-100.000	-96.416	-94.040	-92.463	-91.407	-90.712	-90.274
Exp: Energy (imp. if neg.)	100.000	104.112	111.233	119.753	128.800	137.917	146.861
Energy Profit	100.000	98.647	97.780	97.213	96.840	96.597	96.446
Wages w	100.000	102.528	104.202	105.318	106.064	106.553	106.859
After tax interest rate r in %	5.096	5.096	5.096	5.096	5.096	5.096	5.096
Labor tax τ_L in %	5.005	5.000	5.000	5.000	5.000	5.000	5.000
Consumption tax τ_C in %	16.563	16.563	16.563	16.563	16.563	16.563	16.563
Capital tax τ_K in %	15.000	15.000	15.000	15.000	15.000	15.000	15.000
Infrastruc. Inv. Δ_G in %	2.000	2.733	3.440	4.105	4.725	5.301	5.837
Energy subsidy	100.000	82.218	65.137	49.111	34.244	20.520	7.873
K/GDP	2.936	2.937	2.939	2.943	2.946	2.949	2.953
Energy production/GDP in %	20.756	19.975	19.494	19.191	18.999	18.881	18.814
Cap. exp./GDP (imp.if neg.) %	-7.435	-6.994	-6.716	-6.538	-6.424	-6.351	-6.308
Energy exp./GDP (imp.if neg.) %	5.397	5.482	5.766	6.147	6.570	7.009	7.449
Energy profits/GDP in %	6.986	6.724	6.562	6.460	6.395	6.355	6.333
Energy susidies/GDP in %	4.608	3.696	2.883	2.152	1.491	0.890	0.341
Debt to GDP ratio in %	64.997	64.997	64.997	64.997	64.997	64.997	64.997
Hours worked:	34.929	34.940	34.952	34.964	34.975	34.987	34.998
Hours worked private	35.734	35.745	35.756	35.768	35.779	35.791	35.802
Hours worked public	32.516	32.527	32.539	32.551	32.563	32.574	32.586

Table 6: **Experiment:** Decrease energy subsidies for both, **households and firms** by 15%,30%,45%,60%,75%,and 90%. Column one presents the benchmark economy. We then let public infrastructure investments adjust to clear the government budget constraint.

	Benchmark	τ_L	τ_C	τ_K	Δ_G
GDP	100.000	99.834	99.804	99.417	100.879
Output Y	100.000	100.031	100.021	99.598	101.108
Capital K	100.000	100.894	100.033	102.627	101.022
Capital in fuel K_M	100.000	100.006	100.009	100.043	99.460
Capital in final K_P	100.000	100.031	100.021	99.598	101.108
Human capital private H_P	100.000	100.041	100.038	99.697	100.034
Human capital public H_G	100.000	100.087	100.043	99.716	100.038
Public good G	100.000	99.935	99.899	99.536	106.017
Consumption C	100.000	100.554	100.387	100.458	100.978
Energy production $p_M * M$	100.000	100.006	100.009	100.043	99.460
Energy consumption $p_M * M_C$	100.000	95.588	95.128	95.519	95.932
Energy used in prod. $p_M * M_P$	100.000	100.031	100.021	99.598	101.108
Exp: Capital (imp. if neg.)	-100.000	-94.929	-99.927	-82.681	-98.576
Exp: Energy (imp. if neg.)	100.000	103.588	104.000	104.665	99.027
Energy Profit	100.000	100.006	100.009	100.043	99.460
Wages w	100.000	99.989	99.983	99.921	100.997
After tax interest rate r in %	5.096	5.096	5.096	5.096	5.096
Labor tax τ_L in %	5.005	4.475	5.000	5.000	5.000
Consumption tax τ_C in %	16.563	16.563	16.074	16.563	16.563
Capital tax τ_K in %	15.000	15.000	15.000	13.136	15.000
Infrastruc. Inv. Δ_G in %	2.000	2.000	2.000	2.000	2.183
Energy subsidy	100.000	94.605	94.484	94.279	95.455
K/GDP	2.936	2.967	2.943	3.030	2.940
Energy production/GDP in %	20.756	20.792	20.798	20.886	20.468
Cap. exp./GDP (imp.if neg.) %	-7.435	-7.070	-7.441	-6.184	-7.264
Energy exp./GDP (imp.if neg.) %	5.397	5.600	5.623	5.681	5.301
Energy profits/GDP in %	6.986	6.998	7.001	7.030	6.889
Energy susidies/GDP in %	4.608	4.366	4.362	4.370	4.360
Debt to GDP ratio in %	64.997	64.997	64.997	64.997	64.997
Hours worked:	34.929	34.944	34.945	34.847	34.943
Hours worked private	35.734	35.745	35.749	35.648	35.747
Hours worked public	32.516	32.540	32.531	32.443	32.530

Table 7: **Experiment:** Decrease energy subsidies for **households only** by 15%. Column one presents the benchmark economy. We then let consumption taxes (column 2), labor taxes (column 3), capital taxes (column 4), or infrastructure investments (column 5) adjust to clear the government budget constraint.

	Benchmark	τ_L	τ_C	τ_K	Δ_G
GDP	100.000	98.977	98.891	97.607	101.780
Output Y	100.000	98.904	98.879	97.472	101.796
Capital K	100.000	101.409	98.969	107.340	101.640
Capital in fuel K_M	100.000	100.567	100.576	100.692	99.098
Capital in final K_P	100.000	98.904	98.879	97.472	101.796
Human capital private H_P	100.000	100.014	100.006	98.865	99.994
Human capital public H_G	100.000	100.130	100.007	98.870	99.993
Public good G	100.000	99.436	99.336	98.110	116.560
Consumption C	100.000	100.612	100.169	100.540	101.679
Energy production $p_M * M$	100.000	100.567	100.576	100.692	99.098
Energy consumption $p_M * M_C$	100.000	100.529	99.167	100.497	101.435
Energy used in prod. $p_M * M_P$	100.000	92.930	92.906	91.585	95.647
Exp: Capital (imp. if neg.)	-100.000	-87.301	-101.477	-45.636	-97.739
Exp: Energy (imp. if neg.)	100.000	116.052	117.258	119.285	104.155
Energy Profit	100.000	100.567	100.576	100.692	99.098
Wages w	100.000	98.969	98.952	98.743	101.676
After tax interest rate r in %	5.096	5.096	5.096	5.096	5.096
Labor tax τ_L in %	5.005	3.500	5.000	5.000	5.000
Consumption tax τ_C in %	16.563	16.563	15.147	16.563	16.563
Capital tax τ_K in %	15.000	15.000	15.000	9.296	15.000
Infrastruc. Inv. Δ_G in %	2.000	2.000	2.000	2.000	2.534
Energy subsidy	100.000	85.214	84.806	84.391	87.118
K/GDP	2.936	3.008	2.938	3.228	2.932
Energy production/GDP in %	20.756	21.089	21.109	21.412	20.212
Cap. exp./GDP (imp.if neg.) %	-7.435	-6.558	-7.626	-3.477	-7.138
Energy exp./GDP (imp.if neg.) %	5.397	6.328	6.399	6.595	5.526
Energy profits/GDP in %	6.986	7.099	7.105	7.207	6.803
Energy susidies/GDP in %	4.608	3.967	3.951	3.984	3.944
Debt to GDP ratio in %	64.997	64.997	64.997	64.997	64.997
Hours worked:	34.929	34.929	34.932	34.589	34.927
Hours worked private	35.734	35.725	35.736	35.387	35.731
Hours worked public	32.516	32.543	32.518	32.196	32.514

Table 8: **Experiment:** Decrease energy subsidies for **producers only** by 15%. Column one presents the benchmark economy. We then let consumption taxes (column 2), labor taxes (column 3), capital taxes (column 4), or infrastructure investments (column 5) adjust to clear the government budget constraint.

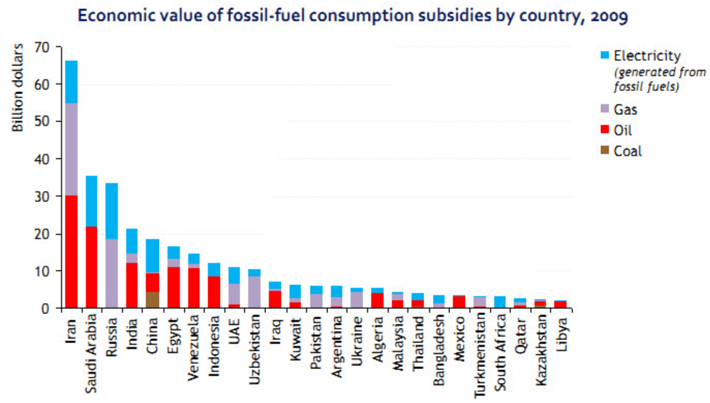

Figure 1: Taken from World Energy Outlook 2010, a publication of the IEA.

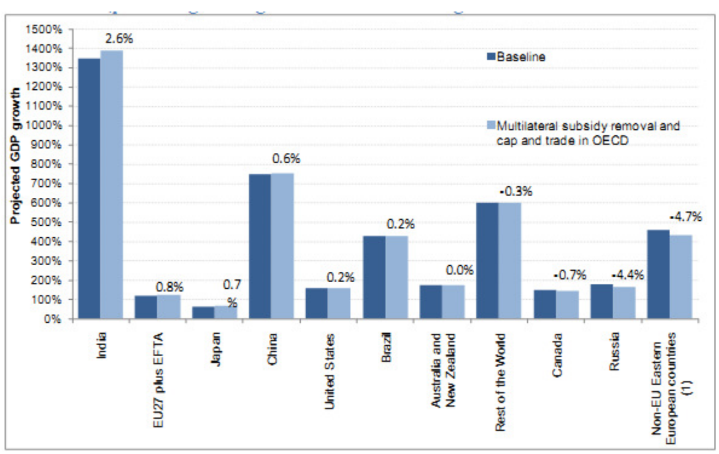

Figure 2: Long term impact on GDP of a multilateral phasing out of fossil-fuel subsidies by regions in 2050 (percentage changes indicate GDP change in 2050 relative to the baseline) - Figure taken from IEA (2010c), page 27.

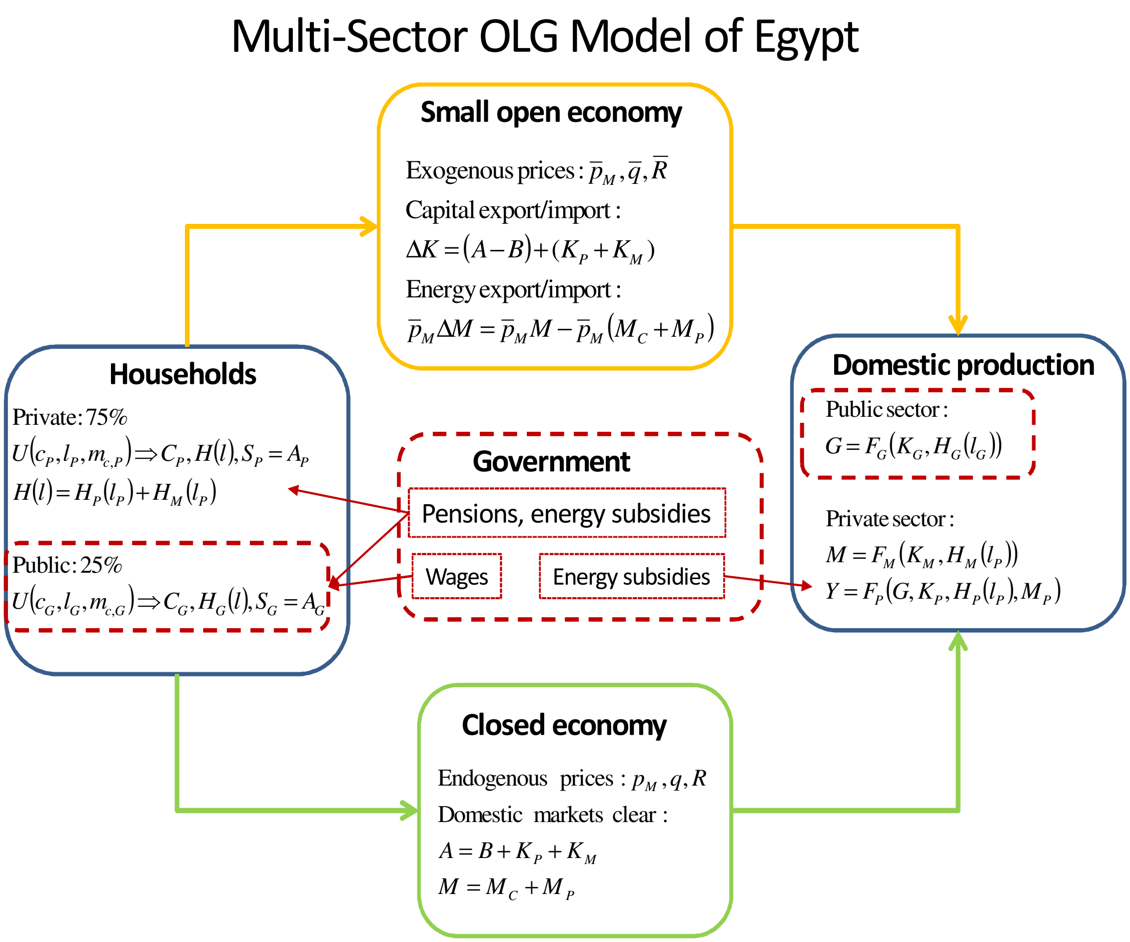

Figure 3: Multi sector OLG model of Egypt.

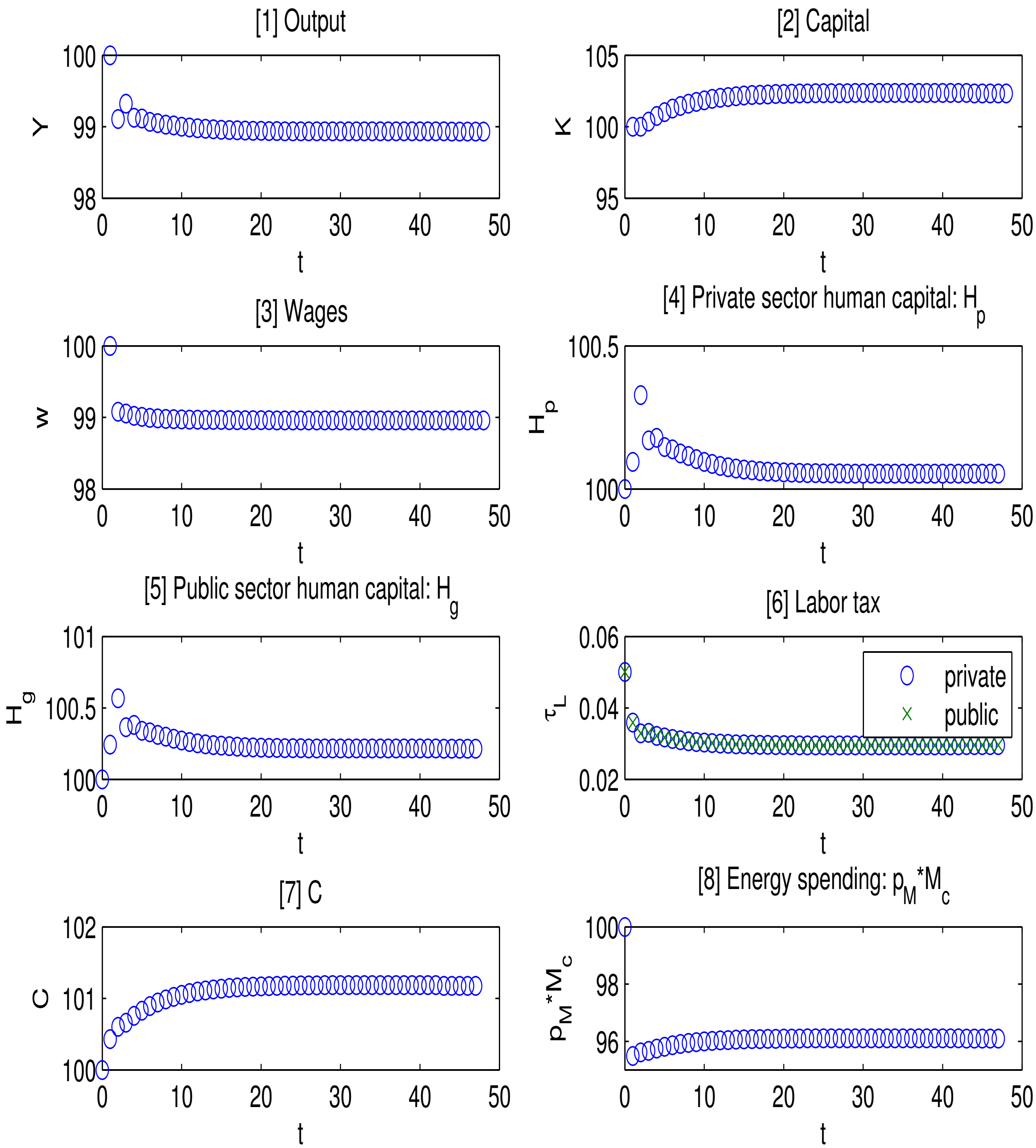

Figure 4: **Transitions**: Decrease energy subsidies for both, **households and producers** by 15% and labor taxes adjust to accommodate the drop in energy subsidies.

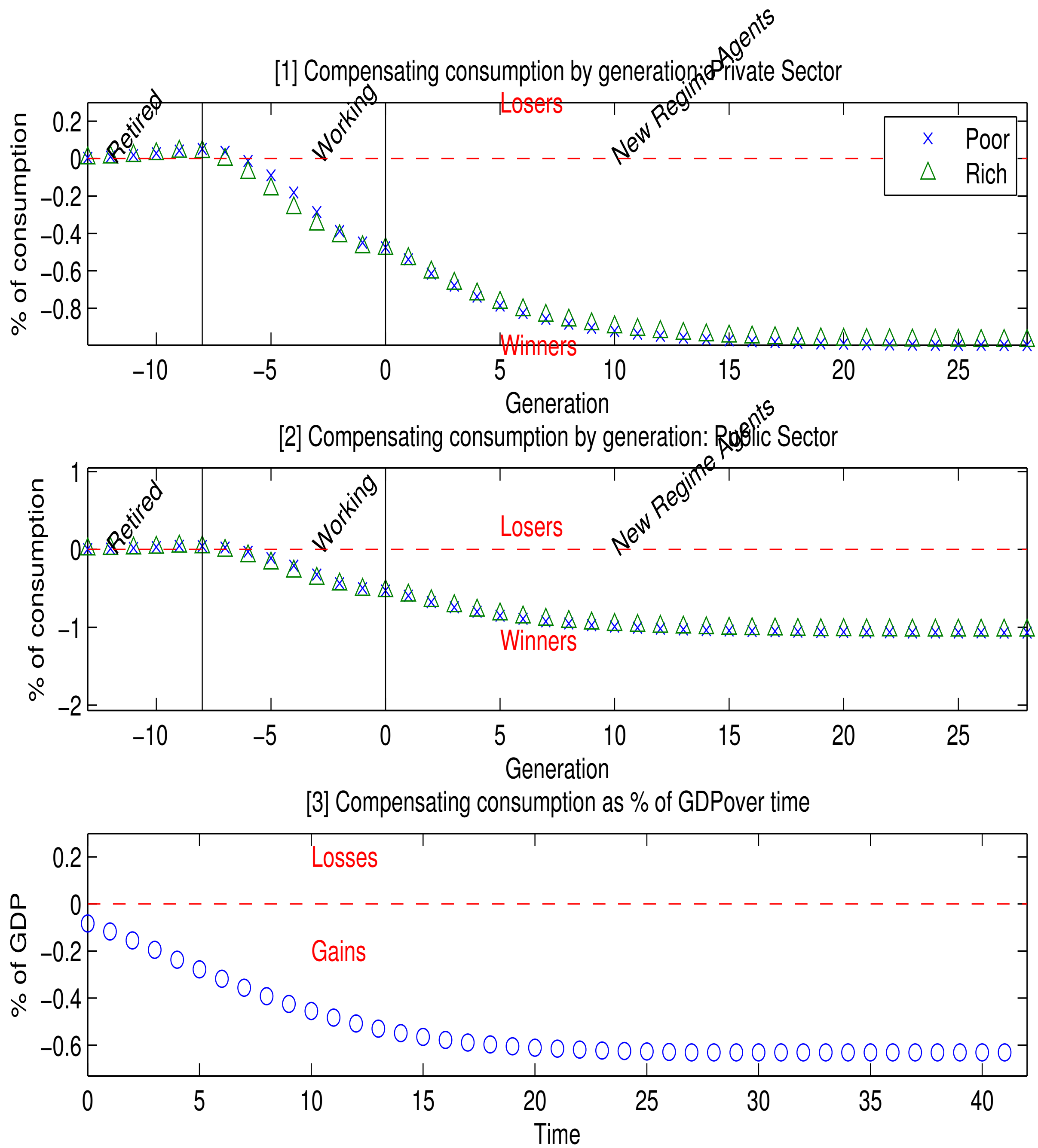

Figure 5: **Welfare dynamics**: Decrease energy subsidies for both, **households and producers** by 15% and labor taxes adjust to accommodate the drop in energy subsidies. Panel [1] and [2] report compensating consumption units as percent of per period consumption of each generation for private and public sector workers respectively. Panel [3] reports total compensating consumption as % of GDP for all generations for each year after the reform.

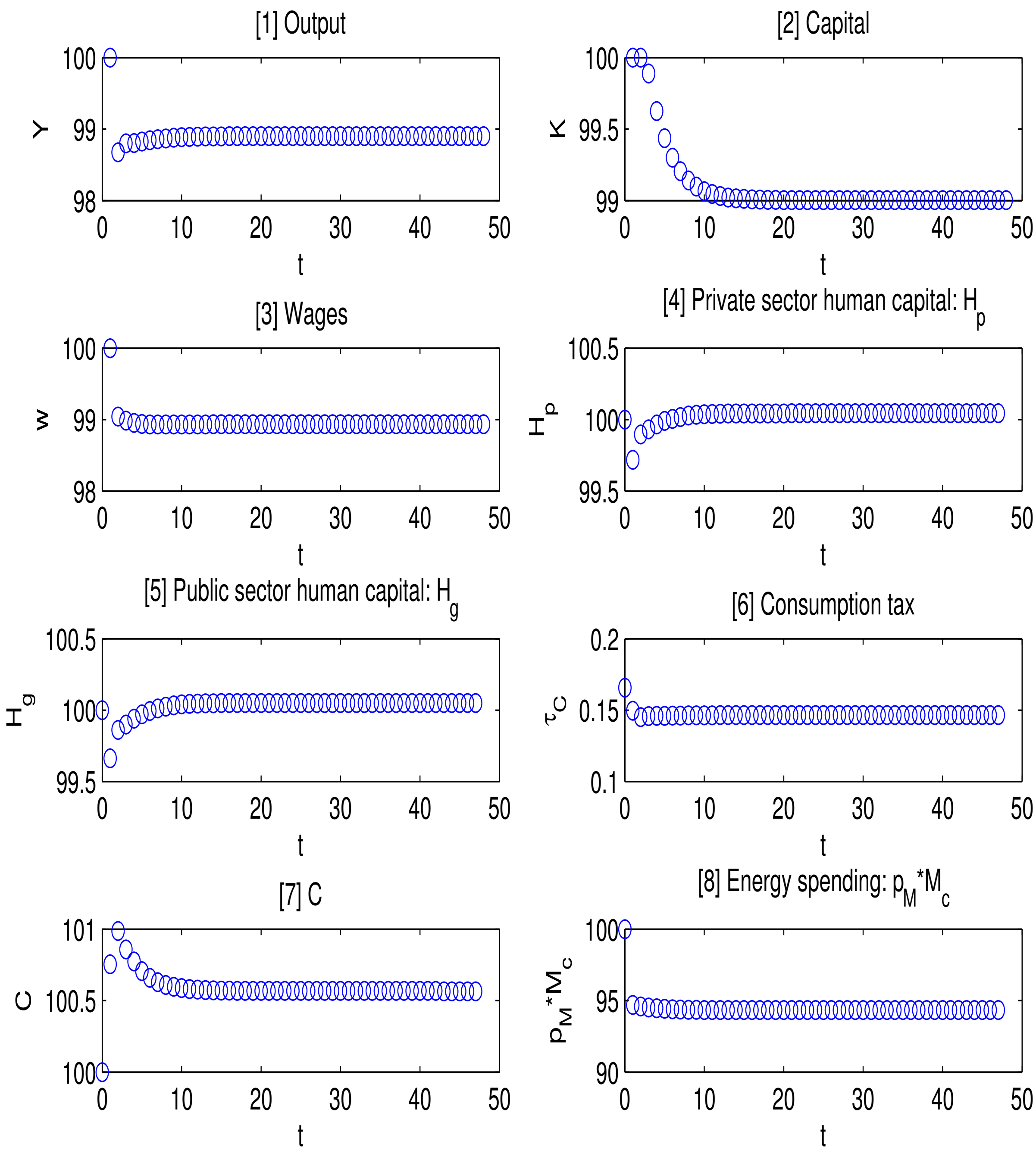

Figure 6: **Transitions**: Decrease energy subsidies for both, **households and producers** by 15% and consumption taxes decrease to accommodate the drop in energy subsidies.

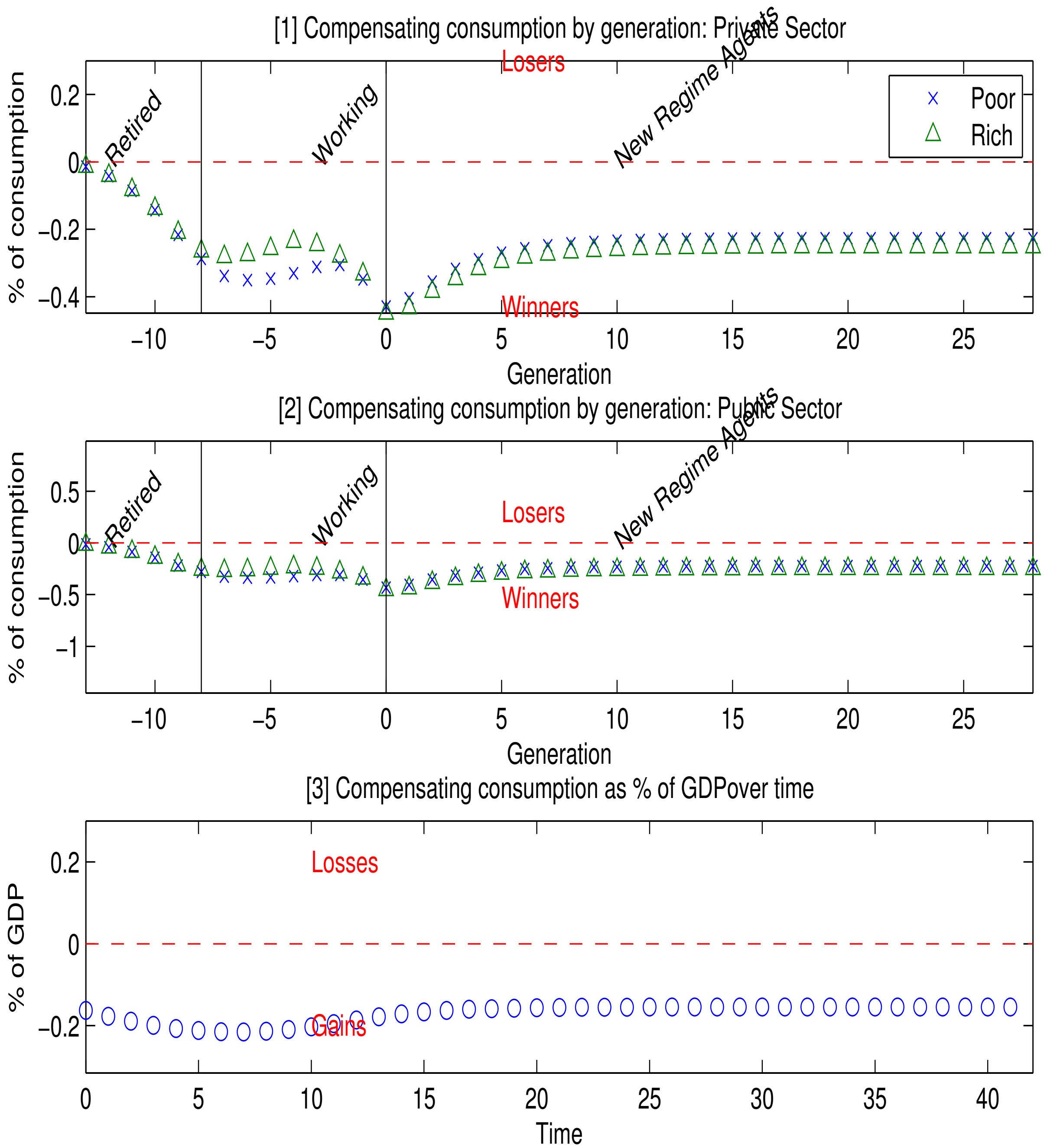

Figure 7: **Welfare dynamics**: Decrease energy subsidies for both, **households and producers** by 15% and consumption taxes decrease to accommodate the drop in energy subsidies. Panel [1] and [2] report compensating consumption units as percent of per period consumption of each generation for private and public sector workers respectively. Panel [3] reports total compensating consumption as % of GDP for all generations for each year after the reform.