Economic Reform in North Korea: A Dynamic General Equilibrium Model

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Abstract

This paper examines the impact of hypothetical market reforms in North. We build a dynamic general equilibrium model and simulate multiple reform scenarios.

We first construct a baseline model which mimicks the current command economy. In this scenario the government allocates output in an inefficient way and simulated economic growth is negative. We next model a semi-market transition that allows producers choices regarding the distribution of available capital. However, total capital is still chosen by the government. Lastly, we consider two scenarios with full market reform allowing for the usual market mechanisms derived from consumer utility maximization, firm profit maximization, and market clearing prices. In one scenario we keep government investment in public infrastructure unchanged at the low baseline level. In the other we drastically increase the rate of infrastructure investment so that it matches that of South Korea. In all we maintain a closed economy assumption and a constant size for the military.

Our simulations show little hope for the North Korean economy without a significant increase in infrastructure. Although all of the reforms raise the level of output and consumption per capita, only with significant increases in infrastructure investment does output growth change from negative to positive.

1. Introduction

Korea was annexed by Japan in 1919 and partitioned into two parts at the end of World War II. At the Yalta Conference in February of 1945 the Allied Powers agreed to a division of the Korean peninsula into two spheres of influence. The Soviet Union would administer the area north of the 38th parallel and the United States administered the south. In June of 1950 war broke out on the peninsula. When the armistice agreement was signed in July of 1953, Korea was effectively divided into the two halves along a border very close to the original 38th parallel. There have been two Koreas with two very different economic systems ever since.

Prior to South Korea's rapid growth beginning in the 1960's, North Korea enjoyed the higher standard of living. With the Soviet Union as the primary source of trade and outside resources, the North maintained a relatively stable economy for decades. Obviously, today much has changed. With the fall of the Soviet Union in the 1990's, and after a series of floods and famines, North Korea experienced a massive drop in standards of living. Many North Koreans illegally cross the border into China in search of food, freedom and opportunity. Meanwhile, the international community has imposed increasingly tighter economic sanctions on North Korea, most recently due to its pursuit of nuclear weapons technology. Even before these sanctions, however, the country's *juche* ideology with its emphasis on self-reliance meant that North Korean traded little with the rest of the world. Today, what little trade does occur comes primarily through China or comes in the form of foreign humanitarian aid.[1] North Korea has a highly planned economy set up along Stalinist lines. While there is some evidence of emerging

[1] One notable exception is the cooperative economic zone in Gaeseong, just across the demilitarized zone from the South. Virtually all the investment and trade here is through South Korean firms.

market activity, the fact remains that North Korea has one of the most rigidly state-controlled economies in the world.

What is the prognosis for the North Korean economy? In some ways this is a trivial question. Without economic reform of some sort the country will remain stagnant and backward, perhaps even falling further into poverty. In other ways, however, this is a very difficult question. No one outside of North Korea (and very few inside) fully understands current economic conditions. The secretive nature of the regime makes in almost impossible for outsiders to guess at likely future changes in economic policy. Still, there are some things we do know, or can deduce. For example, the economy is terribly short of capital goods. What little capital remains from earlier decades is sadly out-of-date, and much of it is no longer functional. We also know that, outside of the capital of Pyeongyang, the country is lacking all but the most rudimentary infrastructure. The telecommunications system is primitive at best, port facilities are minimal, and even major roads are narrow and often in poor repair. The government allocates much of the economy's output to the military spending[2], seemingly regardless of civilian hardship. Per capita GDP for the year 2004, according to Bank of Korea estimates, is less than $1000.

This paper builds a model of the North Korean economy, and attempts to shed light on its likely future, as well as the effects of possible reforms. We note that almost any real reform will improve the North Korean economy. The more difficult task is to estimate the size of the impact on the economy.

We are not the first to attempt forecasts for the North Korean economy. Eberstadt (1990) predicted an utter collapse of the economic system, for example. Since then, there has been a sharp decline in the economy, but it has avoided a total collapse so far. Noland (2000), in

[2] Estimates range from one-third to one-fifth of GDP.

examining recent changes in the North Korean economy, concluded that it does not have the ability to produce the investment needed to escape poverty. He noted that North Korea's economy allocates some limited final goods through price mechanisms, and predicted this trend would continue. North Korea introduced limited market reforma in July of 2002, but the extent of the reform and its consequences seem to be minimal – extreme energy shortages, and other economic factors, may have increased state control, rather than decrease them as intended (Seliger 2005).

Bradford and Phillips (2005) in their analysis of the reunification of South and North Korea, include various reforms of the North Korean economy. However, those simulations start with the baseline assumption of an established market system.

The North Korean economy is an inefficient centrally-planned economy with almost no international trade. The government dictates employment, production, investment, and consumption in the economy. Therefore, we construct a baseline model that resembles an extreme centrally planned economy with complete autarky. We borrow heavily from Bradford and Phillips (2005) in setting up the basic production structure of our model including the characterization of final goods, intermediate goods, technology, infrastructure and the defense burden. However, in our baseline case we do not allow for optimal decision-making on the part of households and firms. Instead, all key decisions are made by the government.

2. Building a Dynamic General Equilibrium Model

We assume there is a single final good which can be used for consumption or investment in physical capital, infrastructure or defense capital. This good is produced by aggregating intermediate goods. We calibrate using eight intermediate sectors. These intermediate goods are

produced using three factors: capital, skilled labor and unskilled labor. The decision-makers in the economy can allocate capital and unskilled labor across the intermediate goods in any way they wish, through command or market mechanisms. Skilled labor, however, is assumed to be useable only in a specific industry. Hence there are eight different kinds of skilled labor. Skilled workers must work in the sector where their skill is used, they cannot produce other intermediate goods. Unskilled workers, on the other hand, can work producing any of the intermediate goods. Both types of labor have permanently fixed supplies[3].

We assume that productivity in North Korea is influenced by two factors. The first is international productivity. As better technologies emerge in the rest of the world, North Korea gradually adopts them. A second factor, that limits technology, is domestic infrastructure. We assume that more infrastructure per worker leads to higher productivity. This implicitly assumes congestion effects; that is, if there are more workers we must have correspondingly more infrastructure to maintain the same level of productivity. With fixed labor supplies, these congestion effects do not materialize as congestion, *per se*, but the amount of infrastructure does impose limits on productivity.

The basic structure of this baseline model will not change when we introduce reforms later in the paper. However, reforms will alter how capital and labor are allocated across the intermediate sectors and how the final goods are allocated over consumption and investment in the three kinds of capital.

We now proceed with a formal mathematical derivation of the baseline model.

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[3] The labor force in North Korea, excluding the military, does not appear to be growing. The declining population of youth, due to low birth-rates and recent famines, indicates at best a stagnant labor growth.

Intermediate Goods

Intermediate goods are produced using the three factors of production: capital, unskilled labor, and skilled labor. The output of each intermediate good is defined by the following constant returns-to-scale production function:

$$Y_i = K_i^{\,b}(ZN_i)^c(ZL_i)^{1-b-c} \tag{1}$$

where Y_i is output of intermediate good i, K_i is the capital stock used to produced good i, N_i and L_i are the quantities of unskilled and skilled labor, and Z is the economy-wide level of labor-augmenting technology.

Final Goods

Aggregate output is a single final good that is also produced with constant returns-to-scale technology and uses intermediate goods only. We use an Armington aggregator:

$$Y = \prod_i Y_i^{a_i}; \sum_i a_i = 1 \tag{2}$$

where the a_i's are industry shares in GDP.

Capital and Investment

Captial for each sector grows according to the following law of motion:

$$K_i' = (1-\delta)(K_i) + \Delta K_i;\ \Delta K_i = \eta_i \phi Y;\ \eta_i = \left(\frac{K_i}{K}\right) \text{ for all } i \tag{3}$$

where K is the aggregate capital stock, δ is the depreciation rate, ϕ is the percentage of final output the government invests in physical capital, and η_i .is the percentage of this new capital that is allocated to industry i. Here and throughout the paper, a $'$ denotes the value of a

variable the following period and a Δ indicates a change in a capital stock; i.e. investment. We assume the central planner invests in each sector proportionally to the size of the sector's capital stock. If a sector has 25% of the total capital stock, the government decides to allocate 25% of the new (invested) capital to that sector.

Infrastructure

The government allocates a portion of its final goods (Y) to build up the domestic infrastructure to desired levels. Over time, infrastructure evolves according to the following law of motion:

$$I' = (1-\delta)I + \Delta I;\ \Delta I = \psi Y \tag{3}$$

where I denotes the infrastructure level, and ψ is the percent of GDP the government invests in infrastructure each period.

Defense

The government allocates a proportion of final output to the creation of new military capital, which evolves over time according the following law of motion:

$$M' = (1-\delta)M + \Delta M;\ \Delta M = \mu Y \tag{4}$$

where M denotes military capital and μ is the percent of GDP invested in military capital.

The government also conscripts soldiers from the ranks of unskilled labor. It combines these soldiers with the military capital to produce a level of national defense as shown below:

$$D = M^{d}(ZfN)^{1-d} \tag{5}$$

where f is the percentage of the unskilled labor force conscripted into the military.

Technology

The economy-wide level of technology changes over time as a function of world technology and domestic infrastructure per unskilled worker according to:

$$Z = z^{h}(I/N)^{1-h} \tag{6}$$

where z denotes world technology levels.

External technology grows at a constant rate g_z each period:

$$z' = (1+g_z)z \tag{7}$$

Combining equations (6) and (7) gives a law of motion for Z that depends on last period's technology level and the growth rate of infrastructure stock:

$$Z' = (1+g_z)^{h}(1+g_I)^{1-h}Z \;;\; 1+g_I = I'/I \tag{8}$$

Aggregation

The aggregation and market-clearing conditions are:

capital stock aggregation,

$$K = \sum_j K_j \tag{9}$$

unskilled labor aggregation,

$$(1-f)\overline{N} = \sum_j N_j \tag{10}$$

skilled labor aggregation,

$$\overline{L}_j = L_j \;\; \forall j \tag{11}$$

and final goods aggregation

$$Y - \delta K = C + \Delta K + \Delta M + \Delta I \tag{12}$$

Utility

In the baseline model, have no control over their consumption levels. However, they still derive utility from the consumption the government gives them. In our final two scenarios we allow consumers to choose savings levels and consumption, so we present that problem here for the sake of parsimony. We imagine an infinitely-lived agent in line with standard macroeconomic models. It is convenient to express the household's problem in the form of a dynamic programming problem:

$$V(K,\Theta) = \underset{K'}{\text{Max}} \; \tfrac{1}{1-\sigma} C^{1-\sigma} + \beta E\{V(K',\Theta')\} ;$$

$$C = \sum_i w_i \bar{L}_i + v(1-f)\bar{N} + (1+r-\delta)K - K' - T \tag{13}$$

Where Θ is the information set available to the household, σ is the elasticity of substitution, C is household consumption, β is the subjective discount rate, the w_i are skilled wages, v is the unskilled wage, r is the return on capital and T is net government lump-sum taxation.

If we solve the problem from equation (13) we get the following Euler equation which describes the behavior of consumption over time and can be used to find the path of the aggregate capital stock.

$$C^{-\sigma} = \beta E\{C'^{-\sigma}(1+r'-\delta)\} \tag{14}$$

3. Baseline Simulation

Accurately parameterizing a model for the North Korean economy is frustrating due to the lack of reliable data. The North Korean government does not publish its economic indicators regularly and the data are often unreliable when they do. We use data and analysis from the Bank of Korea, the United Nations, and the South Korean Unification Ministry.

We choose the parameters for households and production as follows. The subjective discount factor, β, is set to .95, consistent with an annual discount rate of 5%. The elasticity of substitution, σ, is set to .087 which gives a steady state user cost of capital of 3% APR in our simulations. The depreciation rate, δ, is set to 10% per year. We set the annual growth reat of world technology, g_z, to 1.5%. The share of world technology in domestic technology, h, is set rather arbitrarily to one-half. Using data from the GTAP dataset for Korea we find the average share of capital in GDP, b, is .431 and the share of unskilled labor, c, is .394. We use these values for North Korea.

Government policy variables for North Korea are set to match observed data. The conscription rate, f, is 15% and generates a standing army of approximately one million. The physical capital investment rate, φ, of 14% comes from United Nations estimates. The infrastructure investment rate, ψ, is 0.8% and comes from ??????. A military investment rate, μ, of 25% generates a level of defense roughly the same size as that in South Korea.

The fixed labor supplies are carefully constructed from data across sectors reported by the Bank of Korea, the GTAP dataset and North Korean reports to the United Nations[4] in 1993 and 1998. Normalizing so that the number of skilled workers in the South is 100, we get skilled and unskilled labor force values in North Korea of approximately 27 and 186 respectively.

[4] The labor division numbers rely on the DPRK Central Bureau of Statistics, Tabulation of the Population Census of the Democratic People's Republic of Korea, and the ROK National Statistical office. We also use the division of skilled and unskilled labor numbers given by: DPRK, Core Document Forming Part of The Reports of State Parties, United Nations Human Rights Instruments, 24 Jun 2002. The document, "기술자 및 전문가 수" (kisulja mit chŏnmun'ga su, roughly translated, "number of skilled and expert laborers"), gives a 4.5:1 ratio of unskilled to skilled workers. The dynamics of labor growth seem to be stagnant or slightly decreasing. We assume no labor growth due to this estimation.

The distribution of the skilled labor force across intermediate industries is also constructed from the 1993 North Korean census report.

Finally, the shares of each intermediate industry in GDP, the α's, are obtained by using data on sectoral output from the sources mentioned above and from the South Korean Ministry of Unification.

To simulate, we also need to choose starting values for the capital stocks across sectors, the level of infrastructure, and the level of unskilled workers allocated to each sector. We use data from 2004 to calibrate our starting values. We get the unskilled labor data and we also obtain output data for the same sectors. With this in hand and given the parameter values above we can solve for initial capital stocks using equation (1). Infrastructure measures come from the Ministry of Unification[5].

The values of our parameters and initial values are all reported in table 1.

With these initial shares and the described laws of motion, we simulate the North Korean economy under its current central planning policies. We assume that external technology evolves smoothly over time and that there are no policy shocks to disturb the smooth transition of the economy to its long-run steady state.

Figures 1 - 3 show a dramatic decrease in the capital stock and production in the aggregate and across all sectors. The government does not invest enough in capital and infrastructure to maintain positive growth rates. This is true despite its allocating 14% of output to new capital investment. Our results are contrary to forecasts by the Bank of Korea, which predicts a solid 3-4% annual growth in output for North Korea.

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[5] For the initial infrastructure in the North we use $I_N = I_S \Omega$; I_S=100, where Ω is the ratio of three measures of infrastructure indicators between South and North Korea: harbor capacity, energy generation capacity, and shipping tonnage. Ω is 8.08, meaning North Korea is estimated to have about 12% infrastructure of South Korea.

4. Semi-Market Reform

There are many possible ways to implement limited market reforms in North Korea. We focus on the adoption of market mechanisms along the lines of the Chinese reforms of the 1980's. These are likely to be implemented gradually. Indeed, North Korea has already begun to slowly free up some prices, such as those for food and some other consumer goods. This may be in an attempt to stimulate production in the small, but increasingly important, private sector. Or it may be a reluctant recognition that these markets already exist outside state control and have become essential to avoid total collapse of the economy.

Allowing the market to set the price of final goods will reduce waste and inefficiency in the distribution of these goods. However, it will not have any effect on the production of goods unless the producers are also free to respond to price movements. We allow this via a modification to capital investment policy. In our reformed economy we imagine that firms are free to trade capital in a capital market. In this case capital allocation will be determined by the marginal product of capital which will be the same in all sectors. We continue to assume, however, that central planners still determine the size of the aggregate capital stock through control of the percentage of output that is allocated to investment. In other words, the government controls the size of the capital stock, but allows firms to compete with each other for the right to use this capital.

We simulate this change in policy by modifying our original simulation. We keep the baseline simulation for periods 1-9, but implement our reform time period 10.

We expect the overall capital stock to roughly follow the baseline path since the government does not change the percentage of output allocated to the capital stock and infrastructure.

However, we also expect one-time efficiency gains that will raise the level of output due to more efficient allocation of capital.

Reform shifts the capital allocation across sectors radically as shown in table 2. There is a dramatic decrease in sector 7, which is government-related services, and a large increase in sector 5, manufactured goods. This implies that under the baseline regime the governmental service sector has too much capital invested (relative to its labor resources) while the manufacturing sector has too little. The shifting of resources results in a small efficiency gain for overall output which can be seen in Figure 4.

Because the reform is fully implemented in one time period (at t=10), we notice a small rise in aggregate output in that period. While there are short term benefits to this type of reform, the effect in the long-run is close to nil. The economy still follows a slowly deteriorating path.

5. Full Market Reform

More meaningful market reforms would allow for endogenously chosen capital investment, made by savers in the economy rather than by central planners. Unskilled labor movement across sectors would also be allowed and would eliminate differences in unskilled wages across sectors. Even with the adoption of a full market economy, however, the government would most likely maintain control over infrastructure and military investment.

We allow for market reform by adopting more common assumptions about the role that consumers and firms play in the economy. We introduce the following features to the model that do not exist in the baseline or semi-market simulations:

First, we allow consumer choice in consumption and savings. This drives endogenously chosen investment in capital. The household's problem for this case was introduced in section 2 and is described by equations (13) and (14)

Second, we allow firms to compete competitively for both labor and capital with unskilled labor to moving freely across all sectors and equalizing the unskilled wage rates.

Third, we allow the government to impose lump-sum taxes on household which it uses to fund the purchase of infrastructure and military capital.

We consider two parameterizations in this section. In the "Market 1" case, the government maintains an infrastructure investment rate of 0.8%, consistent with the level of previous baseline and semi-market scenarios. In the "Market 2" case, the infrastructure investment rate increases to 2.5%, the same as the rate for South Korea. Increased infrastructure investment lowers consumption in the short term, as the government must tax the consumers in order to build new infrastructure[6]. However, in the long-run it raises the economy's level of technology. We do not model the infrastructure decision as an optimal choice on the part of the government; we simply examine the results from two different values.

Figures 5 – 9 show the effects of both market reforms 1 and 2. They graph four scenarios for comparison purposes. These correspond to simulations where: 1) there is no reform, 2) there is semi-market reform in period 10, but not subsequent reforms, 3) semi-market reform is followed by full market reform in period 20, and 4) full market reform is followed by an increase in infrastructure investment in period 30.

[6] To clarify, capital investment rate in the market reform scenarios are "chosen" by utility maximizing consumers and profit maximizing firms through market mechanisms. Thus capital investment is optimally chosen over time. Infrastructure investment rate, meanwhile, is a government policy choice. No optimality conditions are considered by the government.

The figures show that full market reform still lacks the infrastructure growth necessary to facilitate a growing economy. When the investment rate for infrastructure is increased to 2.5% in the final scenario, the economy turns around and begins to follow a transition path to a steady state with positive growth. Effective reform in North Korea will require more than just adoption of market mechanisms. With an already depleted infrastructure stock, the government must commit to a policy of infrastructure growth.

6. Conclusion

The downward spiral of the North Korean economy will not be easy to remedy. Our baseline, which models the status quo for the North Korean economy, predicts a very grim future. If current economic policies are maintained, slowly deteriorating living standards and even starvation could result. The semi-reform simulation shows that while incomplete reform may be tempting, it is not as beneficial as planners may hope. Full market reform, with efficient capital investment and allocation may restore real growth to the North Korean economy, but only if coupled with increases in infrastructure.

None of our scenarios include any openness to trade. Growth patterns observed in the market reforms would most likely be enhanced by foreign aid, trade in goods, and international borrowing and lending.

In our modeling exercises, we do not take into account the political difficulty of such economic reforms. However, the reforms proposed in this paper do not require opening for foreign trade, although trade would more than likely bring much gain; North Korea can remain a "hermit kingdom" and still adopt a more efficient internal economic system if it so chooses. Moreover, foreign aid and the lifting of sanctions are much more likely if the regime

demonstrates a serious commitment to economic reforms. On the other hand, market reforms by their very nature involve a loss of control by those who administer the central government. So little is known about how political decisions are made in North Korea, that is it impossible to predict how attractive or unattractive this loss of control would be.

Can the North Korean economy be salvaged? Without serious reform, the economy appears to lack the ability and the infrastructure to resurrect itself. Even with reforms, the momentum of the current decline will prove to be difficult to overcome for a number of years. However, any major reform can be a significant marker in North Korea's road to recovery after long years of suffering.

It is worth remembering that South Korea's relative wealth and economic prosperity was not achieved overnight. It was decades after the Korean war before South Korea began to experience high rates of economic growth. As the saying goes, "A journey of a thousand miles must begin with the first step." Though the road seems very far for the North Korean economy, the first steps need to be taken.

Table 1

Economy-wide Parameters

b	capital share	0.441
c	unskilled labor share	0.394
h	foreign technology share	0.5
g_z	foreign technology growth	0.015
β	subjective discount factor	0.95
δ	depreciation rate	0.1
σ	elasticity of substitution	0.087
f	conscription rate	0.15
μ	military investment rate	.25
ψ	infrastructure investment rate	.08
φ	capital investment rate	.14
N	size of unskilled labor force	185.76

Industry-level Parameters

	Description	L_i	α_i
Sector 1	Non-Traded Foods	1.31	0.2090
Sector 2	Natural Resources	0.87	0.0730
Sector 3	Traded foods	6.94	0.1050
Sector 4	Processing	2.26	0.0610
Sector 5	Manufacturing	9.02	0.1220
Sector 6	Utilities	0.04	0.0450
Sector 7	Non-trades Services	4.14	0.2890
Sector 8	Traded Services	2.46	0.0960

Simulation Starting Values

$I = 0.12$, $M = 3.0$

	Description	N_i	K_i
Sector 1	Non-Traded Foods	8.99	0.37
Sector 2	Natural Resources	6.00	0.04
Sector 3	Traded foods	47.68	0.13
Sector 4	Processing	15.50	0.04
Sector 5	Manufacturing	61.98	0.04
Sector 6	Utilities	0.26	0.10
Sector 7	Non-trades Services	28.43	0.83
Sector 8	Traded Services	16.92	0.11

Table 2

Capital and Output Changes in Semi-Market Reform

Sectors	K_9	K_{10}	ΔK_i	$\%\Delta K$	Y_9	Y_{10}	ΔY_i	$\%\Delta Y$
1	0.225	0.185	-0.040	**-18.0%**	0.498	0.447	-0.051	**-10.3%**
2	0.022	0.064	0.042	**189.3%**	0.174	0.272	0.098	**56.5%**
3	0.080	0.092	0.012	**15.4%**	0.249	0.260	0.011	**4.3%**
4	0.026	0.074	0.048	**180.3%**	0.145	0.224	0.079	**54.3%**
5	0.022	0.241	0.219	**998.2%**	0.290	0.819	0.528	**182.0%**
6	0.064	0.055	-0.008	**-13.1%**	0.107	0.099	-0.009	**-7.9%**
7	0.508	0.160	-0.348	**-68.5%**	0.688	0.405	-0.283	**-41.2%**
8	0.066	0.090	0.024	**36.4%**	0.228	0.257	0.028	**12.3%**

Figure 1

Baseline sector capital stocks

(Ratios relative to *K* at time period 0)

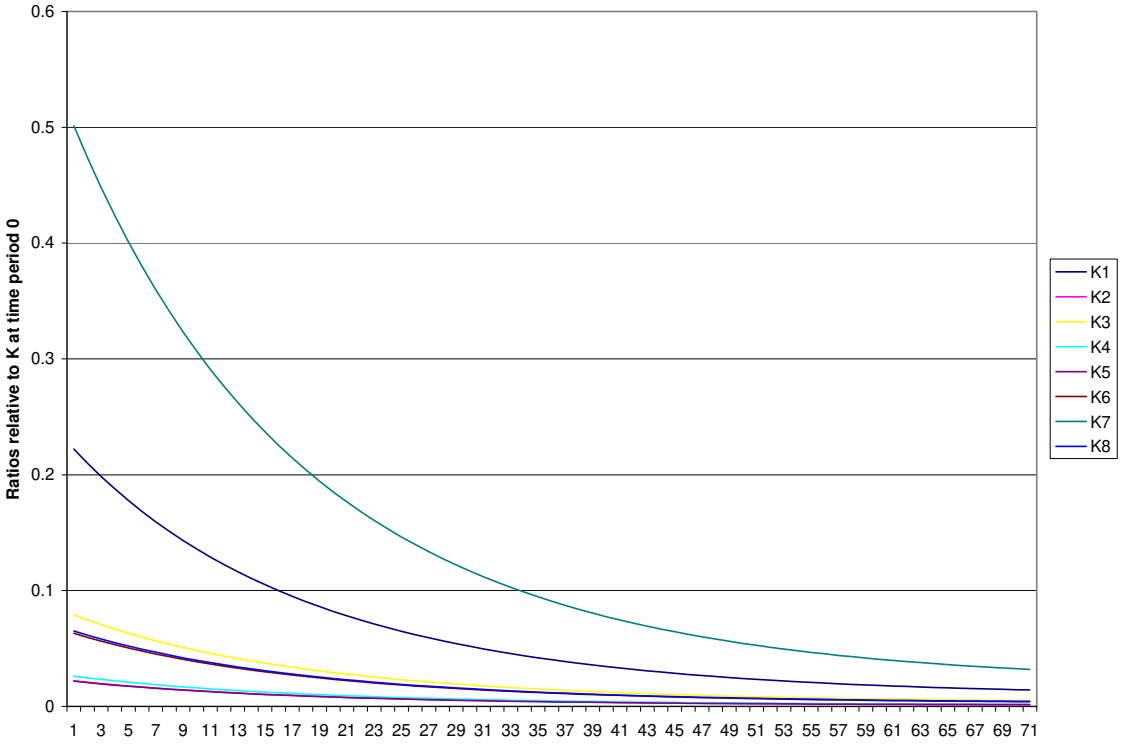


Figure 2

Baseline Sector Outputs

(Ratios relative to sum of Y_i's at time period 0)

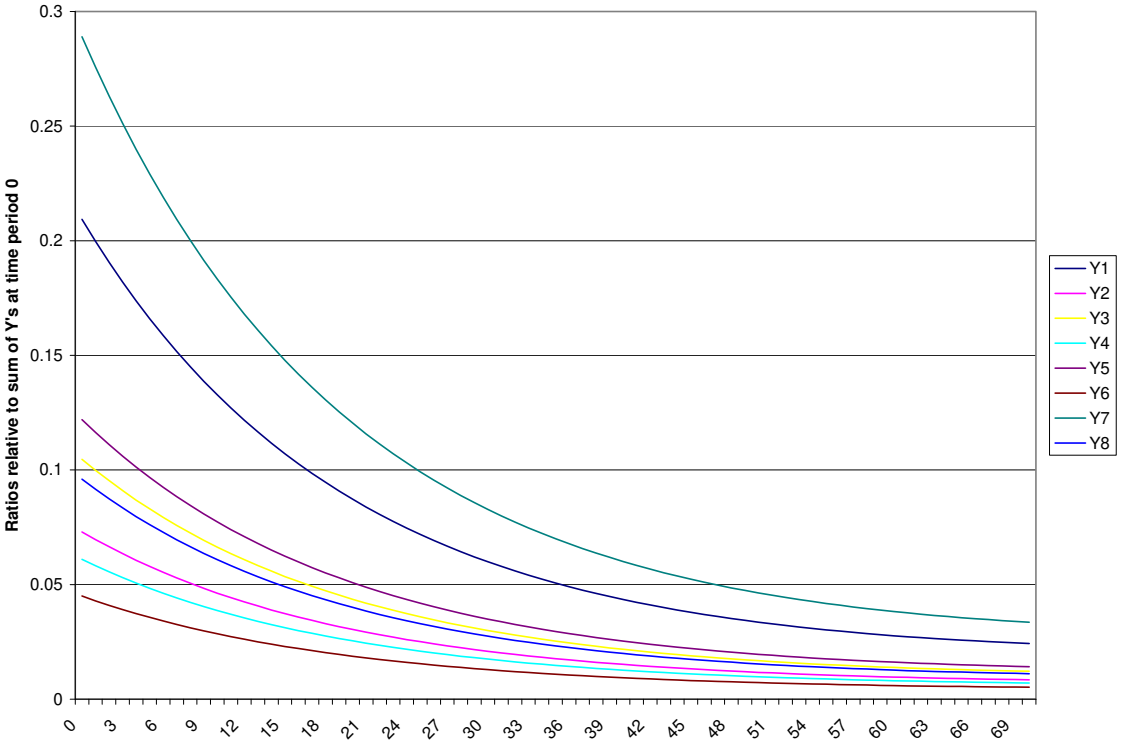


Figure 3

Baseline Dynamics of Key Economic Variables

(Ratios relative to values at time period 0)

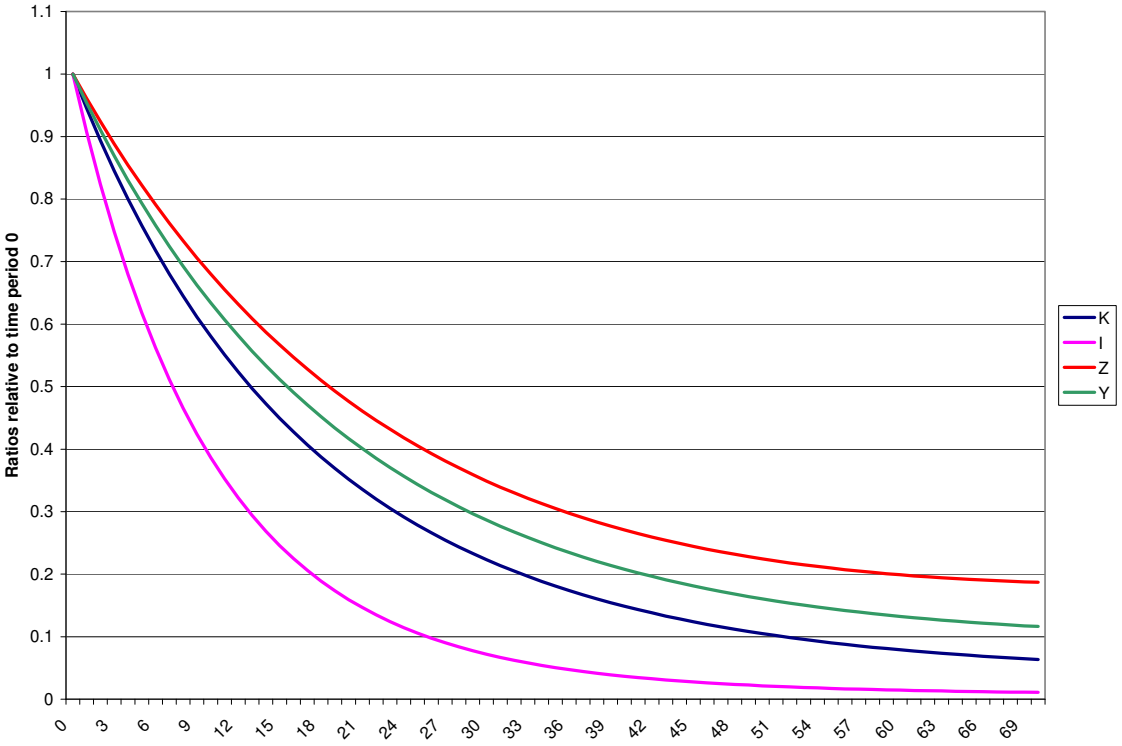


Figure 4

Key Economic Indicators in Semi-Market Reform

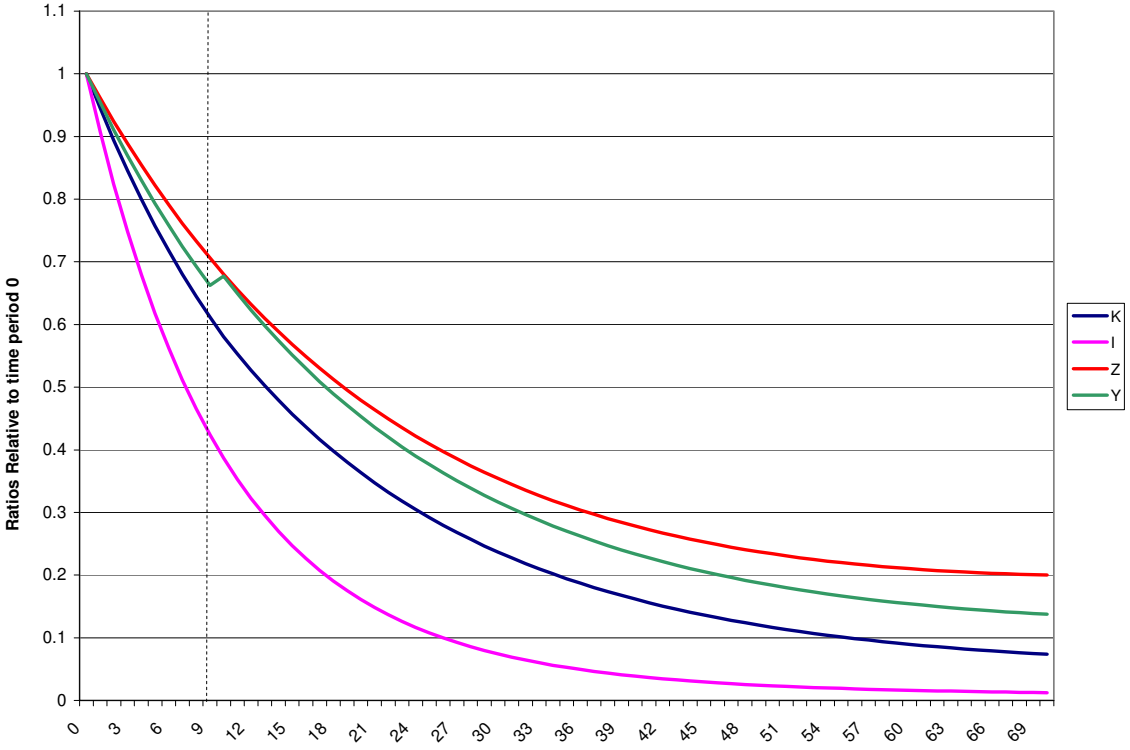


Figure 5

Aggregate Capital (K) Summary

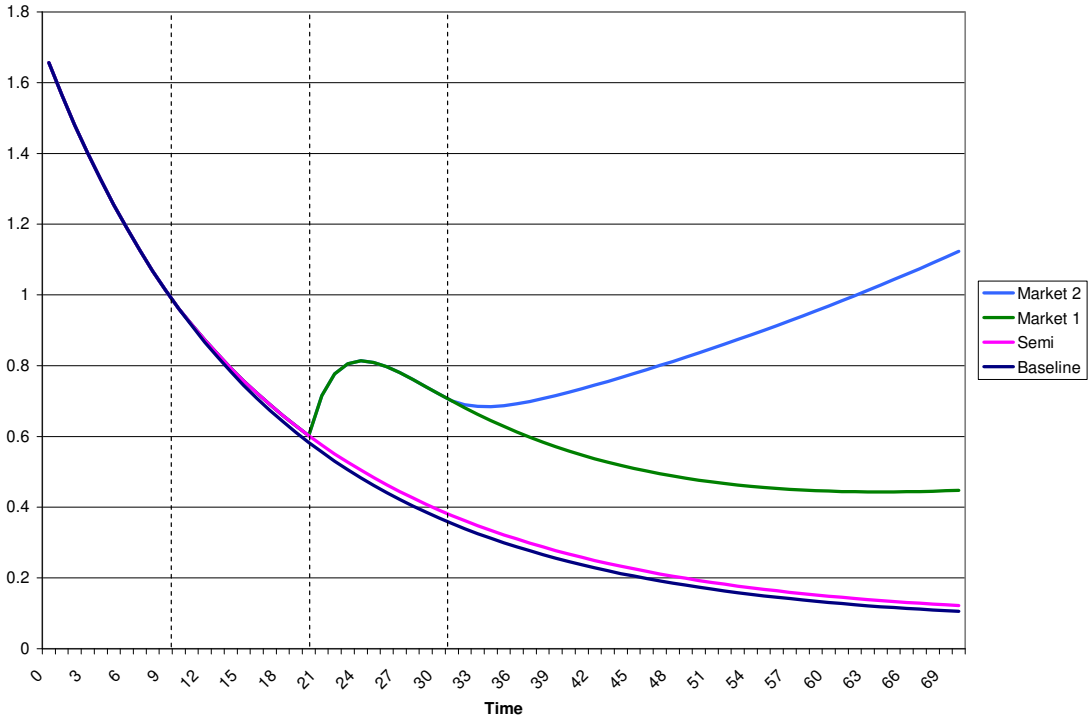


Figure 6

Infrastructure (I) Summary

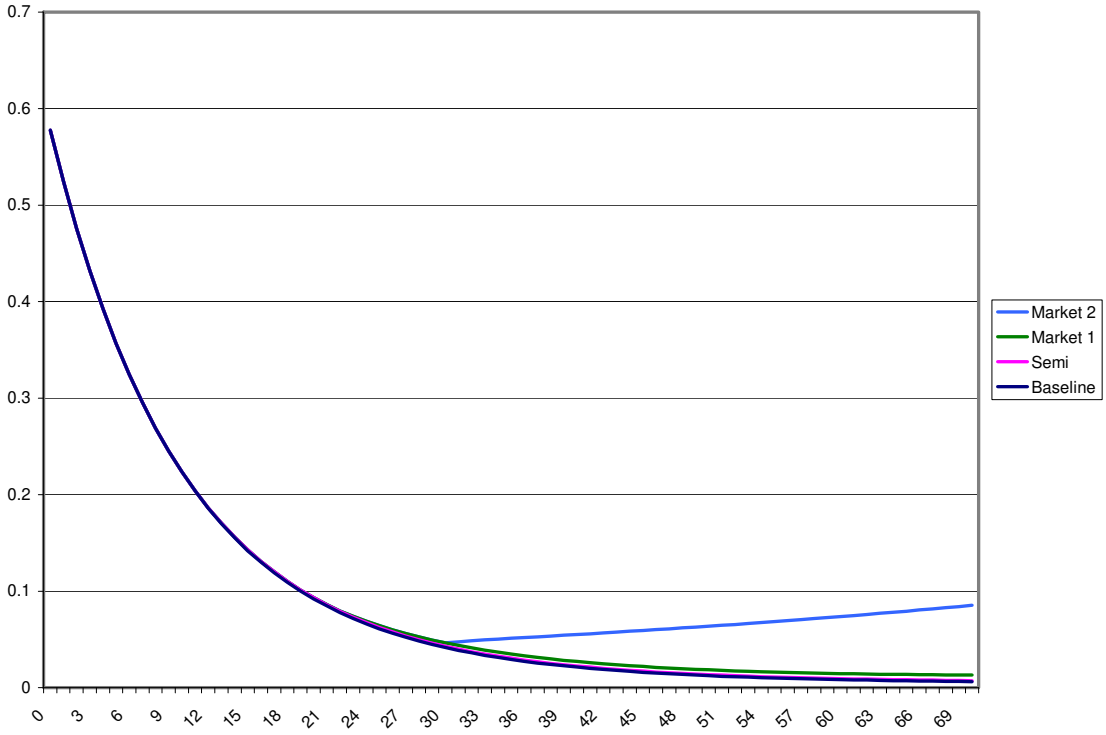


Figure 7

Technology growth (Z) Summary

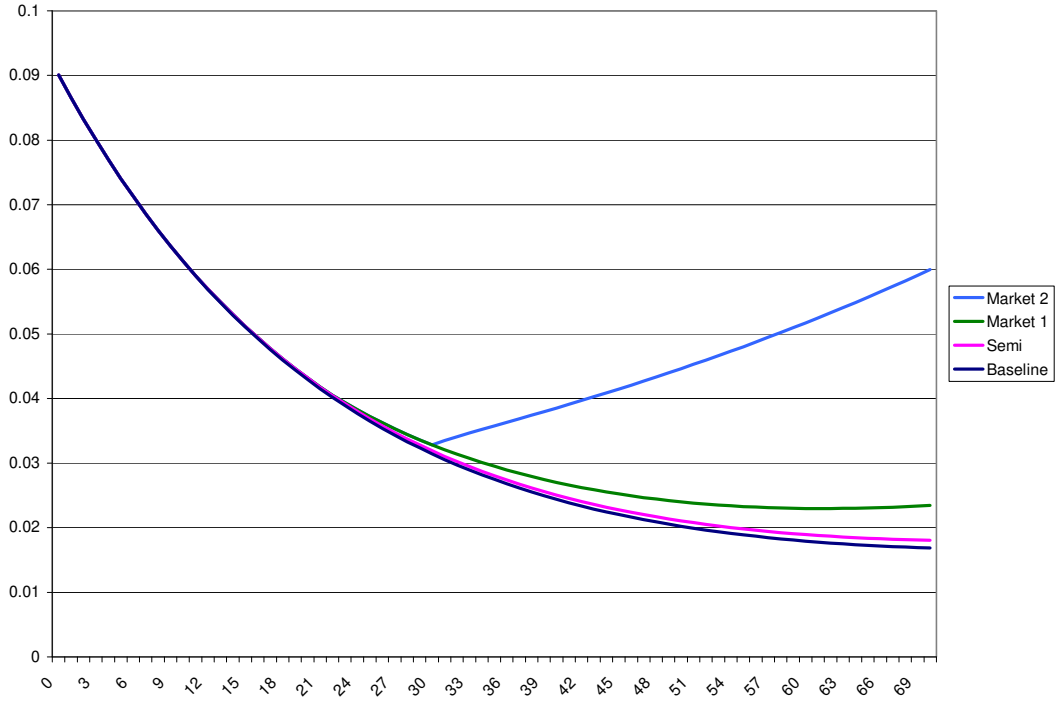


Figure 8

Aggregate Output (Y) Summary

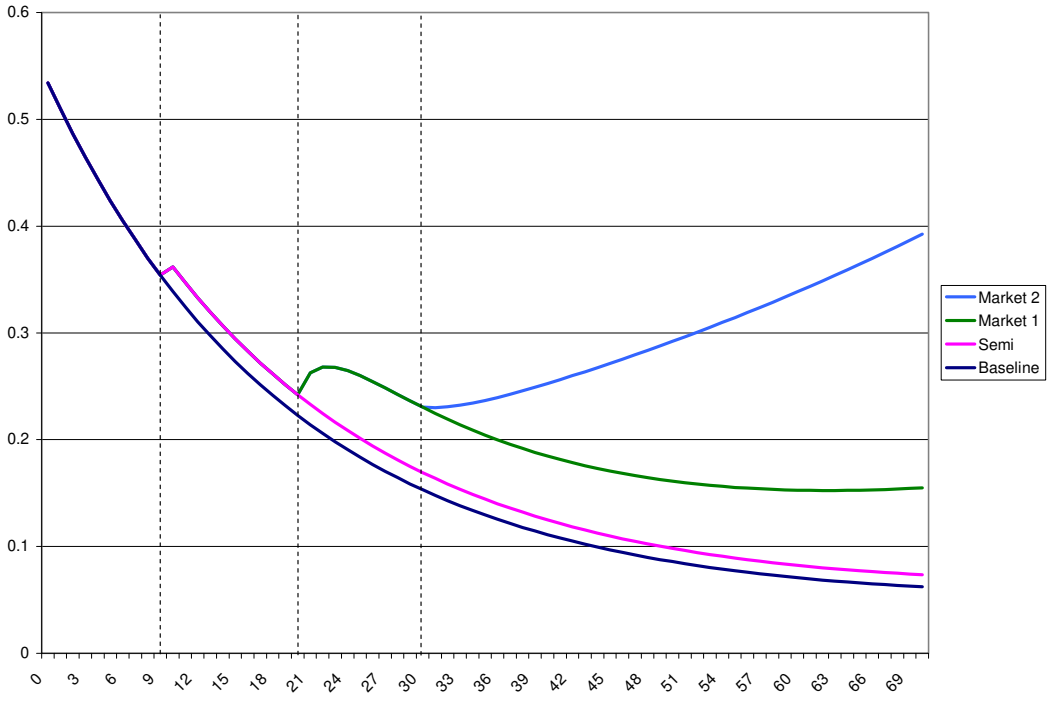
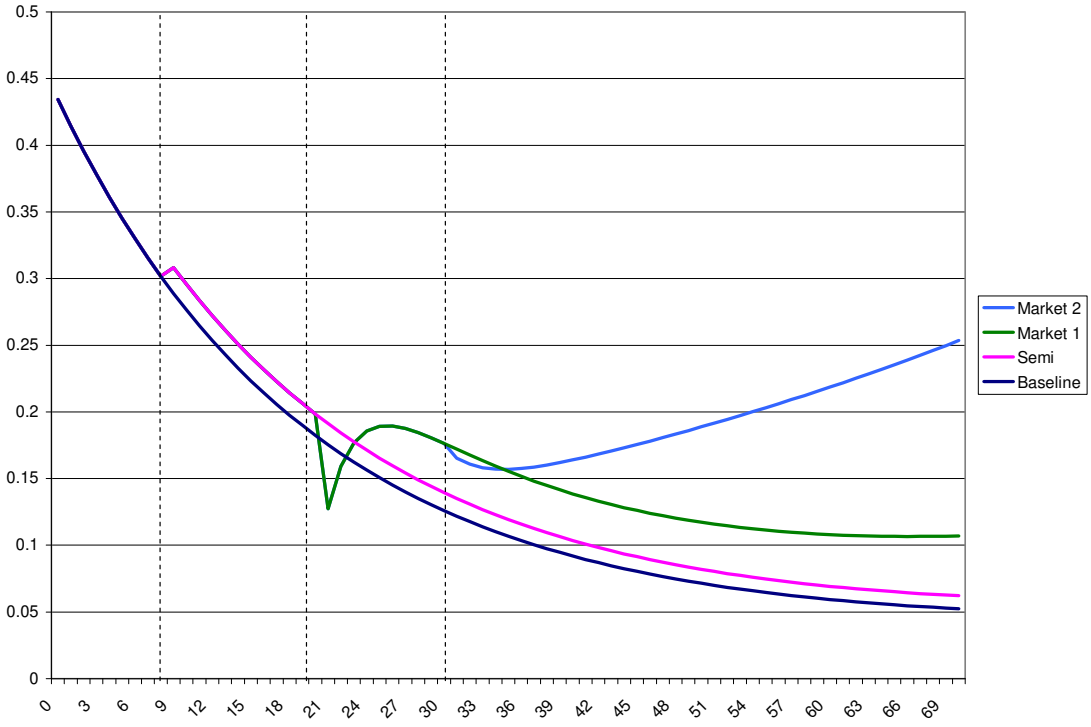


Figure 9

Consumption (C) Summary



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