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Deregulation as a Source of China's Economic Growth*

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Abstract

We develop a two-sector growth model of vertical structure in which the upstream sector features Cournot competition and produces intermediate goods that are used in the downstream sector for the production of final goods. In such a vertical structure, we show that deregulation and increased market competition in the upstream sector does not only increase its own productivity, but also has a substantial spill-over effect on the productivity of the downstream sector through affecting factor prices. We calibrate the model to the Chinese economy and use the calibrated model to quantitatively evaluate the extent to which deregulation in the upstream market in China from 1998 to 2007 accounts for the rapid economic growth over the same period. Our quantitative experiments suggest that deregulation in the upstream market in China from 1998 to 2007 can account for a significant fraction of China's economic growth during this period partly due to the significant spillover effect it has on the downstream sector. In addition, our model can also match several relevant observations in China during the same period including high and rising returns to capital, declining markups.

Keywords: Deregulation; Economic Growth; Vertical Structure

JEL Classifications: E20, O41

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1. Introduction

The Chinese economy has experienced continual deregulation and increasing market competition ever since the implementation of the "reform and open up" policy in 1978.[1] Meanwhile, China has enjoyed approximately 10% economic growth on average over the past several decades. On the other hand, economists have long argued that market competition promotes efficiency and prosperity.[2] Was deregulation and increasing market competition an important cause of China's remarkable economic growth? In this paper, we address this question and quantitatively evaluate the aggregate and growth effects of deregulation and increasing market competition in China in a dynamic general equilibrium model. We highlight the vertical structure of the Chinese economy. That is, the (highly-regulated) upstream sector produces intermediate goods which are in turn used in the production of final goods in the downstream sector. In this economy of vertical structure, deregulation in the upstream sector does not only affect its own productivity, but also generate a spill-over effect on the downstream sector via affecting factor prices. An important goal of this paper is to quantitatively evaluate this spill-over effect and its implication for the aggregate economy.

We develop a two-sector neoclassical growth model of vertical structure. In it, the upstream produces intermediate goods, and the downstream sector produces final goods using intermediate goods (i.e. the outputs from the upstream sector). While the downstream sector features perfect competition, firms in the upstream sector engage in Cournot competition and charge a markup on intermediate goods. In such a model, we show that increasing competition (due to deregulation) in the upstream sector does not only increase the productivity of that sector, but also increases the productivity of the downstream sector by lowering the price of intermediate goods.

To assess the quantitative importance of the aforementioned mechanisms, we calibrate the model to the Chinese economy and use the calibrated model to quantify the aggregate impact of deregulation in the Chinese economy over the last few decades. Ever since the implementation of the "reform and open up" policy in 1978, China has

[1] See section 2.3 for a detailed description of deregulations in China in the past several decades.

[2] For example, see Alesina, et al (2005), Holmes and Schmitz (2010), and among others.

gradually deregulated its upstream sector and the level of competition in this sector has substantially increased. Meanwhile, it is well-known that the Chinese economy has grown rapidly over the same period. Was the deregulation (especially in the intermediate goods market) an important cause of China's growth? To what extent can it account for the rapid growth in China's TFP? We address these quantitative questions in a version of the model that is calibrated to match some key moments of the Chinese economy. Our quantitative analysis focuses on the period from 1998 to 2007. During this period, China experienced substantial reforms such as deregulations in certain upstream markets that will be discussed in details later and the privatization of large-scale enterprises, which led to increasing market competition in the Chinese economy. Our quantitative experiments show that the deregulation in the intermediate goods market in China since 1998 can account for approximately a quarter of China's growth. In addition, our model can also match several relevant observations in China during the same period including high and rising returns to capital, and declining markups.

This paper contributes to the macro-growth literature that studies the Chinese economy in dynamic general equilibrium models.[3] We differentiate our paper from the literature by introducing a model of vertical structure and emphasizing the spill-over effect from the upstream sector on the downstream sector. We find that capturing this spillover is quantitatively important for understanding the aggregate impact of deregulation and market competition.

This paper is closely related to a paper by Li, Liu, and Wang (2015), who study the role of "state capitalism" in the Chinese economy. They also consider a vertical structure of production and study how the government (and state-owned enterprises) by monopolizing the upstream sector can extract rents from the downstream sector mainly consisting of private enterprises. However, they abstract from any dynamic issues by studying a static model. This paper is also related to the literature that study the macro effects of monopolistic competition (such as Bils (1987), Rotemberg and Woodford (1991,1993), Jaimovich and Floetotto (2008), and among others). Most studies in this literature focus on the short-term business cycle implications of monopolistic competition. We instead

[3]See Song, Storesletten, Zilibotti (2011), Zhu(2012), Hsieh and Song (2015), Imrohoroglu and Zhao (2018, 2019), and among others.

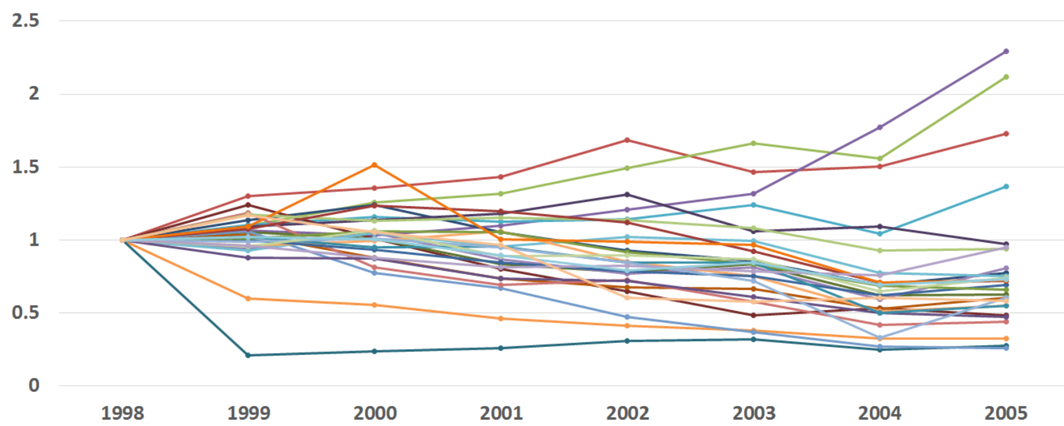

Figure 1: Deregulation in China: Changes in Sectoral Herfindahl-Hirschman Index

focus on the long-term growth effects of deregulation and market competition.

The remainder of the paper is organized as follows. Section 2 presents some important stylized facts institutional details that motivate this paper, and section 3 presents the benchmark model. The quantitative exercises and results are presented in Section 4. Section 5 is the concluding remarks.

2. Motivating Facts

2.1. Deregulation and Increasing Market Competition

We motivate our study by first examining changes in the degree of market competition in 28 industrial sectors in China since the year of 1998. In Figure 1, each line represents the sectoral Herfindahl-Hirschman Index (HHI) of a specific two-digit sector, with the HHI of 1998 being normalized to 1 for all sectors.[4] Out of 28 sectors, only 4 sectors have a HHI that is greater than 1 in 2005, which means that other 24 sectors (86.7% of the total) in the Chinese economy have experienced an increase in the degree of market competition since 1998. Note that the 4 sectors with higher HHI in 2005 are food processing, beverage manufacturing, textile, and tobacco, which are often considered as down stream sectors.

[4]Herfindahl-Hirschman Index is a commonly used measure for the amount of competition among firms. Please refer to Rhoades (1993) for a detailed explanation of the index.

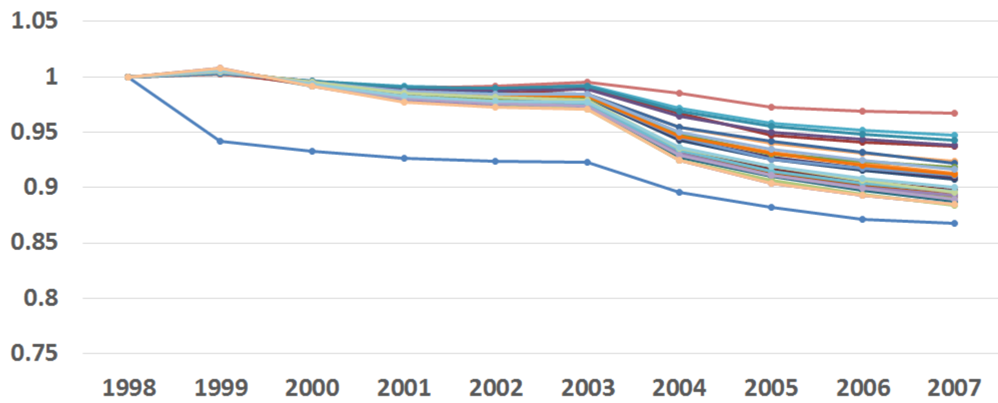

Figure 2: Deregulation in China: Changes in Sectoral Average Markups

The increasing market competition in China can also be confirmed by examining the changes of sectoral average markups for the period between 1998 and 2007. Figure 2 plots the average markup of each sector for the period between 1998 and 2007, where each line represents a specific two-digit sector. As the figure clearly shows, all 28 sectors have experienced significant declines in average markups during the aforementioned period, which is also evidence of higher market competition in the Chinese Economy.

The findings reported in Figures 1 and 2 suggest that the degree of market competition in China's industrial sectors has substantially increased between 1998 and 2007. In the rest of the section, we examine the potential causes of this phenomenon.

2.2. SOE's Shares in the Upstream and Downstream Sectors

Coincided with the increasing market competition is the substantial decline in the share of State-Owned Enterprises (SOE). As Table 1 shows, while both upstream and downstream sectors have witnessed similar large declines in SOE's share, the upstream sectors in China experienced a larger increase in the degree of market competition than the downstream sectors. As shown in the same table, while the HHI in the downstream sectors declined by 24% from 1998 to 2007, this same number was 34% for the upstream sector.

Another interesting and important observation is that SOEs in the upstream sector on average have substantially lower productivity than non-SOEs, whereas such differ-

Table 1: Share of SOE and Degree of Competition (weighted by revenue)

	State Share$_{1998}$	State Share$_{2007}$	$\frac{HHI_{2007}}{HHI_{1998}}$
Downstream	32.0%	2.0%	76.2%
Upstream	25.5%	1.8%	66.4%

ences in productivity are much smaller or do not exist in the downstream sector. To see this, we first compute TFPs at the firm level, and then normalize each firm's TFP to its respective sector's median TFP. Doing so allows us to consistently compare the productivity differences between SOEs and non-SOEs across different sectors. The results are summarized in Table 2. For instance, in 1998 the SOE's TFP was 31% lower than the Non-SOE's TFP in the upstream sector while the TFPs of the SOEs and Non-SOEs are much closer to each other in the downstream sector. Similar patterns of TFPs are also observed in other years during 1998-2007. This observation suggests that deregulation in the upstream sectors is more relevant for productivity gains and thus growth than that in the downstream sectors. In this paper, we focus on deregulation and changes in the degree of market competition in the upstream sectors.

The findings from Table 2 highlight the important differences between the upstream and downstream sectors in China.[5]

2.3. Notable Events Leading to Deregulation

Given the facts outlined in the previous sections, one might ask whether we can point to specific events or policies that were directly responsible for the deregulations in China. Although we do not believe that a single policy or event had led to all the deregulations we have outlined previously, we argue that a number of policies can be viewed as sources of deregulation. In this section, we give a brief discussion of these events or policies.

First, between 1995 and 2002, the Chinese government had attempted to reform the massive SOE sector by instituting a policy known as "Guan Ting Bing Zhuan". Quite

[5] Such differences are also emphasized in Li, Liu, and Wang (2015).

Table 2: % Difference of SOE's TFP and Non-SOE's TFP

Year	Downstream	Upstream	All Industry
1998	0.20%	-31.48%	-10.68%
1999	-0.39%	-30.73%	-10.69%
2000	-0.90%	-33.15%	-10.83%
2001	-1.72%	-32.00%	-11.89%
2002	-1.88%	-31.87%	-10.97%
2003	-3.02%	-36.60%	-13.47%
2004	-1.29%	-23.16%	-9.40%
2005	-2.83%	-18.64%	-9.63%
2006	-4.14%	-24.83%	-10.01%
2007	-7.80%	-36.48%	-18.69%

Note: these numbers are referring to the TFP difference between SOE and Non-SOE as a percentage of Non-SOE's TFP.

literally, it means that the government asked a large number of SOEs to shut down ("Guan"), pause production ("Ting"), merge with other SOEs ("Bing"), or change production ("Zhuan"). As a result of this policy, large number of SOEs had disappeared and large number of workers had been laid off. Many believe that this reform represented a pivotal moment for SOEs' development in China.

Closely related to the "Guan Ting Bing Zhuan" reform, the Chinese government in 1997 proposed a strategy called "Zhua Da Fang Xiao", which is widely known as "grabbing the large ones and letting go the small ones". Essentially, the goal of this strategy is to correct the fact that there were too many SOEs in too many industries, which created two main problems. First, a large number of SOEs means most SOEs were small with inefficient scale of production. Second, the presence of SOEs in almost all industries reduced the level of specialization. While SOEs could play a vital role in certain industries (for example, industries deemed "strategic"), there was no doubt that non-SOEs were more competitive in many other industries (for example, manufacturing sectors such as textile or electronics). As a response to these two problems, the Chinese government had tried to make small SOEs to either merge with other small SOEs to take advantage of scale economies or to exit.

Perhaps more on the idealogy side and less on the policy side, the National Congress of China had made an important amendment to the constitution, clearly stating that the non-public sector is an important component of the socialist market economy. Although there were no immediate policies following the amendment, this event was significant to the development of China's market economy as it provided the necessary foundation for the proliferation of the non-SOEs in China's many industries.

As a milestone of China's "reform and open up" policy, in 2001 China formally became a member of the World Trade Organization (WTO). In order to join the WTO, China had accepted a large number of conditions and promised to open its markets and reduce tariffs. It is difficult to overstate the importance of the impact of China's entry to WTO. While our paper does not specifically model this event, our results do partly capture the profound impact of China's entry into WTO on China's regulatory policies and the degree of market competition in the Chinese economy.

To further develop the capital market, the Chinese government in 2004 announced the so called "Nine National Policies" with regard to the capital market. According to this announcement, such policy has three main purposes. First, it tends to further develop the capital market so that resources can more efficiently allocated between sectors. Second, it also aims at helping the restructuring of SOEs and to accelerate the development of the non-public sector. Third, the government hopes that this policy can increase the share of direct financing in China's capital market.

Overall, we believe that these aforementioned events and policies together have contributed to the substantial amount of deregulation and the increase in market competition in China. A main goal of this paper is to formally model such changes, and quantitatively evaluate their impact on the aggregate economy through the lenses of quantitative macroeconomic models.

3. Model

3.1. Household

We consider a model inhabited with an infinitely-lived representative individual. Time is discrete and denoted by $t \in \{0, 1, ..., \infty\}$. We assume that the individual is endowed with one unit of labor in each period and supply it inelastically. She makes decisions of consumption and saving to maximize her lifetime discounted utility which are specified as,

$$\sum_{t=0}^{\infty} \beta^t u(c_t)$$

where β is the time discount factor, and the utility function is assumed to take the CRRA form, that is, $u(c_t) = \frac{c_t^{1-\sigma}}{1-\sigma}$.

In each period t, the individual faces the following budget constraint:

$$c_t + a_{t+1} = w_t + (1 + r_t)a_t + N\pi_{mt},$$

where c_t denotes the current consumption, a_{t+1} is the assets saved for the next period, and $N\pi_{mt}$ is the upstream firms' profits which will be specified later. Here w_t and r_t are representing the wage rate and the interest rate respectively.

Thus, the individual solves the following optimization problem:

$$\max_{\{c_t, k_{t+1}\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t \frac{c_t^{1-\sigma}}{1-\sigma}$$

subject to the budget constraints specified before.

3.2. Production

The production side of the model features a vertical structure. That is, there are two sectors, the upstream and downstream sectors, with the upstream sector producing intermediate goods which in turn are used in the production of final goods in the downstream sector.

In the following, we describe in details each of the two sectors respectively.

Downstream Sector

The downstream sector is perfect competitive and features a representative firm. The downstream firm produces according to a Cobb-Douglas technology with capital, labor and intermediate goods as its inputs, and the outputs of this firm are final goods that can be used as either final consumption good or capital. Specifically, the representative firm solves the following profit-maximization problem:

$$\max_{K_{dt},L_{dt},M_t} \pi_{dt} = A_{dt}(K_{dt}^{\alpha}L_{dt}^{1-\alpha})^{\theta}M_t^{1-\theta} - (r_t+\delta)K_{dt} - w_tL_{dt} - P_{mt}M_t,$$

where K_d and L_d are the capital and labor used in the downstream sector. Here M is intermediate goods with P_m representing its price, and A_d is the TFP in the downstream sector.

The profit-maximizing behaviors of the firm imply that,

$$w_t = (1-\alpha)\theta A_{dt}(K_{dt}^{\alpha}L_{dt}^{1-\alpha})^{\theta-1}M_t^{1-\theta}(\frac{K_{dt}}{L_{dt}})^{\alpha}$$

$$r_t = \alpha\theta A_{dt}(K_{dt}^{\alpha}L_{dt}^{1-\alpha})^{\theta-1}M_t^{1-\theta}(\frac{K_{dt}}{L_{dt}})^{\alpha-1} - \delta$$

$$P_{mt} = (1-\theta)A_{dt}(K_{dt}^{\alpha}L_{dt}^{1-\alpha})^{\theta}M_t^{-\theta}$$

Upstream Sector

To capture the highly-regulated feature of China's upstream sector, we assume that the upstream sector in the model features Cournot competition.[6] Specifically, we assume that there exist N symmetric firms in the upstream sector. Each of these firms produces a homogenous intermediate good, which can be used in the production of final goods in the downstream sector.

Let q_t represent the output of an upstream firm at period t, which is produced according to $q_t = A_{mt}k_{mt}^{\alpha}l_{mt}^{1-\alpha}$, and let P_{mt} represent the price of intermediate good (or the output of the upstream sector) at period t. An upstream firm solves the following maxi-

[6]See Varian (2006) for a detailed introduction of Cournot competition.

mization problem:

$$\max_{q_t} \pi_{mt} = P_{mt} q_t - (r_t + \delta) k_{imt} - w_t l_{mt},$$

with $q_t = A_{mt} k_{mt}^{\alpha} l_{mt}^{1-\alpha}$.

It is important to note that the upstream firms engage in Cournot competition when making their production decisions. That is, at each period t, each upstream firm internalizes the fact that its choice of q_t will impact the price of intermediate good P_{mt} and will choose q_t that maximizes its profit π_{mt}. The upstream firms' optimal choices are determined in the equilibrium, which we will discuss further at the end of this section.

3.3. Equilibrium

An equilibrium consists of prices $\{w_t, r_t, P_{mt}\}_{t=0}^{\infty}$ and allocations for the representative household $\{c_t, a_{t+1}\}_{t=0}^{\infty}$, for N upstream firms $\{k_{mt}, l_{mt}\}_{t=0}^{\infty}$, and for the downstream firm $\{K_{dt}, L_{dt}, M_t\}_{t=0}^{\infty}$ such that:

(a) Given prices $\{w_t, r_t\}_{t=0}^{\infty}$ and dividends from the upstream firms $\{\pi_{mt}\}_{t=0}^{\infty}$, allocations $\{c_t, a_{t+1}\}_{t=0}^{\infty}$ solve the household's problem.

(b) Given prices $\{w_t, r_t, P_{mt}\}_{t=0}^{\infty}$, allocations $\{K_{dt}, L_{dt}, M_t\}_{t=0}^{\infty}$ solve the downstream firm's problem.

(c) Given prices $\{w_t, r_t\}_{t=0}^{\infty}$ and the number of upstream firms N, allocations $\{k_{m,t}, l_{m,t}\}_{t=0}^{\infty}$ solve individual upstream firms' problem.

(d) Markets clear:

Intermediate Goods Market:

$$N q_t = M_t;$$

Labor Market:

$$1 = L_{dt} + N l_{mt};$$

Capital Market:

$$a_t = K_{dt} + N k_{mt}.$$

3.4. Equilibrium Analysis

The detailed analysis of the upstream and downstream firms' optimization problems in the equilibrium can be found in the appendix. Their optimizing behaviors imply that in the equilibrium, there exists an optimal division of aggregate labor (as well as aggregate capital) between the upstream and downstream sector. The aggregate amount of labor employed in the upstream sector is given by

$$L_{mt} = \left(1 - \frac{1}{N}\right)(1-\theta)$$

where $L_{mt} = Nl_{mt}$, and $l_{mt} = \left(\frac{N-1}{N^2}\right)(1-\theta)$. Let Υ denote . It is easy to see that the share of aggregate labor allocated to the downstream sector is $1 - L_{mt}$.

Note that a key component of the production side is the Cournot competition among N symmetric firms in the upstream sector. Here we consider a few special cases of the Cournot competition to gain further understanding of the problem.

The Case of Perfect Competition

In the case of perfect competition in the upstream market, $N \to \infty$. In this case, $L_{mt} = 1 - \theta$. That is, in the case of perfect competition, the share of aggregate labor allocated to the upstream sector (or the intermediate goods sector) is equal to the income share of intermediate goods in the production of final goods.

The Case of Pure Upstream Monopolist

On the other hand, as the economy gets closer to the case of pure monopoly (that is, $N \to 1$), the upstream sector is able to extract all revenues from the downstream sector as rents, and the share of aggregate labor allocated to the upstream sector is getting close to zero (i.e. $L_{mt} \to 0$).

Table 3: Parameter values

Parameter	Description	Value
σ	Intertemporal substitution of consumption	2
α	Share of capital	0.5
$1-\theta$	**Share of intermediates in final production**	**0.7178**
δ	Depreciation	0.1
β	Time discount factor	0.95
A_{m0}	Upstream firm's TFP at $t=0$	1
A_{d0}	Downstream firm's TFP at $t=0$	1

The Degree of Competition in the Upstream Market

One common measure of the degree of competition in a given market is the Hirschman-Herfindahl Index. It is defined as

$$HHI = \sum_{i=1}^{n} s_i^2,$$

where s_i is firm i's output share of the industry. In the case of symmetric firms as in this model, s_i is simply equal to $1/N$ for all firms. Therefore, the HHI index implied in the model is simply given as follows,

$$HHI = \frac{1}{N}$$

.

4. Quantitative Analysis

In this section, we calibrate the model to the Chinese economy between 1998 and 2007, and use the calibrated version of the model to address the following quantitative question: to what extent can deregulation and increased market competition account for China's economic growth from 1998 to 2007?

4.1. Calibration

Our calibration strategy consists of two steps. In the first step, we predetermine the values of some standard parameters based on the existing literature. In the second step, we calibrate the rest of the parameters simultaneously to match a set of key moments of the Chinese economy from 1998 to 2007. We discuss the details of our calibration strategy in the following.

One period is assumed to be one year. The utility function is assumed to take the CRRA form: $u(c) = \frac{c^{1-\sigma}}{1-\sigma}$, where σ is set to 2.0. The subjective time discount factor β is set to 0.95. The capital depreciation rate δ is set to 10% and the capital share α is set to 0.5 based on the estimates in Song, Storesletten , and Zilibotti (2011), and Imrohoroglu and Zhao (2018). The TFPs A_{mt} and A_{dt} in 1998 are normalized to one.

Our main goal is to study the aggregate impact of deregulation on the Chinese economy from 1998 to 2007. Thus, we assume that the initial steady state of the benchmark model mimics the Chinese economy in 1998 with the value of θ, which is the value-added share of the downstream sector, chosen to match its data counterpart in 1998.

A key component of our calibration exercise is to obtain reasonable estimates of the level of competition in the upstream sector in 1998 as well as that in 2007. To do this, we choose the value of N in 1998, which measures the degree of competition and is the inverse of the HHI, so that the labor share of the upstream sector in the benchmark model matches the data, that is 0.4831 in 1998. The rationale behind this calibration strategy is that the upstream labor share is directly affected by the level of competition in that sector. As the level of competition increases, the optimal size of production and thus the employment share of the upstream sector will also increase in the model. We then calibrate the value of N in 2007 so that the implied steady- state change in the degree of competition is consistent with that observed in the data.

The key parameter values are summarized in Table 3.

Table 4: Comparisons of steady-state

year	HHI	N_{ss}	$L_{m,ss}$	k_{ss}	P_m	y_{ss}
1998	0.327	3.06	0.4831	0.4743	0.7316	0.3391
2007	0.1899	5.27	0.5815	0.8382	0.6542	0.4852
$\frac{\triangle_{2007-1998}}{1998}$	-42%	72%	20%	77%	-10.6%	43%

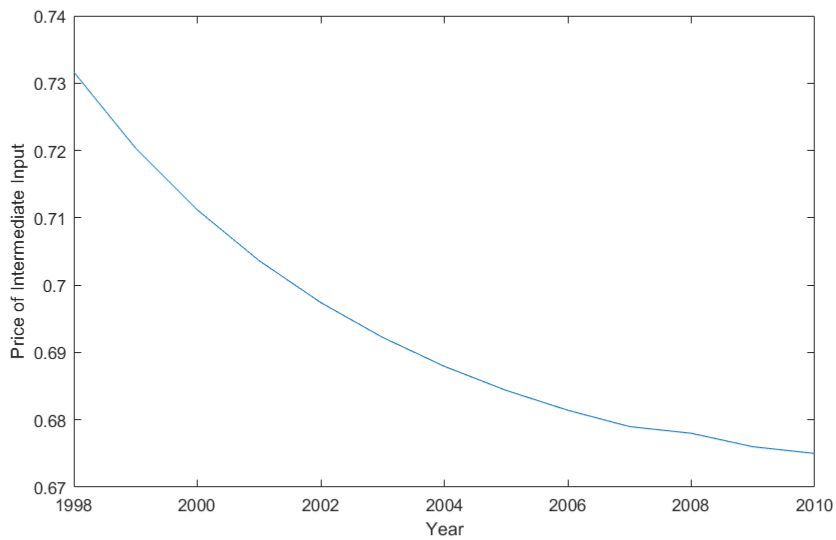

Figure 3: Price of Intermediate Goods along the Transition Path

4.2. Impact of Deregulation and Increased Market Competition

We first analyze the impact of deregulation and increased market competition in the upstream sector by comparing the following two steady states, the initial steady state with the 1998 level of competition and the new steady state with the 2007 level of competition. The key statistics of the two steady states are summarized in Table 4. As the table shows, as the level of competition increases from the 1998 level to 2007 level, the aggregate output of the economy increases by 43%, which is equivalent to 4.1% annual growth. We argue that the large effect of deregulation in the upstream sector on aggregate output is partly due to its spillover effect on the downstream sector via factor prices. This can be seen by comparing the prices of intermediate goods in the two steady states, which are also reported in Table 4. That is, the price of intermediate goods declined by approximately 11% from the 1998 steady state to the 2007 steady state.

Of course, the steady-state comparison can be somewhat misleading as China was clearly *not* at steady state in the past few decades. To gain a better understanding of the impact of deregulation on the Chinese economy, we also conduct the transition path analysis. Specifically, we simulate the transition path of the model economy from the 1998 steady state by assuming that the model experiences two types of changes over time: (1) the degree of market competition (determined by N) increases linearly from 1998 to 2007, and then remain constant after 2007, (2) TFP grows at a constant rate of g_A from 1998 to 2007, and then remains constant after that. We choose the value of g_A so that the implied output growth between 1998 and 2007 along the transition path is consistent with China's actual real GDP growth rate during this period, that is 9.49% annually. The resulting value of g_A is 4.04%. We assume individual and the firms have full foresight in the transition path analysis.[7]

To examine the importance of increased competition in the upstream sector along the transition path, we simply simulate a counterfactual transition path in which the model only experiences the TFP growth over time with the degree of competition being kept constant.

Comparing the output growth between the benchmark case and the counterfactual case highlights the effect of deregulation in the upstream sector on output growth along the transition path. The quantitative results are included in Table 5. As we can see, assuming no deregulation in the upstream sector, the annual growth rate would have decreased from 9.49% to 7.08%, which is approximately 25% of the actual real GDP growth rate in China during this period. This quantitative result suggests that the deregulation and increased competition in the upstream sector can account for about a quarter of China's growth between 1998 and 2007.

We argue that an important reason for the significant role of deregulation in shaping China's economic growth is that deregulation in the upstream sector can generate a spill-over effect on the downstream sector via changing factor prices. As shown in Fig-

[7]This assumption has been commonly made and justified in the literature including Chen, Imrohoroglu, and Imrohoroglu (2006), and Imrohoroglu and Zhao (2018), and among others.

Table 5: Output/Real GDP along the Transition Paths

year	Data	Benchmark	Counterfactual: no deregulation
1998	..	0.3391	0.3391
2007	..	0.7664	0.6273
Annualized growth: 1998-2007	9.49%	9.49%	7.08%

ure 3, the price of intermediate goods declined substantially along the transition path, from 0.73 to 0.68, approximately a 7% drop. It is worth noting that the magnitude of the drop in intermediate goods price generated in our model is consistent with the drops in average markups we documented in China during the same period (see Figure 2). In our model, this change in intermediate goods price is the result of the upstream sector deregulation, which in turn boosts the production of final goods in the downstream sector.

4.3. China's High Returns to Capital

Another relevant and important observation during this period is China's high returns to capital, which often at the heart of many macroeconomic issues in China. As documented in Song et al. (2011), China's return to capital was high and experienced an increase during this transition period of China's economy. They argue that financial frictions facing the Chinese firms (especially private firms) were an important reason for the high and rising returns to capital in China. Our theory provides a complementary explanation for this phenomenon. That is, the increased competition in the upstream sector can sustain a period of high return to capital despite the increase in aggregate capital stock.

To see this, we plot the returns to capital along the transition path in the benchmark case in Figure 4. As can be seen, the return to capital was high and went through a substantial rise during the period from 1998 to 2007, and then declined afterwards.

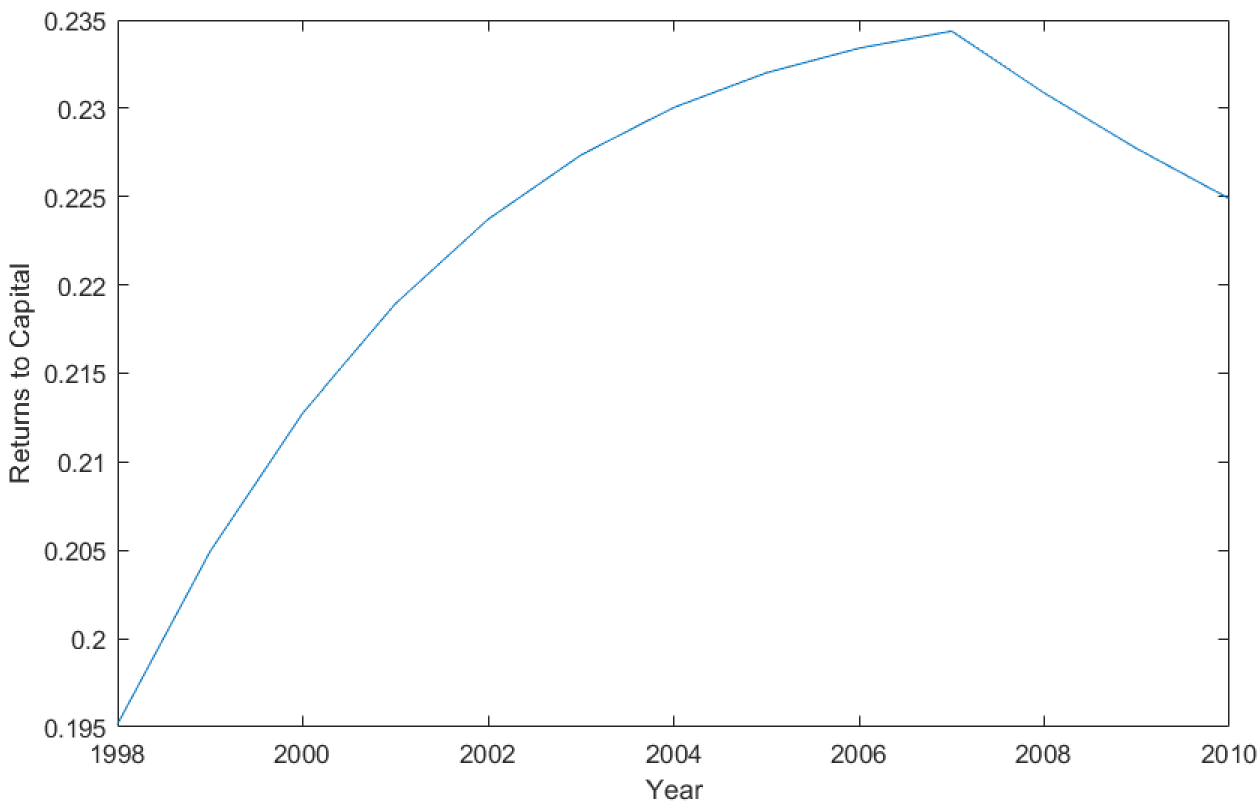

Figure 4: Returns to capital along the Transition Path

5. Conclusion

In this paper, we first document a substantial increase in the degree of market competition in China between 1998 and 2007, especially in the upstream sector. We argue that this was a result of a series of deregulation policies/events occurred during this period. We then study the role of deregulation and increased market competition in understanding China's economic growth via the lenses of a quantitative two-sector growth model of vertical structure. Our quantitative results suggest that deregulation and increased market competition can account for approximately a quarter of China's economic growth during 1998-2007. This result is partly due to the vertical structure of the Chinese economy and that deregulation in the upstream sector has a significant spillover effect on the downstream sector through changing facto prices. In addition, our model can also match several relevant observations in China during the same period including high and rising returns to capital, declining markups.

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6. Appendix (not for publication)

6.1. Upstream Firm's Problem

First we look at firm i's choice of k_{it} and l_{it}, given it wishes to produce q_{it}:

$$\min_{k_{it},l_{it}} C_{q_{it}} = r_t k_{it} + w_{it} l_{it}$$

such that $q_{it} = A_{mt} k_{it}^{\alpha} l_{it}^{1-\alpha}$.

From first-order conditions, we have:

$$\begin{aligned} r_t &= \alpha A_{mt} \left(\frac{k_{it}}{l_{it}}\right)^{\alpha-1} \\ w_t &= (1-\alpha) A_{mt} \left(\frac{k_{it}}{l_{it}}\right)^{\alpha} \end{aligned}$$

Hence we have:

$$\frac{r_t}{w_t} = \left(\frac{\alpha}{1-\alpha}\right)\left(\frac{k_{it}}{l_{it}}\right)^{-1}$$

Therefore

$$k_{it} = \left(\frac{\alpha}{1-\alpha}\right)\left(\frac{w_t}{r_t}\right) l_{it}. \tag{1}$$

Plug Eq.(1) into the constraint $q_{it} = A_{mt} k_{it}^{\alpha} l_{it}^{1-\alpha}$, we have:

$$q_{it} = A_{mt} \left[\left(\frac{\alpha}{1-\alpha}\right)\left(\frac{w_t}{r_t}\right)\right]^{\alpha} l_{it}$$

Hence we know there exists a one-to-one relationship between q_{it} and l_{it}, k_{it}.

$$\begin{aligned} l_{it} &= \frac{q_{it}}{A_{mt}} \left[\left(\frac{\alpha}{1-\alpha}\right)\left(\frac{w_t}{r_t}\right)\right]^{-\alpha} \\ k_{it} &= \frac{q_{it}}{A_{mt}} \left[\left(\frac{\alpha}{1-\alpha}\right)\left(\frac{w_t}{r_t}\right)\right]^{1-\alpha} \end{aligned}$$

Also note that total costs of producing q_{it} units of goods is:

$$\begin{aligned} C_{q_{it}} &= r_t k_{it} + w_i l_{it} \\ &= r_t \frac{q_{it}}{A_{mt}} \left[\left(\frac{\alpha}{1-\alpha} \right) \left(\frac{w_t}{r_t} \right) \right]^{1-\alpha} + w_t \frac{q_{it}}{A_{mt}} \left[\left(\frac{\alpha}{1-\alpha} \right) \left(\frac{w_t}{r_t} \right) \right]^{-\alpha} \\ &= \left(\frac{q_{it}}{A_{mt}} \right) \left[\left(\frac{\alpha}{1-\alpha} \right) \left(\frac{w_t}{r_t} \right) \right]^{1-\alpha} \left[r_t + w_t \left(\frac{1-\alpha}{\alpha} \right) \left(\frac{r_t}{w_t} \right) \right] \\ &= \left(\frac{q_{it}}{A_{mt}} \right) \left[\left(\frac{\alpha}{1-\alpha} \right) \left(\frac{w_t}{r_t} \right) \right]^{1-\alpha} \left(\frac{r_t}{\alpha} \right) \\ &= \frac{q_{it} \alpha^{-\alpha} (1-\alpha)^{-(1-\alpha)} r_t^{\alpha} w_t^{1-\alpha}}{A_{mt}} \end{aligned} \tag{2}$$

From Eq.(2), we know that the cost of producing one unit of intermediate good is invariant to output level q_i. Hence we can define unit cost c_i as:

$$c_{it} = A_{mt}^{-1} \alpha^{-\alpha} (1-\alpha)^{-(1-\alpha)} r_t^{\alpha} w_t^{1-\alpha} \tag{3}$$

Going back to upstream firm i's problem. Suppose that the total output and total labor demanded of all firms except for firm i in the upstream sector are $Q_{-it} = \sum_{k=1,k\neq i}^{N} q_{kt}$ and $L_{-it} = \sum_{k=1,k\neq i}^{N} l_{kt}$, respectively. Hence $m_t = q_{it} + Q_{-it}$. Relating to Eq.(2), we have:

$$m_t = A_{mt} \left[\left(\frac{\alpha}{1-\alpha} \right) \left(\frac{w_t}{r_t} \right) \right]^{\alpha} l_{it} + Q_{-it}$$

Notice that downstream firm's labor $L_{dt} = 1 - L_{-it} - l_{it}$. Denote $\Omega_t = A_{mt} \left[\left(\frac{\alpha}{1-\alpha} \right) \left(\frac{w_t}{r_t} \right) \right]^{\alpha}$. Hence the price of upstream good can be written as:

$$\begin{aligned} P_{mt} &= \left[\frac{1-\theta}{\theta(1-\alpha)} \right] \frac{w_t L_{dt}}{m_t} \\ &= \left[\frac{1-\theta}{\theta(1-\alpha)} \right] \frac{w_t (1 - L_{-it} - l_{it})}{\Omega_t l_{it} + Q_{-it}} \end{aligned}$$

Therefore, upstream firm i's problem can be reformulated as: given w_t, r_t, Q_{-it}, L_{-it}, firm i chooses labor input l_{it} to solve the following problem:

$$\max_{l_{it}} \qquad \pi_{it} = P_{mt} q_{it} - c_{it} q_{it},$$

where $P_{mt} = \left[\frac{1-\theta}{\theta(1-\alpha)}\right] \frac{w_t(1-L_{-it}-l_{it})}{\Omega_t l_{it}+Q_{-it}}$ and $q_{it} = \Omega_t l_{it}$.

From first-order condition, we have:

$$\left[\frac{-w_t(1-L_{-it}-l_{it})}{(\Omega_t l_{it}+Q_{-it})^2}\Omega_t + \frac{-w_t}{\Omega_t l_{it}+Q_{-it}}\right]\left[\frac{1-\theta}{\theta(1-\alpha)}\right](\Omega_t l_{it}) + \left[\frac{1-\theta}{\theta(1-\alpha)}\right]\left[\frac{w_t(1-L_{-it}-l_{it})}{\Omega_t l_{it}+Q_{-it}}\right]\Omega_t = c_{it}\Omega_t$$

Further simplify, we have:

$$\begin{aligned}
\left[\frac{-w_t(1-L_{-it}-l_{it})}{(\Omega_t l_{it}+Q_{-it})^2}\Omega_t + \frac{-w_t}{\Omega_t l_{it}+Q_{-it}}\right]\left[\frac{1-\theta}{\theta(1-\alpha)}\right] l_{it} + \left[\frac{1-\theta}{\theta(1-\alpha)}\right]\left[\frac{w_t(1-L_{-it}-l_{it})}{\Omega_t l_{it}+Q_{-it}}\right] &= c_{it} \\
\left[\frac{-w_t(1-L_{-it}-l_{it})}{(\Omega_t l_{it}+Q_{-it})^2}\Omega_t + \frac{-w_t}{\Omega_t l_{it}+Q_{-it}}\right] l_{it} + \left[\frac{w_t(1-L_{-it}-l_{it})}{\Omega_t l_{it}+Q_{-it}}\right] - \left[\frac{\theta(1-\alpha)}{1-\theta}\right] c_{it} &= 0
\end{aligned} \tag{4}$$

Eq.(4) is the response function of upstream firm i. Since there exist N firms in the upstream sector, with a system of N equations, one can solve for l_{it} for all $i \in [1, N]$.

In the case of symmetric upstream firms and denote $l_t^* = l_{it} = l_{kt}, q_t^* = q_{it} = q_{kt}$, we know $Q_{-it} = (N-1)q_t^*$ and $L_{-it} = (N-1)l_t^*$. We also know

$$q_t^* = \Omega_t l_t^*$$

Therefore Eq.(4) becomes the following:

$$\begin{aligned}
\left[\frac{-w_t(1-Nl_t^*)}{(N\Omega_t l_t^*)^2}\Omega_t + \frac{-w_t}{N\Omega_t l_t^*}\right] l_t^* + \frac{w_t(1-Nl_t^*)}{N\Omega_t l_t^*} - \left[\frac{\theta(1-\alpha)}{1-\theta}\right] c_{it} &= 0 \\
\frac{-w_t(1-Nl_t^*)}{(N\Omega_t)^2 l_t^*}\Omega_t + \frac{-w_t}{N\Omega_t} + \frac{w_t(1-Nl_t^*)}{N\Omega_t l_t^*} - \left[\frac{\theta(1-\alpha)}{1-\theta}\right] c_{it} &= 0 \\
\frac{-w_t(1-Nl_t^*)}{(N\Omega_t)^2}\Omega_t + \frac{-w_t}{N\Omega_t} l_t^* + \frac{w_t(1-Nl_t^*)}{N\Omega_t} - \left[\frac{\theta(1-\alpha)}{1-\theta}\right] c_{it} l_t^* &= 0 \\
\frac{-w_t}{N^2\Omega_t} + \frac{w_t l_t^*}{N\Omega_t} + \frac{-w_t}{N\Omega_t} l_t^* + \frac{w_t}{N\Omega_t} - \frac{w_t l_t^*}{\Omega_t} - \left[\frac{\theta(1-\alpha)}{1-\theta}\right] c_{it} l_t^* &= 0 \\
\frac{w_t}{N\Omega_t} - \frac{w_t}{N^2\Omega_t} - \left\{\frac{w_t}{\Omega_t} + \left[\frac{\theta(1-\alpha)}{1-\theta}\right] c_{it}\right\} l_t^* &= 0
\end{aligned} \tag{5}$$

One can then solve for l^* from Eq.(5):

$$l_t^* = \frac{\frac{w_t}{N\Omega_t} - \frac{w_t}{N^2\Omega_t}}{\frac{w_t}{\Omega_t} + \left[\frac{\theta(1-\alpha)}{1-\theta}\right] c_{it}} = \frac{\frac{N-1}{N^2}}{1 + \left[\frac{\theta(1-\alpha)}{1-\theta}\right]\left(\frac{\Omega_t}{w_t}\right) c_{it}}$$

Note that

$$\begin{aligned}\left(\frac{\Omega_t}{w_t}\right) c_{it} &= \left(\frac{A_{mt}\left[\left(\frac{\alpha}{1-\alpha}\right)\left(\frac{w_t}{r_t}\right)\right]^{\alpha}}{w_t}\right)\frac{r_t^{\alpha} w_t^{1-\alpha}}{A_{mt}\alpha^{\alpha}(1-\alpha)^{(1-\alpha)}} \\ &= \frac{1}{1-\alpha}\end{aligned}$$

This means that the optimum choice of labor input of upstream firm i (in the case of symmetric firms) is

$$l_t^* = \frac{\left(\frac{N-1}{N^2}\right)}{1 + \frac{\theta}{1-\theta}} = \left(\frac{N-1}{N^2}\right)(1-\theta)$$

Since there are N firms in the upstream sector, we can infer the relative size of the upstream sector from L_{mt}:

$$\begin{aligned}L_{mt} &= N l_t^* \\ &= \left(\frac{N-1}{N}\right)(1-\theta) \\ &= \left(1 - \frac{1}{N}\right)(1-\theta)\end{aligned}$$

6.2. Downstream Firm's Problem

The first order conditions from this representative firm's profit maximization problem are:

$$A_{dt}\theta\alpha(K_{dt}^{\alpha}L_{dt}^{1-\alpha})^{\theta-1}K_{dt}^{\alpha-1}L_{dt}^{1-\alpha}m_t^{1-\theta} = r_t \tag{6}$$

$$A_{dt}\theta(1-\alpha)(K_{dt}^{\alpha}L_{dt}^{1-\alpha})^{\theta-1}K_{dt}^{\alpha}L_{dt}^{-\alpha}m_t^{1-\theta} = w_t \tag{7}$$

$$A_{dt}(1-\theta)(K_{dt}^{\alpha}L_{dt}^{1-\alpha})^{\theta}m_t^{-\theta} = P_{mt} \tag{8}$$

From Eq.(6) - Eq.(8), we can solve for downstream firm's optimal capital-labor ratio

$\frac{K_{dt}}{L_{dt}}$ and intermediate input-labor ratio $\frac{m_t}{L_t}$:

$$
\begin{aligned}
\frac{K_{dt}}{L_{dt}} &= \left(\frac{\alpha}{1-\alpha}\right)\left(\frac{w_t}{r_t}\right) \\
\frac{m_t}{L_{dt}} &= \left[\frac{1-\theta}{\theta(1-\alpha)}\right]\left(\frac{w_t}{P_{mt}}\right)
\end{aligned} \tag{9}
$$

6.3. Equilibrium Analysis

Note that from Eq.(1) and Eq.(9), we know that the capital-labor ratio is the same across the two sectors. Let Υ_k denote the share of capital in the downstream sector and Υ_l denote the share of labor in the downstream sector. We then know

$$
\frac{K_{dt}}{L_{dt}} = \frac{\Upsilon_k K_t}{\Upsilon_l} = \frac{K_{mt}}{L_{mt}} = \frac{(1-\Upsilon_k)K_t}{1-\Upsilon_l}
$$

Hence we know $\Upsilon_k = \Upsilon_l = \Upsilon$.

Plugging the production function of the upstream firms into the downstream's representative firm's production function, we have

$$
\begin{aligned}
Y_{dt} &= A_{dt}(K_{dt}^{\alpha}L_{dt}^{1-\alpha})^{\theta}m_t^{1-\theta} \\
&= A_{dt}\left[(\Upsilon_t K_t)^{\alpha}\Upsilon_t^{1-\alpha}\right]^{\theta}\left(A_{mt}[(1-\Upsilon_t)K_t]^{\alpha}(1-\Upsilon_t)^{1-\alpha}\right)^{1-\theta} \\
&= A_{dt}A_{mt}^{1-\theta}K_t^{\alpha}\Upsilon_t^{\theta}(1-\Upsilon)^{1-\theta}
\end{aligned}
$$

Given K_t, A_{dt}, and A_{mt}, we can formulate the following optimization problem:

$$
\max_{\Upsilon^*} \qquad Y_{dt} = A_{dt}A_{mt}^{1-\theta}K_t^{\alpha}\Upsilon_t^{\theta}(1-\Upsilon)^{1-\theta}
$$

First order condition gives us that

$$
\theta(\Upsilon^*)^{\theta-1}(1-\Upsilon^*)^{1-\theta} - (\Upsilon^*)^{\theta}(1-\theta)(1-\Upsilon^*)^{-\theta} = 0
$$

Hence we can solve for optimal division of input resources:

$$
\Upsilon^* = \theta
$$

In this case, the optimal labor input in the upstream and downstream sector are:

$$\begin{aligned} L^*_{mt} &= 1-\theta \\ L^*_{dt} &= \theta \end{aligned}$$

6.4. Computational Algorithm

Computing the Steady State

From the first-order conditions of the household problem, we have the standard Euler equation:

$$\frac{1}{\beta}\left(\frac{c_t}{c_{t+1}}\right)^{-\sigma} = 1 + r_{t+1}$$

For de-trending the model, define the following variables:

$$\tilde{k}_t = \frac{k_t}{A_{dt}^{\frac{1}{1-\alpha}} A_{mt}^{\frac{1-\theta}{1-\alpha}}};\tilde{c}_t = \frac{c_t}{A_{dt}^{\frac{1}{1-\alpha}} A_{mt}^{\frac{1-\theta}{1-\alpha}}};\tilde{y}_t = \frac{y_t}{A_{dt}^{\frac{1}{1-\alpha}} A_{mt}^{\frac{1-\theta}{1-\alpha}}}.$$

We then have:

$$\frac{1}{\beta}\left(\frac{\tilde{c}_t A_{dt}^{\frac{1}{1-\alpha}} A_{mt}^{\frac{1-\theta}{1-\alpha}}}{\tilde{c}_{t+1} A_{dt+1}^{\frac{1}{1-\alpha}} A_{mt+1}^{\frac{1-\theta}{1-\alpha}}}\right)^{-\sigma} = 1 + r_{t+1}$$

At steady state, $\tilde{c}_t = \tilde{c}_{t+1} = c_{ss}$. Let the upstream TFP grow at rate g_{Am} and the downstream TFP grow at g_{Ad} at steady state (assuming no steady state population growth):

$$r_{ss} = \frac{1}{\beta}\left(\frac{1}{1+g_{Ad}}\right)^{\frac{-\sigma}{1-\alpha}}\left(\frac{1}{1+g_{Am}}\right)^{\frac{-\sigma(1-\theta)}{1-\alpha}} + \delta - 1$$

Given the number of upstream firms N and the evolution of TFP $\{A_{mt}, A_{dt}\}_{t=0}^{+\infty}$, the computation of the steady state is straight-forward.

1. First note that the division of labor between the upstream and the downstream L_m^{ss}

can be directly derived from Eq.(26) and the ensuing L_d^{ss}:

$$\begin{aligned} 1-\Upsilon_t &= L_m^{ss} = (1-\frac{1}{N})(1-\theta) \\ \Upsilon_t &= L_d^{ss} = 1 - L_m^{ss} \end{aligned}$$

2. The marginal return of capital of the downstream firm is:

$$\begin{aligned} \alpha\theta \frac{A_{dt}A_{mt}^{1-\theta}K_t^{\alpha}\Upsilon_t^{\theta}(1-\Upsilon_t)^{1-\theta}}{\Upsilon_t K_t} - \delta &= r_{ss} \\ \alpha\theta A_{dt}A_{mt}^{1-\theta}\left(\frac{1-\Upsilon_t}{\Upsilon_t}\right)^{1-\theta} K_t^{\alpha-1} - \delta &= r_{ss} \end{aligned}$$

Therefore, total capital stock at the balanced growth path K_t is

$$K_t = \left[\frac{r_{ss}+\delta}{\alpha\theta A_{dt}A_{mt}^{1-\theta}\left(\frac{1-\Upsilon_t}{\Upsilon_t}\right)^{1-\theta}}\right]^{\frac{1}{\alpha-1}}$$

3. Total output of the downstream sector can be calculated as:

$$Y_{dt} = A_{dt}A_{mt}^{1-\theta}K_t^{\alpha}\Upsilon_t^{\theta}(1-\Upsilon_t)^{1-\theta}$$

4. The invariant components of total capital stock $\tilde{k}$ and total final output hence are:

$$\begin{aligned} \tilde{k} &= \frac{K_{mt}+K_{dt}}{A_{dt}^{\frac{1}{1-\alpha}}A_{mt}^{\frac{1-\theta}{1-\alpha}}} \\ \tilde{y} &= \frac{Y_{dt}}{A_{dt}^{\frac{1}{1-\alpha}}A_{mt}^{\frac{1-\theta}{1-\alpha}}} \end{aligned}$$

5. Lastly, restating the final goods market clearing condition we have:

$$\begin{aligned} c_t &= Y_{dt} - k_{t+1} + (1-\delta)k_t \\ \tilde{c}A_{dt}^{\frac{1}{1-\alpha}}A_{mt}^{\frac{1-\theta}{1-\alpha}} &= \tilde{y}A_{dt}^{\frac{1}{1-\alpha}}A_{mt}^{\frac{1-\theta}{1-\alpha}} - \tilde{k}A_{dt+1}^{\frac{1}{1-\alpha}}A_{mt+1}^{\frac{1-\theta}{1-\alpha}} + (1-\delta)\tilde{k}A_{dt}^{\frac{1}{1-\alpha}}A_{mt}^{\frac{1-\theta}{1-\alpha}} \\ \tilde{c} &= \tilde{y} + \left[1-\delta-(1+g_{Ad})^{\frac{1}{1-\alpha}}(1+g_{Am})^{\frac{1-\theta}{1-\alpha}}\right]\tilde{k} \end{aligned}$$

Computing the Transition Path

We employ the shooting algorithm to compute the transition path. Specifically, we assume that it takes 50 years for the economy to transition from the initial state with aggregate capital K_0, and TFP levels $\{A_{d0}, A_{m0}\}$ to a new steady state K_{50} with TFP A_{d50} and A_{m50}.

The computation procedure for the transition path of this economy is:

1. Given K_0, guess a c_0.

2. Note that the sequence of number of upstream firms $\{N_t\}_{t=0}^{50}$ is given. Hence the sequence of division of labor between upstream and downstream sectors $\{L_{mt}\}_{t=0}^{50}$ can be directly calculated using Eq.(26).

$$1 - \Upsilon_t = L_{mt} = \left(1 - \frac{1}{N_t}\right)(1-\theta)$$

3. For each $t \in [0, 50]$:

(a). Output of final good Y_{dt} can be calculated as

$$Y_{dt} = A_{dt} A_{mt}^{1-\theta} K_t^{\alpha} \Upsilon_t^{\theta} (1-\Upsilon_t)^{1-\theta}$$

(b). Real interest rate r_t can be calculated as:

$$r_t = \frac{\alpha\theta Y_{dt}}{\Upsilon_t K_t} - \delta$$

(c). With K_t, c_t, and Y_{dt}, one can calculate K_{t+1} from the final goods market clearing condition. With c_t and r_t, one can calculate c_{t+1} from the Euler Equation.

$$\begin{aligned} K_{t+1} &= Y_{dt} + (1-\delta)K_t - c_t \\ c_{t+1} &= \left[(1+r_t)\beta\right]^{\frac{1}{\sigma}} c_t \end{aligned}$$

4. Repeat Step 3 until we find K_{50}. Check if $K_{50} = K_{50}^*$. If equal, we stop. If not equal, we go back to Step 1 and guess a different c_0.