A Model of China's Economic Vertical Structure*

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Abstract

We document a prominent yet underappreciated feature of the post-2000 Chinese economy: a vertical structure in which key upstream industries are dominated by state-owned enterprises (SOEs), while downstream industries are largely open to private competition. We develop a general-equilibrium model to analyze how this vertical structure—interacting with industrialization, globalization, and labor abundance—has shaped the Chinese economy. The framework offers new insights into SOE profitability, structural change, resource misallocation, and economic reform. First, upstream SOEs become more profitable as downstream private firms raise their productivity and face greater external demand during industrialization and globalization, helping explain the unprecedented prosperity of SOEs between 2002 and 2007. Second, reducing upstream market power would facilitate labor reallocation from agriculture to non-agricultural sectors, raising GDP and aggregate welfare. Third, preferential credit subsidies to SOEs can improve welfare by alleviating upstream under-supply; consequently, removing these subsidies without dismantling SOE monopoly power could reduce welfare. Quantitative analyses using firm-level data support the theoretical findings. We further show that this vertical structure can arise endogenously as an equilibrium outcome.

Key Words: Vertical Structure; Structural Change; Chinese Economy; State-Owned Enterprises; Globalization

JEL Classifications: E02, F63, O10, O43, P31

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1 Introduction

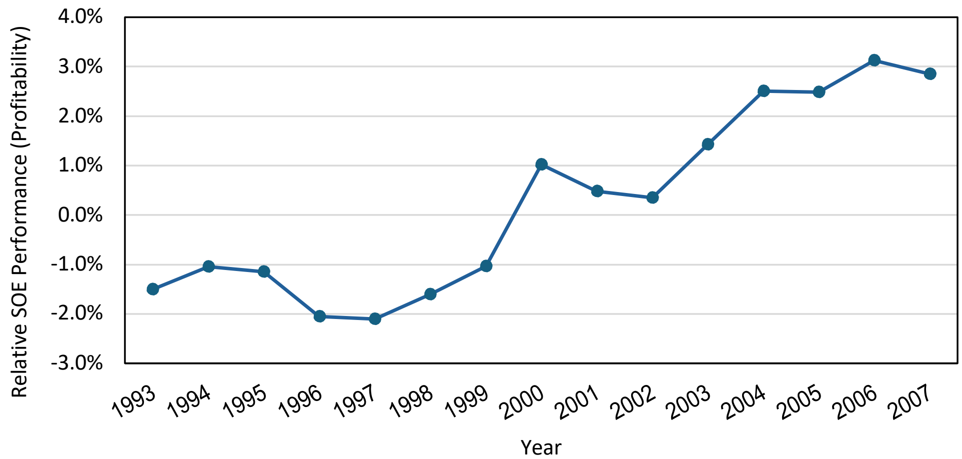
As a hallmark feature of the Chinese economy, state-owned enterprises (SOEs) have continuously received enormous attention in academia and policy circles (e.g., Naughton, 1995, 2018; Xu, 2011; Szamosszegi and Kyle, 2011; World Bank, 2013; Lardy, 2014; Huang et al., 2017; Liu, Wang and Xu, 2021; Chen et al., 2023; Allen et al., 2024, 2025). Yet one fundamentally important feature of the Chinese economy that emerged in the years after 2000 has been overlooked: SOEs monopolized key upstream industries (such as energy, telecommunications, and finance) and continually consolidated this dominance through government-arranged mergers, while downstream industries (such as most manufacturing of consumption goods and consumption services) were largely liberalized and became open to private competition. This asymmetry in both ownership and market structure between upstream and downstream industries is referred to as "vertical structure". Detailed documentation of this fact is provided in Section 2.

This paper proposes a macroeconomic theory of vertical structure and shows how this underappreciated feature can provide new perspectives to better understand an array of important issues in China's economic development, including the performance of SOEs, structural change, resource misallocation, and economic reforms.

More concretely, we develop a parsimonious general-equilibrium model consisting of two sectors: an agricultural sector and a non-agricultural sector (see Section 3). Within the non-agricultural sector, a vertical structure exists: upstream industries are monopolized by SOEs, while private firms in downstream industries are engaged in perfect competition. The agricultural sector is more labor-intensive than the non-agricultural sector. In equilibrium, when the productivity of the downstream private firms increases or when capital accumulates, labor is reallocated from agriculture to the non-agricultural sector, and the value-added share of the agricultural sector declines. However, wages remain low in this industrialization process because of labor abundance in the agricultural sector. This helps downstream private firms remain cost-competitive. The expansion of downstream private production thus enables upstream SOEs to sell more and consequently earn more profits. Furthermore, trade liberalization in the downstream industries further creates external demand for downstream goods, which not only facilitates industrialization but also enables upstream SOEs to capture even more profits from the expanding downstream industries now dominated by private enterprises.

The model yields several implications. First, the vertical structure helps explain why the profitability of SOEs relative to non-SOEs substantially improved after China's accession to the World

Trade Organization (WTO) in December 2001, as shown in Figure 1.[1,2]



Note: We use CEIC (Table CN.BF: Industrial Financial Data: By Enterprise Type) to obtain profit margin defined as total profit to sales revenue. In this table, CEIC categorizes industrial enterprises into state owned & holding, private, HMT & foreign, collective owned, shareholding corporations, foreign funded, and Hong Kong, Macau & Taiwan funded. We plot the profit margin of state owned & holding enterprises minus that of the rest.

Figure 1: Performance of SOEs Relative to Non-SOEs

This fact may appear puzzling because the relative improvement in SOE profitability after WTO accession seems to contradict the common notion that enhanced competition due to trade liberalization (or other market-oriented reforms) should hurt less efficient firms.[3] Our theoretical model of vertical structure resolves this puzzle (see Propositions 2 and 5), and the core mechanisms are directly supported by firm-level evidence (see Section 2).

Second, the vertical structure has important implications for structural change, GDP levels, and welfare (see Propositions 1 and 3). Our model explicitly characterizes the so-called "Lewis turning point", industrial employment, and hence the entire structural change process in equilibrium. We show that key macroeconomic variables—including upstream SOE profits and GDP—are all intrinsically linked to industrial employment, which in turn is shaped by the vertical structure. The model implies that reducing the upstream SOE monopoly would facilitate industrialization, boost GDP, increase returns on capital, and enhance social welfare. The upstream SOE monopoly should therefore not be understood merely as a partial-equilibrium feature with only micro-level impli-

[1] Different from the aggregate analysis in Figure 1, which shows that the profit margin of SOEs eventually exceeded that of non-SOEs, we find that the profit margins of SOEs only relatively improve but never exceed that of non-SOEs in the post-2001 period, after including control variables in the firm level regressions. Most importantly, despite differences in magnitude, both the aggregate and firm-level analyses show a significant relative profit margin improvement of SOEs in the post-2001 period.

[2] Similar patterns hold when using alternative measures such as profit per firm or profit per employment. This paper focuses on the pre-2008 period. The global financial crisis in 2008 is more complicated and deserves separate detailed treatment. We leave it for future research.

[3] Abundant empirical evidence shows that SOEs are less productive and efficient than non-SOEs; see, e.g., Sun and Tong (2003); Dollar and Wei (2007); Liu and Siu (2011); Zhu (2012); Hsieh and Song (2015).

cations for firms or industries; rather, it has important general-equilibrium effects and significant macroeconomic consequences.

Third, the vertical structure helps shed new light on China's preferential credit policies and resource misallocation. Preferential credit policies towards SOEs are well documented in the literature and are widely regarded as a significant advantage of SOEs over non-SOEs in China (see, e.g., Song, Storesletten and Zilibotti, 2011). We show that, in the presence of the upstream SOE monopoly, credit subsidies to these SOEs may actually improve welfare by mitigating the standard under-supply effect of monopoly. Theoretically, we prove that there exists a unique optimal capital subsidy rate to upstream SOEs as the second-best policy (see Proposition 4). Consequently, from a reform perspective, only removing the credit subsidy to SOEs without simultaneously eliminating the upstream monopoly could exacerbate the under-supply problem and lead to welfare loss, echoing the view of Liu (2019).

In Section 5, we use China's 1998-2007 Industrial Firm Survey data to quantify the impact of the upstream SOE monopoly on structural change, total GDP, and social welfare based on our vertical-structure model with preferential credit policies for SOEs. Our quantitative analysis delivers two key findings. First, counterfactual exercises show that both distortions—upstream monopoly and credit subsidies to SOEs—caused significant welfare loss. However, the output gain from eliminating the upstream monopoly alone is, in every year of our 2002–2007 sample period, larger than that from eliminating only the credit subsidy, suggesting that the upstream monopoly is quantitatively more harmful than the credit subsidy. Second, the GDP gain is consistently positive in all years when the upstream monopoly is removed; however, eliminating the credit subsidy alone would actually reduce GDP from 2004 to 2007. This confirms that the credit subsidy has partly mitigated the under-supply problem caused by the upstream monopoly and that removing it without eliminating the upstream monopoly could reduce welfare loss. Furthermore, we disentangle upstream monopoly power into natural monopoly power inherent in upstream industries and additional market power arising from state ownership, providing a quantitative decomposition of their respective roles (see Section 5.3).

We also explain how the vertical structure emerges as an equilibrium outcome (see Section 4). We show that when non-SOEs are sufficiently more productive than SOEs, it is optimal to liberalize all downstream industries and keep only upstream industries monopolized by SOEs in order to maximize the total profits of SOEs in the whole economy. Section 6 concludes.

Related literature. State control of basic economic resources is one of the most fundamental features of the political-economic institution of China (see Xu, 2011). To the best of our knowledge, this paper is the first to document and the first to theoretically formalize the vertical structure of the Chinese economy, which remains relevant today. Our paper is most closely related to four strands of literature.

First, it sheds new light on structural change and economic growth by introducing the vertical structure into the non-agriculture sector (see Herrendorf, Rogerson and Valentinyi, 2013; Ngai and Pissarides, 2007; Ngai, Pissarides and Wang, 2019; Buera and Kaboski, 2012). We show how upstream monopolist firms may impede industrialization and lower GDP when an economy features a vertical structure, whereas the existing literature mostly assumes a horizontal structure (i.e., resource reallocation across horizontally substitutable industries with symmetric market structures).[4]

Second, our model contributes to the literature on economic transition and institutions, especially the role of the state in development, by analyzing the vertical structure as a new dimension of incompleteness in market-oriented reforms (see Qian and Xu, 1993; Roland, 2000; Xu, 2011; Naughton, 2018). Specifically, we show how the vertical structure endogenously emerged, how it drove the subsequent prosperity of SOEs, and why that prosperity of SOEs was an undesirable symptom of partial reforms rather than evidence against further SOE reforms. Our paper thus echoes the view that partial reforms have pitfalls[5] and the finding of Allen, Qian and Qian (2005) that the private sector in China contributed to most of its economic growth. Our model also characterizes a new type of development paradigm, in which the state runs the economy by controlling the commanding heights (i.e., key upstream industries) amid (downstream industry) liberalization, industrialization, and globalization (see Wen, 2015; Bardhan, 2016; Song and Xiong, 2023).[6]

Third, our paper contributes to the literature studying SOEs in China. The existing literature has extensively discussed various determinants and symptoms of SOE inefficiency, such as misalignment of managerial incentives, state property rights, extra social and policy objectives, factor market distortions (especially in the financial market), and information asymmetry (e.g., Groves et al., 1994; Goodhart and Xu, 1996; Li, 1997; Lin, Cai and Li, 1998; Naughton, 1995, 2018; Hsieh and Klenow, 2009; Song, Storesletten and Zilibotti, 2011; Hsieh and Song, 2015; Huang et al., 2017). In contrast, we highlight the SOE monopoly of upstream industries as a distinct and independent source of inefficiency. A general equilibrium model is developed to explore both qualitatively and quantitatively the implications of the upstream SOE monopoly and how this monopoly interacts with credit subsidies to SOEs.

Fourth, our paper complements the literature on resource misallocation, which largely assumes a horizontal structure (e.g., Hsieh and Klenow, 2009; Buera, Kaboski and Shin, 2011; Buera and Shin, 2013; Moll, 2014; Itskhoki and Moll, 2019; David and Venkateswaran, 2019). In contrast,

[4]Exceptions include Sposi (2019), but his focus is not on SOEs or China. Other recent literature on China's structural change includes Cao and Birchenall (2013); Yao and Zhu (2021); Fang and Herrendorf (2021), but none of them examines the role of vertical structure.

[5]For analyses emphasizing the negative side of gradualism and/or partial reforms, see Bruno (1972); Murphy, Shleifer and Vishny (1992); Young (2000); Xu (2011). For more positive views, see Lau, Qian and Roland (2000); Roland (2000); Che (2009); Lin (2009); Wang (2015); Chen and Zha (2023).

[6]See also Wang (2013); Naughton and Tsai (2015).

we show how a vertical structure can generate opposite results. Namely, when the productivity of private firms increases, it enhances the profits of SOEs in upstream industries but hurts the profits of SOEs in a horizontally substitutable industry. In a closely related paper, Liu (2019) builds a more sophisticated model of production networks to show that subsidizing upstream industries may improve welfare when market imperfections exist, but his model does not focus on explaining the profitability of SOEs, nor does it analyze the role of structural change and trade globalization as in our paper.[7]

2 Background and Facts

This section first briefly reviews the history of China's SOE reforms, then documents quantitative facts about the vertical structure, and finally provides regression analyses of our model's key mechanism: positive shocks to downstream industries benefit upstream firms.

2.1 Brief History of China's SOE Reforms

Until the start of "reform and opening up" in 1978, virtually all firms in China were SOEs or collectively-owned in both upstream and downstream industries. During the 1980s, the first stage of SOE reforms started, focusing on increasing enterprise autonomy through a system that required managers to meet performance targets in return for retained profit. This system initially improved SOEs' performance (Groves et al., 1994; Li, 1997). However, it quickly ran into trouble because managers were rewarded for success but not punished for failure and they were able to exploit their effective control over SOE assets.

The second stage of SOE reforms began after the historic Southern Tour of Deng Xiaoping in 1992. The state eventually launched a so-called "three-year battle" to restructure SOEs between 1998 and 2000. Massive privatization of SOEs and layoffs of tens of millions began in 1995, when the central government formally set the policy of "nurturing the large and letting the small go". The central government explicitly pursued the strategy of retaining state control of 500 to 1,000 large SOEs in strategic industries, where competition was severely restricted through administrative regulation.[8] Meanwhile, the government shut down or privatized most of the small and medium-sized SOEs, which were typically located in downstream industries such as footwear and apparel (Lin, Cai and Li, 1998; Hsieh and Song, 2015; Naughton, 1995, 2018).

Throughout and after this round of SOE reform, central SOEs consolidated their monopoly

[7] Jones (2013) discusses misallocation with vertical linkages, but not specifically about SOEs or China.

[8] The State-Owned Assets Supervision and Administration Commission (SASAC hereafter) designated defense, electric power and grid, petroleum and petrochemical, telecommunications, coal, civil aviation, and shipping to be strategic industries. These turned out to be mostly upstream industries.

position in upstream industries and reinforced their advantageous position even further through reorganizations such as mergers and groupings within the same industry. Since the upstream industries are generally nontradable or regulated, central SOEs were still shielded from competition after the WTO entry. By contrast, non-SOEs faced fierce competition in the largely liberalized downstream industries, which are typically tradable and open to foreign direct investment. Overall, the monopoly position of SOEs in upstream industries was protected and strengthened while downstream industries became more competitive.

2.2 Data and Sample Construction

Our analyses use both the aggregate and firm-level data. We begin with the aggregate data from the National Bureau of Statistics (NBS), which we use to document aggregate trends and to construct measures of production linkage based on input–output (IO) tables.

While the upstream–downstream dichotomy is conceptually useful, the real economy is more complex, with industries distributed along a continuous production spectrum. To empirically characterize this structure, we follow the methodology of Antràs et al. (2012) and compute an upstreamness score for each industry using China's IO tables. The score measures an industry's distance from final consumption: industries with higher scores are more upstream (such as energy or petrochemicals), whereas those with lower scores are more downstream and closer to final household consumers (such as apparel or food). Based on the upstreamness scores, we classify industries into upstream, midstream, and downstream corresponding to the top, middle, and bottom tercile of the score distribution, respectively, and use this classification for all the subsequent empirical and quantitative analyses. In the appendix, Table A1 lists the industries and their upstreamness scores within the industrial sector, and Table A2 does so for all sectors.

In addition to the aggregate NBS data, we assess the robustness of the empirical results using the firm-level data from China's Annual Survey of Industrial Enterprises (ASIE) with alternative definitions of SOE ownership. Our approach is motivated by Allen et al. (2024) who conduct a detailed analysis based on proprietary data with full ownership network structures. While we do not have access to their data, we follow their spirit by making the most of the available ASIE data to construct multiple SOE definitions.

The ASIE data offers two different approaches to SOE classification. The first approach uses the state ownership indicator `gykgqk` (code 110), where `gykgqk` = 1 denotes a state-owned or state-controlled enterprise with a state ownership share exceeding 50%. This serves as our baseline definition, as it produces upstream SOE shares (aggregated from the firm level) that closely match the one reported later in Figure 2 in Section 2.3, which are based on the aggregate data from the NBS. The second approach uses the share of state capital, `gjzb/sszb`, where `gjzb` is state capital and `sszb` is actually contributed capital. Following Allen et al. (2024), we treat this measure as an alternative classification. We also try to combine both approaches.

To make our robustness checks span a broad range of possible classifications, from relatively narrow to relatively broad, as in Allen et al. (2024), we construct five different SOE definitions: (1) `gjzb/sszb` > 0.5 (the narrowest definition); (2) `gjzb/sszb` > 0; (3) `gykgqk` $= 1$ (baseline definition); (4) `gykgqk` $= 1$ or `gjzb/sszb` > 0.5; (5) `gykgqk` $= 1$ or `gjzb/sszb` > 0 (the broadest definition).

As a confirmation, we compare the SOE value-added share in the upstream industries under each definition. Table 1 shows a downward trend over time, yet SOEs still account for a substantial share of the upstream value added in 2007. As expected, broader definitions would suggest consistently higher SOE shares throughout the sample period.

Table 1: SOE Value-Added Share in the Upstream Industries

Year	SOE 1	SOE 2	SOE 3	SOE 4	SOE 5
1998	57.9	63.7	77.2	78.0	80.9
1999	64.7	70.1	72.6	76.9	79.5
2000	64.1	69.4	75.5	76.4	79.1
2001	61.2	66.0	73.5	74.5	77.3
2002	50.6	55.7	70.7	72.5	75.3
2003	45.7	52.3	66.7	68.6	71.4
2004	42.0	47.6	61.2	63.4	65.9
2005	39.2	45.8	58.7	61.0	63.5
2006	37.2	44.6	60.0	60.7	62.6
2007	34.8	41.7	57.2	57.6	59.1

For regression analyses, we construct our sample following standard procedures (Zhu, 2012). We drop firms with fewer than eight employees as such small firms are unlikely to maintain reliable statistical records. We also exclude firms with missing or ill-defined characteristics, such as zero or negative sales, value added, or total assets. We classify firms into the upstream, midstream, and downstream industries based on their two-digit industry codes, following Table A1 and A2. A small number of industries that are either unmatched or yield conflicting classifications are excluded. We use profit margin as an important outcome variable and define it as operating profit divided by sales revenue with winsorization at the top and bottom 1% to mitigate the influence of extreme values. After these adjustments, we arrive at a baseline sample of about 1.8 million observations. Table 2 reports the summary statistics.

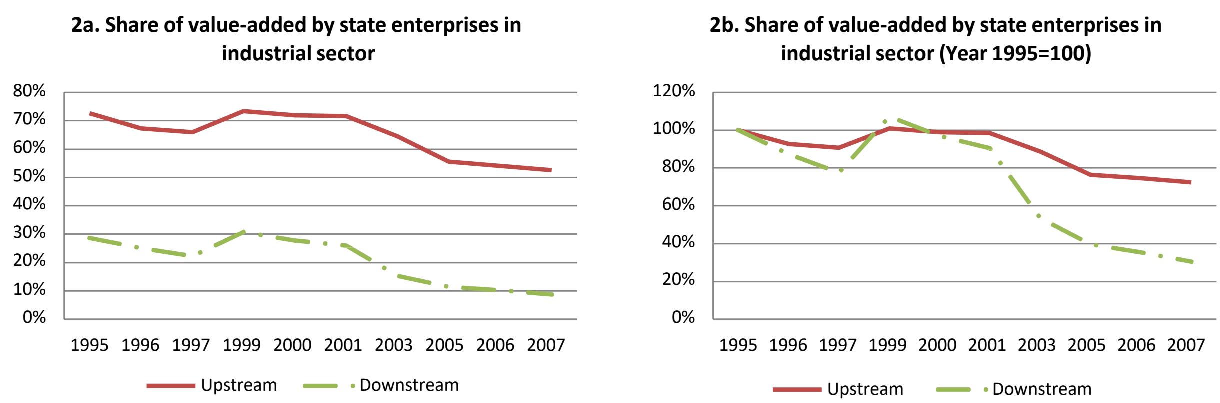
Table 2: Summary Statistics

	Mean	SD	Min	Median	Max	N
Panel A: Firm Characteristics						
Profit margin	0.022	0.128	-1.340	0.022	0.391	1,801,318
Profit	5,098	205,306	-5,579,620	346	1.190e+08	1,801,318
Sales revenue	83,119	811,598	1	17,202	1.870e+08	1,801,318
Value-added	24,775	346,611	1	4,831	1.624e+08	1,801,318
Total asset	91,438	1,194,011	1	13,720	5.649e+08	1,801,318
Firm age	10.9	12.224	0	7	290	1,801,318
Exports	15,480	312,732	-8,260	0	1.810e+08	1,801,318
Employment	290	1,502	9	110	569,670	1,801,318
Real capital	50,117	796,933	0.063	4,818	1.766e+08	1,801,318
Panel B: SOE Proportion						
SOE 1	0.143	0.350	0	0	1	1,801,318
SOE 2	0.168	0.373	0	0	1	1,801,318
SOE 3	0.166	0.372	0	0	1	1,801,318
SOE 4	0.177	0.382	0	0	1	1,801,318
SOE 5	0.196	0.397	0	0	1	1,801,318
Panel C: Proportions of the Three Streams of Firms						
Upstream	0.242	0.428	0	0	1	1,801,318
Midstream	0.359	0.480	0	0	1	1,801,318
Downstream	0.400	0.490	0	0	1	1,801,318

Note: Data are from China's Annual Survey of Industrial Enterprises (ASIE), covering 1998–2007. All monetary variables (profit, sales revenue, value-added, total asset, exports, and real capital) are in thousands of RMB. Real capital is deflated to 1998 prices. Employment is measured in number of workers. Firm age is in years. Profit margin is defined as operating profit divided by sales revenue, winsorized at the top and bottom 1%. SOE 1 through SOE 5 are binary variables corresponding to increasingly broad definitions of state ownership. Upstream, Midstream, and Downstream are binary variables classifying firms into terciles of the upstreamness score distribution following Antràs et al. (2012).

2.3 Emergence of vertical structure

We first document the evidence of vertical structure using the aggregate NBS data. Figure 2 compares the value-added shares of SOEs in the upstream and downstream industries within the industrial sector from 1995 to 2007. Two patterns stand out: SOEs consistently dominated the upstream industries, whereas their presence in the downstream industries was not only low but also decreased more dramatically in percentage terms. The year 2001 serves as a natural breakpoint, coinciding with both China's WTO accession and the conclusion of the three-year reform campaign. As Figure 2b makes clear, the share of SOEs in the downstream industries dropped more significantly (from 100 to around 30) relative to the upstream counterpart (from 100 to around 70) after 2001. Throughout the paper, we refer to the period between 2002 and 2007 as the period with vertical structure, because the share of SOEs in the downstream industries was always lower than 20 % and eventually fell even below 10 %, whereas the upstream counterpart was always more than half.[9]



Note: Figure 2 reports share of state enterprises in industrial value added with the data from National Bureau of Statistics (NBS) of China, Table 14-2, and Table 14-6. Note that NBS has changed the title of state related enterprises over time. NBS uses "state-owned industrial enterprises" in 1995-1997; "state-owned and state-holding" in 1999-2003 and 2005-2007. The data are missing for 1998, 2002, and 2004.

Figure 2: SOE Share Distribution across the Upstream and Downstream in the Industrial Sector

We next use regressions with control variables and the five SOE definitions to reexamine the results in Figure 2b with the firm-level ASIE data. Note that Figure 2b shows that the relative concentration of SOEs in the upstream industries intensified during the period of the vertical structure. Since firm-level regressions cannot capture the industry-level change, we use an industry-level analysis focusing on the log of the SOE value-added share.

Specifically, we aggregate the firm-level ASIE data to the four-digit industry level and estimate

[9] Note that we confirm in Appendix B that the ASIE data produces the same aggregate time trends reported in Figures 1–2 based on NBS aggregate data.

the following regression:

$$\log(\text{SOE Share})_{st} = \alpha + \beta(\text{Upstream}_s \times \text{Post2001}_t) + \gamma \mathbf{X}_{st} + \delta_s + \delta_t + \epsilon_{st}. \tag{1}$$

The outcome variable is the log of SOEs' value-added share in industry s and year t. The control variables $\mathbf{X}_{st}$ are constructed as value-added-weighted averages of the following firm characteristics: firm size (log sales revenue), firm age (log age), export share (export revenue over sales revenue), and capital intensity (log K/L). These control variables will be consistently used across all regressions reported thereafter. We also control for industry fixed effects (δ_s) and year fixed effects (δ_t). The indicators for the upstream industries and the years after 2001 are absorbed by industry and year fixed effects, respectively.

Table 3: Relative Presence of SOEs in the Upstream Industries Over Time

	Dependent Variable = Log(SOE Share)				
SOE Measure	SOE 1 (1)	SOE 2 (2)	SOE 3 (3)	SOE 4 (4)	SOE 5 (5)
Upstream×Post2001	0.4384*	0.4643***	0.3823**	0.3543**	0.4075***
	(0.2060)	(0.1379)	(0.1305)	(0.1288)	(0.1186)
Observations	5,125	5,125	5,125	5,125	5,125
Adjusted R^2	0.9309	0.9223	0.9324	0.9335	0.9377
Year FE	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes
Weighted	Yes	Yes	Yes	Yes	Yes

Note: All regressions include control variables as well as year and industry fixed effects, and are weighted by industry value added. The upstream indicator is absorbed by industry fixed effects. Standard errors are clustered at the industry and year levels. *** p<0.01, ** p<0.05, * p<0.1.

Table 3 reports the results. The coefficient estimates on the interaction term are positive and significant across all five SOE definitions, indicating that the relative presence of SOEs in the upstream industries became more pronounced after 2001, confirming the pattern in Figure 2.

Further stylized facts on vertical structure. Table 4 documents several additional features of the vertical structure. Table 4a reports the robust regression results showing that even after controlling for industry-level capital intensities, SOEs are still disproportionately concentrated in the upstream industries, indicating that the vertical structure is not simply an artifact of SOEs clustering in capital-intensive industries. Table 4b presents two other important facts. First, both the profit margin and the average revenue-based Herfindahl-Hirschman indices (HHI) of the upstream industries were about three times as high as those of the downstream industries during the sample period, suggesting a less competitive market structure in the upstream industries than in the downstream ones. Second, the upstream output almost exclusively served the domestic market, whereas the downstream industries were much more export-oriented. For the industrial sector, the export-to-output ratio (export exposure) is 21.9% in the downstream industries versus 5.5% in the upstream industries. The upstream-downstream difference in export exposure is presumably even more striking for the whole economy if the nontradable service sector are also included. Although certain upstream inputs or services are technically tradable, the downstream private firms must purchase from the domestic upstream SOEs rather than importing directly from abroad due to government regulations.[10] Table 4c shows that the vertical structure is a salient and unique feature of China when considering the largest firms; that is, the largest firms in China are more likely to be SOEs and operate in the upstream industries, compared to those in the US and France. Note that France is reputed to have very high proportion of SOEs among large Western economies.[11]

[10] Petroleum is a case in point. China is a net importer of crude petroleum. However, virtually no downstream private firms are allowed to directly import oils from abroad; instead, they must purchase oil or related products from domestic upstream SOEs such as Sinopec Group and China National Petroleum.

[11] The facts documented above apply to the industrial sector. The same features remain true at the national level, although data availability is severely limited, especially time series data for various performance measures (see Figure A4).

Table 4: Further Stylized Facts on Vertical Structure

(a) SOE Shares and Upstream Indices

SOE Share	Industrial Output (1)	Employees (2)	Industrial Value (3)	Sales Revenue (4)	Fixed Asset (5)	Total Asset (6)
Up Dummy	0.175***	0.199***	0.183***	0.188***	0.233***	0.223***
	(3.232)	(3.531)	(3.344)	(3.491)	(4.093)	(3.962)
Capital Intensity	0.001***	0.001**	0.001***	0.001***	0.001**	0.001**
	(3.171)	(2.493)	(2.711)	(3.302)	(2.164)	(2.101)
Constant	0.297***	0.339***	0.314***	0.289***	0.392***	0.388***
	(9.383)	(10.252)	(9.763)	(9.144)	(11.712)	(11.773)
Observations	373	407	373	407	407	407

(b) Several Features of the Industrial Sector in China: 1998-2007

Industries	Profit Margin	HHI	Export Exposure
Average across upstream enterprises	0.0257	0.0065	0.0554
Average across downstream enterprises	0.0073	0.0028	0.2188

(c) Comparison of Fortune Global 500 Firms in 2011 from China, U.S., and France

	Total	SOE		Upstream		Downstream		Misc.	
Country	Count	Count	Percent	Count	Percent	Count	Percent	Count	Percent
China	57	53	93	25	46	11	20	3	5
US	133	4	3	17	14	64	51	8	6
France	35	4	11	3	9	16	46	0	0

Note: The data are from National Bureau of Statistics (NBS) of China. The upstream classification of industries is according to Table A2 in the appendix which is based on the scores computed with Chinese input-output table following the methodology of Antràs et al. (2012). Misc. refers to those companies whose industries are miscellaneous such as aerospace or defense, which cannot be classified into any stream based on the IO table. The classification criterion for SOEs and Non-SOEs is whether the government owns at least 50% of the firm. Significance levels 10%, 5%, 1% are denoted by *, **, and ***, respectively.

2.4 Profitability Gap between SOEs and non-SOEs

We next examine whether SOEs systematically differ from non-SOEs in terms of profit margins, and whether this relationship shifts after 2001. Specifically, we estimate the following firm-level regression:

$$\text{ProfitMargin}_{it} = \alpha + \beta_0 \text{SOE}_{it} + \beta_1 (\text{SOE}_{it} \times \text{Post2001}_t) + \gamma \mathbf{X}_{it} + \delta_c + \delta_s + \delta_t + \epsilon_{it}, \qquad (2)$$

where i indexes firms, c cities, s industries, and t years. We include the same control vector $\mathbf{X}_{it}$ as in Equation (1) but using the firm level data. We also control for city fixed effects (δ_c), industry fixed effects (δ_s), and year fixed effects (δ_t). Note that the Post2001 indicator is absorbed by the year fixed effects.

Table 5: Profit Margin of SOE vs. Non-SOE over Time

	Dependent Variable = Profit Margin				
SOE Measure	SOE 1 (1)	SOE 2 (2)	SOE 3 (3)	SOE 4 (4)	SOE 5 (5)
SOE	-0.0234***	-0.0168***	-0.0284***	-0.0275***	-0.0221***
	(0.0035)	(0.0031)	(0.0031)	(0.0028)	(0.0028)
SOE×Post2001	0.0158**	0.0118**	0.0109**	0.0107**	0.0099**
	(0.0051)	(0.0043)	(0.0038)	(0.0034)	(0.0033)
Observations	1,801,306	1,801,306	1,801,306	1,801,306	1,801,306
Adjusted R^2	0.2554	0.2543	0.2581	0.2578	0.2560
Year FE	Yes	Yes	Yes	Yes	Yes
City FE	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes
Weighted	Yes	Yes	Yes	Yes	Yes

Note: All regressions include control variables as well as year, city, and industry fixed effects, and are weighted by firm sales revenue. Standard errors are clustered at the firm and year levels. *** p<0.01, ** p<0.05, * p<0.1.

Table 5 shows that the SOE indicator has a negative and significant coefficient estimate in the regressions where profit margin is the dependent variable, whereas its interaction with the Post2001 indicator has a positive and significant coefficient estimate. These results indicate that SOEs generally have lower profit margins than non-SOEs after controlling for firm-level characteristics, but their profitability increased more than that of non-SOEs after 2001. Note that the positive and significant coefficient on SOE×Post2001 is smaller in magnitude than the negative and significant coefficient on the SOE indicator, implying that SOEs' profit margins remain below those of non-SOEs even after 2001. This pattern holds across all five SOE definitions. Thus, SOEs were significantly closing the gap with non-SOEs in profit margin after 2001.

The aggregate level analysis in Figure 1 shows that the profit margin of SOEs eventually exceeded that of non-SOEs but it includes no controls. The most important fact here is that although the magnitude of the relative profit margin improvement is somewhat different in Figure 1 and Table 5, both confirm a significant relative profit margin improvement of SOEs in the period of vertical structure.

Selection: Balanced Panels, Upstream and Downstream SOEs. The shrinking profitability gap documented above likely reflects in part a composition effect: the "grasp the large, let go of the small" reform mechanically raised average SOE performance by eliminating the worst performers. This selection channel is consistent with our narrative, as it constitutes one historical force shaping the vertical structure. However, it is not the whole story. Selection alone predicts nothing about whether surviving SOEs continue to improve once entry and exit are held fixed, nor whether such improvement differs across the upstream and downstream industries. The vertical structure by contrast predicts both: the gap in profit margin between SOEs and non-SOEs should narrow even among survivors, and it should do so asymmetrically, with the upstream SOEs improving more than both SOEs and non-SOEs in the downstream.

To test whether the gap narrows even among the surviving firms, we use the balanced panel samples by requiring that a firm appears in each year of the 1998-2007 period for the regressions in Equation (2). This requirement ensures that any effect that we find is not driven by the composition effect; it also reduces the regression sample by almost 90%, from about 1.8 million observations to just over 200,000.

Note that this requirement is even more stringent than it appears at first glance. This is because the ASIE data is actually the enterprise-level data, even though most researchers refer to it as the firm-level data. A firm could be comprised of hundreds or thousands of enterprises at any point in time. For example, a firm could have several enterprises even in the same city. Thus, some of the attrition in observations reflects genuine firm disappearance through bankruptcies and mergers. But the reductions were also due to within-firm business reorganizations. This means that we are even less likely to find significant results if all our findings are due to the composition effect because we are excluding the composition effects at both the firm and enterprise levels.

Panel A of Table 6 shows that, even after requiring balanced panel samples, the results are qualitatively the same as those in Table 5. Across all five SOE definitions, we continue to observe a relatively greater improvement in SOE profit margins in the period of vertical structure.

It is also critical to investigate where in the production chain this convergence occurs. Specifically, we further decompose the balanced panel into different subsamples and estimate Equation (2) again using different subsamples. Panels B and C of Table 6 report the results. For each SOE definition, we consider two subsamples. Panel B compares the upstream SOEs to the mid- and downstream non-SOEs, whereas Panel C compares the SOEs to non-SOEs within the midstream and downstream. So in both Panels B and C, we always use non-SOEs in the midstream and downstream as the benchmark. We investigate if the upstream SOEs perform differently from downstream SOEs after 2001 using this same benchmark. Note that in Panel B, the SOE indicator is absorbed by industry fixed effects and is therefore not separately identified.

Table 6: Profit Margin of SOE vs. Non-SOE over Time (Balanced Panel)

	Dependent Variable = Profit Margin				
SOE Measure	SOE 1 (1)	SOE 2 (2)	SOE 3 (3)	SOE 4 (4)	SOE 5 (5)
	Panel A: All Continuing Firms				
SOE	-0.0444***	-0.0274***	-0.0332***	-0.0283***	-0.0200***
	(0.0077)	(0.0058)	(0.0052)	(0.0051)	(0.0044)
SOE×Post2001	0.0252**	0.0144**	0.0110*	0.0099*	0.0082*
	(0.0085)	(0.0063)	(0.0052)	(0.0050)	(0.0046)
Observations	238,750	222,374	254,147	247,927	233,730
Adjusted R^2	0.1635	0.1889	0.3082	0.3043	0.3228
	Panel B: Upstream SOE vs Mid- and Downstream Non-SOE				
SOE×Post2001	0.0311**	0.0257**	0.0211**	0.0189**	0.0169**
	(0.0104)	(0.0088)	(0.0072)	(0.0071)	(0.0068)
Observations	176,035	160,365	179,750	174,457	160,860
Adjusted R^2	0.1723	0.2078	0.3634	0.3610	0.3914
	Panel C: SOE vs Non-SOE in Mid- and Downstream				
SOE	-0.0287***	-0.0167***	-0.0197***	-0.0190***	-0.0145***
	(0.0050)	(0.0050)	(0.0052)	(0.0051)	(0.0044)
SOE×Post2001	0.0039	-0.0016	-0.0032	-0.0030	-0.0025
	(0.0047)	(0.0049)	(0.0048)	(0.0048)	(0.0044)
Observations	179,397	165,791	189,202	184,249	172,991
Adjusted R^2	0.1387	0.1805	0.1515	0.1515	0.1689
Year FE	Yes	Yes	Yes	Yes	Yes
City FE	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes
Weighted	Yes	Yes	Yes	Yes	Yes

Note: All regressions include control variables as well as year, city, and industry fixed effects, and are weighted by firm sales revenue. Standard errors are clustered at the firm and year levels. *** p<0.01, ** p<0.05, * p<0.1.

A pure selection story would predict uniform improvements, if any, across all surviving SOEs whether an SOE is in the upstream or downstream of the production chain, implying significant estimates for SOE×Post2001 in both Panels B and C under each SOE definition. The alternative vertical-structure story would suggest that only SOE×Post2001 in Panel B is significant, i.e., only upstream SOEs relatively improve profit margin when compared to the same set of benchmark firms of the mid- and downstream non-SOEs.

Panel B of Table 6 reveals a pronounced post-2001 improvement in profit margin among the upstream SOEs relative to the mid- and downstream non-SOEs, whereas Panel C shows no such convergence between the mid- and downstream SOEs and their non-SOE counterparts. The results are robust across all five SOE definitions. Using the same benchmark of the mid- and downstream non-SOEs, only the upstream SOEs exhibited relatively improving profit margins; the mid- and downstream SOEs did not.

This contrast is important: the post-2001 catch-up in SOE profit margin is driven by the upstream SOEs, precisely the firms that benefit from downstream expansion through the vertical production linkage in our theory. The fact that only the upstream SOEs' profitability improves when compared to the same set of benchmark firms is a pattern uniquely consistent with the vertical-structure mechanism.[12] We next turn to a direct test of this mechanism.

2.5 Testing Vertical Linkage: Downstream Shocks and Upstream Profitability

To empirically test our core theoretical prediction that positive shocks to the downstream industries benefit the upstream firms, we investigate the relationship between the profitability of the upstream firms and the performance of the downstream industries they supply. We conduct a firm-level regression analysis using the following first-difference specification[13]:

$$\Delta \log(\text{Profit}_{it}) = \beta \Delta D_{st} + \gamma \mathbf{X}_{it} + \delta_t + \epsilon_{it}.$$

Here, the indices are i for firm, s for the industry, and t for year. The dependent variable, $\Delta \log(\text{Profit}_{it})$, measures the profit growth of upstream firm i. The key independent variable, ΔD_{st}, represents a shock at the industry-year level, constructed from performance changes in the downstream industries that the upstream industry s supplies. We measure this shock in two ways: as a change in the downstream total factor productivity (TFP) and as a change in the tariffs faced by the downstream exporters. The specification includes year fixed effects, δ_t, and a vector of firm-

[12]Using aggregate data, we find that, within the same ownership type, the upstream firms are more profitable than the downstream firms. Moreover, the upstream SOEs exhibit faster profitability growth than the downstream non-SOEs (see Figure A2 in the appendix), reinforcing the importance of the upstream–downstream distinction.

[13]Following recent trade literature (Tian, 2024), this first-difference specification focuses on growth rates, which avoids cross-industry comparability issues (e.g., in TFP) and yields more meaningful measures of downstream exposure.

level controls, $\mathbf{X}_{it}$, including firm size, firm age, export share, and capital intensity, to mitigate potential time-varying confounding effects.

Downstream TFP Shock. To measure an upstream firm's exposure to productivity improvements in its customer base, we construct a downstream TFP shock variable. We start by estimating industry-level TFP using the ASIE data and the Levinsohn-Petrin (LP) method (Levinsohn and Petrin, 2003). Then, for each upstream industry s, we compute a weighted average of TFP growth across the corresponding downstream industries. Formally, the TFP shock for a firm in upstream industry s in year t, transmitted via its downstream industries, is defined as:

$$\Delta \text{TFP}_{st} = \sum_j \omega_{sj} \Delta \log(\text{TFP}_{jt}),$$

where the weight $\omega_{sj} = \frac{\text{IO}_{sj}}{\sum_k \text{IO}_{sk}}$ reflects the share of the upstream industry s that is sold to its downstream industry j, based on China's 2002 IO table. Here, IO_{sj} is (s, j) entry of the IO table, representing the flow of goods from industry s to industry j.

Downstream Tariff Shock. To capture the impact of downstream trade liberalization, we construct a shock based on changes in the export tariffs faced by the downstream industries. Formally, the tariff shock for a firm in upstream industry s in year t, transmitted via its downstream industries, is defined as:

$$\Delta \text{Tariff}_{st} = \sum_j \omega_{sj} \Delta \log(1 + \tau_{jt}),$$

where τ_{jt} is the volume-weighted export tariff that the downstream industry j faces in year t.[14]

Following Brandt et al. (2017), we use the lagged value $\Delta \text{Tariff}_{s,t-1}$ in the regression analysis, instead of the contemporaneous shock. This lagged approach accounts for uncertainty in the timing of tariff changes within a year and for potential delays in the pass-through of trade policy changes.

Estimation Results. Table 7 presents the main regression results using all the upstream firms from 2003 to 2007, a period chosen to ensure that the IO weights (from the 2002 IO table) used in shock construction are predetermined. We find that the TFP growth in the downstream industries is positively and significantly associated with the profitability of the upstream firms. In contrast,

[14] Following Tian (2024), we use $\Delta \log(1 + \tau_{jt})$ to capture proportional changes in trade barriers. We compute τ_{jt} following Bas and Strauss-Kahn (2015): $\tau_{jt} = \sum_n \theta_{jn} \tau_{jnt}$, where θ_{jn} is the share of industry j's exports to country n, fixed at their 2002 levels to avoid potential endogeneity, and τ_{jnt} is the ad-valorem tariff imposed by country n on exports from industry j. Bilateral tariff rates and export values come from UNCTAD TRAINS and are available at the HS-6 product level. We map HS-6 codes to CIC-4 industries using the concordance table from Brandt et al. (2017), and then link CIC-4 to the 2002 IO industries.

increases in export tariffs faced by the downstream industries are negatively and significantly associated with the upstream firm profitability.

Table 7: Does Downstream Firm TFP or Export Tariff Affect Upstream Firm Profits

	Dependent Variable = Change in Log(Profit)					
	(1)	(2)	(3)	(4)	(5)	(6)
ΔTFP_t	1.375***		1.295***	1.375***		1.295**
	(0.083)		(0.085)	(0.473)		(0.481)
$\Delta\text{Tariff}_{t-1}$		-19.95***	-14.43***		-19.95***	-14.43**
		(2.284)	(2.316)		(4.459)	(5.170)
Observations	147,907	144,488	144,488	147,907	144,488	144,488
Adjusted R^2	0.0227	0.0214	0.0228	0.0227	0.0214	0.0228
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Cluster SE	Firm	Firm	Firm	Industry	Industry	Industry

Note: Only upstream firms are included in the analysis. All regressions include control variables as well as year fixed effects. Standard errors are clustered at either the firm or the industry level. *** p<0.01, ** p<0.05, * p<0.1.

When both the downstream TFP growth and changes in export tariffs are included as regressors in the same specification, both remain statistically significant at the 5% level or better. This finding suggests that the productivity and trade channels operate simultaneously on the downstream firms' influence in shaping the upstream firm performance.

To interpret the magnitudes, the coefficient on TFP growth (1.295) implies that a 1 percentage point increase in the downstream TFP growth is associated with a 1.3 percentage point increase in the upstream profit growth. At one standard deviation of the shock (SD $\approx$ 0.040), this corresponds to approximately a 5 percentage point effect. The coefficient on tariff changes (-14.43) is larger in absolute value but reflects the much smaller variation in the tariff shock (SD $\approx$ 0.002). For context, a 0.5 percentage point reduction in the downstream tariffs (e.g., from 2% to 1.5%) corresponds to $\Delta \log(1+\tau) \approx -0.005$, implying roughly a 7 percentage point increase in the upstream profit growth. At one standard deviation, the implied effect is approximately 3 percentage points. Taken together, despite the difference in coefficient magnitudes, the two channels have comparable economic significance.

Our results are robust to alternative clustering of standard errors (at the firm or industry level) and to different sample definitions, including using only the upstream firms or both the upstream and midstream firms (see Table A4 in the appendix).

3 Benchmark Model

In this section, we develop a general equilibrium model of vertical structure with structural change based on the facts and empirical findings documented in Section 2. We study autarky and open economy sequentially.

3.1 Autarky

3.1.1 Model Environment

Consider a closed economy populated by a continuum of agents with a measure equal to unity. Agents are divided into two groups: state-affiliated agents with a measure equal to $\theta \in (0,1)$ and private agents with a measure $1-\theta$. Agents are identical within each group. The economy has two sectors: an agriculture sector producing the numeraire good n and an industrial sector. Within the industrial sector, there is a vertical structure with the upstream industry producing intermediate good m and the downstream industry producing a composite consumption good d. All the agents share the following utility function

$$u(c_n, c_d) = c_n + \frac{\epsilon}{\epsilon - 1} c_d^{\frac{\epsilon-1}{\epsilon}}, \ \epsilon > 1, \tag{3}$$

where c_n and c_d denote consumption of good n and good d, respectively. ϵ is the price elasticity of demand for good d. Both c_n and c_d must be nonnegative. All technologies are constant returns to scale. One unit of labor produces A_n units of good n. To produce good d requires capital k, labor l, and intermediate good m. The production function is

$$F_d(k, l, m) = Ak^{\alpha} l^{\beta} m^{1-\alpha-\beta}, \tag{4}$$

where $\alpha \geq 0, \beta > 0, \alpha+\beta < 1$. The intermediate good m is produced with the following technology:

$$F_m(k, l) = A_m k^{\gamma} l^{1-\gamma}, \tag{5}$$

where $\gamma \in [0, 1)$. Each agent, state-affiliated or private, is endowed with L units of time (labor) and K units of capital. Good m is produced by a monopolist firm, which is owned by the "state" but fully controlled by the state-affiliated agents as if the state-affiliated agents own it. Goods n and d are produced by competitive privately owned enterprises (POEs hereafter), which are owned by the private agents. Only the upstream market is a monopoly, whereas all other goods and factor markets are perfectly competitive with free entry.[15] Recall that the sectorial asymmetry in both

[15] If we instead assume that each subindustry in the downstream is monopolized by a distinct private firm, which earns positive profits through monopolistic competition, the key results of our model do not change.

state ownership and market structure (upstream SOE monopoly plus downstream POEs perfect competition) is referred to as the "vertical structure", as documented in Section 2.

3.1.2 Characterizing Equilibrium

Let W, R, p_n, p_d, and p_m denote the wage, rental price of capital, prices of good n, downstream good d, and intermediate good m, respectively. Without loss of generality, normalize p_n to one. Let I_s and I_p denote the total income of a representative agent in the state-affiliated agent group and in the private agent group, respectively. Clearly, $I_p = WL + RK$ and $I_s = I_p + \frac{\Pi_m}{\theta}$, where Π_m is the total profit of the SOE. An agent with income I maximizes the utility function (3) subject to the budget constraint $p_n c_n + p_d c_d \leq I$, where $I \in \{I_s, I_p\}$.

Perfect competition with free entry in the downstream industry implies that the price equals the marginal cost:

$$p_d = \frac{R^\alpha W^\beta {p_m}^{1-\alpha-\beta}}{A\alpha^\alpha \beta^\beta (1-\alpha-\beta)^{1-\alpha-\beta}}. \tag{6}$$

Applying Shephard's Lemma on (6), together with the aggregate demand for d, $D_d = \left(\frac{p_n}{p_d}\right)^\epsilon$, derived from household utility maximization, we obtain the demand function for m:

$$D_m = (1-\alpha-\beta) \cdot p_n^\epsilon \cdot [\frac{R^\alpha W^\beta}{A\alpha^\alpha \beta^\beta (1-\alpha-\beta)^{1-\alpha-\beta}}]^{1-\epsilon} \cdot {p_m}^{-[(1-\alpha-\beta)(\epsilon-1)+1]}. \tag{7}$$

The upstream monopolist SOE maximizes its profit, which implies

$$p_m = \mu \frac{R^\gamma W^{1-\gamma}}{A_m \gamma^\gamma (1-\gamma)^{1-\gamma}}, \tag{8}$$

where μ is the endogenous markup given by

$$\mu \equiv \frac{(1-\alpha-\beta)(\epsilon-1)+1}{(1-\alpha-\beta)(\epsilon-1)} > 1, \tag{9}$$

because the price demand elasticity for m from downstream good d is $(1-\alpha-\beta)(\epsilon-1)+1$, as shown in (7).

The labor market clearing condition is given by

$$L = \underbrace{D_m \frac{\partial \frac{R^\gamma W^{1-\gamma}}{A_m \gamma^\gamma (1-\gamma)^{1-\gamma}}}{\partial W}}_{\text{by producer of intermediate good } m} + \underbrace{D_d \frac{\partial p_d}{\partial W}}_{\text{by producers of downstream good } d} + \underbrace{D_n \frac{1}{A_n}}_{\text{by producers of good } n}, \tag{10}$$

where D_d and D_n are the aggregate demand for goods d and n, given by $D_d = \left(\frac{p_n}{p_d}\right)^\epsilon$ and (7), respectively (here we presume that all agents, whether state-affiliated or private, consume both good d and good n). Let $\overline{L}$ denote the total industrial employment or the sum of the first two terms on the right-hand side of (10). As long as good n is produced in equilibrium, wages are equal to the marginal product of labor in the agriculture sector:

$$W = A_n, \tag{11}$$

which implies that wage increases with agricultural productivity A_n but does not change with K, A_m, A, or L.[16] The capital market also clears:

$$K = \underbrace{D_m \frac{\partial \frac{R^\gamma W^{1-\gamma}}{A_m \gamma^\gamma (1-\gamma)^{1-\gamma}}}{\partial R}}_{\text{by producer of intermediate good } m} + \underbrace{D_d \frac{\partial p_d}{\partial R}}_{\text{by producers of downstream good } d}. \tag{12}$$

By combining (12), (6), (8) and (11), we obtain the equilibrium prices as summarized in the following lemma.

Lemma 1 *Suppose L is sufficiently large (or, more precisely, inequality (19) holds). There exists a unique equilibrium, in which wage W is given by (11) and the other prices are given by*

$$R = \varkappa^\xi \left[\left(A_n^{\alpha+\gamma(1-\alpha-\beta)-1} A_m^{1-\alpha-\beta} A \right)^{\epsilon-1} K^{-1} \right]^\xi, \tag{13}$$

$$p_m = \frac{\mu \varkappa^{\xi\gamma} A_n^{1-\gamma} A_m^{-1}}{\gamma^\gamma (1-\gamma)^{1-\gamma}} \left[\left(A_n^{\alpha+\gamma(1-\alpha-\beta)-1} A_m^{1-\alpha-\beta} A \right)^{\epsilon-1} K^{-1} \right]^{\xi\gamma}, \tag{14}$$

$$p_d = \left(\frac{\gamma(1-\alpha-\beta)+\alpha\mu}{\varkappa^\xi \mu} \right)^{\frac{1}{\epsilon-1}} \left[A_n^{\alpha+\gamma(1-\alpha-\beta)-1} A_m^{1-\alpha-\beta} A K^{\alpha+\gamma(1-\alpha-\beta)} \right]^{-\xi}, \tag{15}$$

where $\varkappa$ and ξ are exogenous parameters defined as

$$\varkappa \equiv \frac{\gamma(1-\alpha-\beta)+\alpha\mu}{\mu} \left\{ \frac{\left[\frac{\mu}{\gamma^\gamma (1-\gamma)^{1-\gamma}} \right]^{1-\alpha-\beta}}{\alpha^\alpha \beta^\beta (1-\alpha-\beta)^{1-\alpha-\beta}} \right\}^{1-\epsilon}, \tag{16}$$

$$\xi \equiv \frac{1}{1+\alpha(\epsilon-1)+\gamma(1-\alpha-\beta)(\epsilon-1)}. \tag{17}$$

Observe that (14) implies $\frac{\partial p_m}{\partial A} > 0$, that is, an increase in the TFP of downstream private firms yields a higher price of good m monopolized by the upstream SOE. This is due to the general equilibrium effect that R is driven up as the marginal productivity of capital increases ($\frac{\partial R}{\partial A} > 0$ implied by (13)), so p_m increases with the upstream production cost as the markup stays unchanged. On the other hand, (15) implies $\frac{\partial p_d}{\partial A_m} < 0$, that is, a more productive upstream SOE helps lower

[16] When all the labor has been absorbed into the industrial sector (that is, when the economy has passed the so-called "Lewis turning point" defined below), the equilibrium wage depends on K, A_m, A, and L.

the price of the downstream good produced by private firms. This is because an increase in the upstream TFP lowers p_m (as implied by (14)), which dominates the resulting increase in R.

We can easily obtain the total industrial employment:

$$\overline{L}(A_n, A, A_m, K) \equiv \varkappa^{\xi} \frac{(1-\gamma)(1-\alpha-\beta)+\beta\mu}{\gamma(1-\alpha-\beta)+\alpha\mu} \left[\frac{\left(A_m^{1-\alpha-\beta} A\right)^{\epsilon-1}}{A_n^{\epsilon}} \right]^{\xi} K^{1-\xi}. \tag{18}$$

An increase in industrial productivity, A or A_m, will attract more labor from the agriculture sector into the industrial sector, whereas an increase in agricultural productivity A_n has the opposite effect on industrialization. Industrialization is also facilitated by capital accumulation ($\frac{\partial \overline{L}(A_n,A,A_m,K)}{\partial K} > 0$), since it tends to increase the marginal product of labor in the industrial sector. To ensure that the private agents also consume good n, we must require:

$$L > \frac{\mu-\gamma(1-\alpha-\beta)-\alpha\mu}{(1-\gamma)(1-\alpha-\beta)+\beta\mu} \overline{L}(A_n, A, A_m, K), \tag{19}$$

which we impose throughout the paper unless otherwise specified. Observe that $\frac{\mu-\gamma(1-\alpha-\beta)-\alpha\mu}{(1-\gamma)(1-\alpha-\beta)+\beta\mu} > 1$.

Proposition 1 *Suppose (19) is true. In the autarky equilibrium, the upstream SOE's profit* Π_m *and the total GDP (per capita)* Y *are given by*

$$\Pi_m = \frac{(1-\alpha-\beta)(\mu-1)}{(1-\gamma)(1-\alpha-\beta)+\beta\mu} \overline{L}(A_n, A, A_m, K) A_n, \tag{20}$$

$$Y = \left[L + \frac{\alpha\mu+(1-\alpha-\beta)(\gamma+\mu-1)}{(1-\gamma)(1-\alpha-\beta)+\beta\mu} \overline{L}(A_n, A, A_m, K) \right] A_n, \tag{21}$$

where $\overline{L}(A_n, A, A_m, K)$ *is given by (18).*

Proposition 1 is a novel result of our paper. It underscores, when labor is abundant (condition (19) holds), how the key macroeconomic variables in our model are related to structural change (industrialization) characterized by $\overline{L}$. (20) implies that the upstream SOE profit is proportional to the total industrial employment $\overline{L}(A_n, A, A_m, K)$, reflecting the fact that the upstream earns more profits as industrialization deepens. (21) indicates that GDP strictly increases with total industrial employment $\overline{L}$, revealing that structural change drives up total output. Also, (21) and (18) together imply that aggregate output exhibits decreasing returns to scale with respect to the factor inputs, even though all the technologies are constant returns to scale. This "efficiency loss" is due to the upstream SOE earning monopoly profit.

To highlight the determinants of the upstream SOE's profit, we summarize the comparative static results on (20) as follows.

Proposition 2 *Suppose (19) is true. In the autarky equilibrium, an increase in the productivity of downstream POEs will increase the monopoly profit of the upstream SOE ($\frac{\partial \Pi_m}{\partial A} > 0$).*

Proposition 2 states that, under the vertical structure, an increase in the productivity of private firms in the downstream industry actually benefits the upstream SOE ($\frac{\partial \Pi_m}{\partial A} > 0$).[17] This is a key result of the paper. The intuition is as follows. First, an increase in the downstream productivity A lowers the price for the downstream final good ($\frac{\partial p_d}{\partial A} < 0$) and hence increases its demand ($\frac{\partial D_d}{\partial A} > 0$), which in turn raises the demand for the upstream intermediate good ($\frac{\partial D_m}{\partial A} > 0$). Second, an increase in the downstream productivity A increases the equilibrium price for the upstream intermediate good ($\frac{\partial p_m}{\partial A} > 0$ as explained earlier) and hence also increases the profit margin ($\frac{\mu-1}{\mu} p_m$). These two forces jointly generate a higher profit for the upstream SOE ($\frac{\partial \Pi_m}{\partial A} > 0$). Note that the prediction is exactly opposite in the horizontal structure when SOEs and non-SOEs are located in horizontally substitutable sectors, as usually assumed in the resource misallocation structure (see the formal proof in Appendix C).

Observe that labor abundance is important for the mechanism in Proposition 2. Without abundant labor, the expansion of the industrial sector, induced either by an increase in productivity or by capital accumulation, would push up the wage, which in turn would cause the profit of the upstream SOE not to grow as fast. Formally, we first find the "Lewis turning point" in our model—the critical value of labor endowment, denoted by $\underline{L}$, such that the numeraire good n is marginally produced in equilibrium (i.e., $D_n = 0^+$). That is, if $L > \underline{L}$, some labor remains in the agricultural sector; if $L < \underline{L}$, all labor is absorbed in the industrial sector. We then look at how the profit of the upstream SOE is related to productivity and the capital stock before and after passing the Lewis turning point. We have the following corollary.

Corollary 1 *The monopoly profit of the upstream SOE increases faster with the productivity of the downstream POEs, its own TFP and the total capital stock before passing the Lewis turning point than after passing the Lewis turning point ($\frac{\partial \Pi_m}{\partial A}\big|_{L=\underline{L}^+} > \frac{\partial \Pi_m}{\partial A}\big|_{L=\underline{L}^-}$, $\frac{\partial \Pi_m}{\partial A_m}\Big|_{L=\underline{L}^+} > \frac{\partial \Pi_m}{\partial A_m}\Big|_{L=\underline{L}^-}$, and $\frac{\partial \Pi_m}{\partial K}\big|_{L=\underline{L}^+} > \frac{\partial \Pi_m}{\partial K}\big|_{L=\underline{L}^-}$).*

The key intuition behind Corollary 1 can be understood from the following result

$$\frac{dF\left(K, L^d\right)}{dK} = \frac{\partial F\left(K, L^d\right)}{\partial K} + \underbrace{\frac{\partial L^d}{\partial K} \frac{\partial F\left(K, L^d\right)}{\partial L^d}}_{\text{absorb more labor into industrial sector}},$$

where $Y_d = F\left(A, A_m, K, L_d\right)$ is defined as the aggregate production function of the industrial goods sector, Y_d is the output quantity of the downstream good d (in equilibrium $Y_d = D_d$), and L_d is the

[17]Not surprisingly, the upstream SOE's profit also increases with its own TFP ($\frac{\partial \Pi_m}{\partial A_m} > 0$) and the capital stock K ($\frac{\partial \Pi_m}{\partial K} > 0$).

total industrial employment. Before passing the Lewis turning point, an increase in K increases the output of the industrial sector through two forces: a direct effect of more input K and an indirect effect of absorbing additional input L^d. After passing the Lewis turning point, the second force no longer exists. Considering that the profit of the upstream SOE is proportional to the output value of the industrial sector,[18] we obtain $\frac{\partial \Pi_m}{\partial A}\big|_{L=\underline{L}^+} > \frac{\partial \Pi_m}{\partial A}\big|_{L=\underline{L}^-}$. Similarly, the results regarding the effect of A and A_m on Π_m around the Lewis turning point can also be obtained.

The following proposition characterizes the equilibrium when the upstream monopoly is completely eliminated (i.e., free entry) so that the upstream market is perfectly competitive.

Proposition 3 *Suppose (19) is true. Under certain mild regularity conditions, when the upstream industry is fully liberalized and hence becomes perfectly competitive, the rental price of capital will rise, both the intermediate good and the downstream good will become cheaper, total industrial employment and total GDP will both become larger, and the welfare of the private agents will be strictly higher whereas the state-affiliated agents will become strictly worse off.*

The proof of Proposition 3 is delegated to the Appendix. The intuition for this proposition is the following. Reducing the upstream monopoly lowers p_m, which in turn lowers p_d. Therefore, the output of good d increases, absorbing more labor from the agriculture sector. It, in turn, drives up R. GDP expands primarily because reducing the upstream monopoly facilitates structural change, moving more labor from the relatively low value-added agriculture sector to the relatively high value-added industrial sector. The total capital income rises because the increase in the total rental income of capital (RK) more than compensates for the dissipation of the monopoly profit (Π_m). Meanwhile, W stays unchanged, as ensured by $L > \overline{L}$. Thus, the total GDP increases from the factor income point of view.

From 2002 to 2007, China witnessed a more rapid increase in the profitability of SOEs than private firms (recall Figure 1), while the aggregate GDP continued to rise steadily. As such, some claimed that there was no need for major reforms as SOEs performed better than non-SOEs. Our analysis suggests an opposite possibility: the unusual prosperity of SOEs could be an undesirable symptom of the incompleteness of the SOE reforms. In particular, Proposition 1 and Proposition 2 show that both total GDP and the upstream SOE's profits would increase when the TFP of downstream private firms increases, even if the TFP of the upstream SOE remains unchanged. In other words, high profits of the upstream SOE could be merely a consequence rather than a cause of economic growth; it was the downstream private firms that were the key engine for GDP expansion. In fact, Proposition 3 makes it clear that the SOE monopoly undermines GDP and welfare.[19]

[18]Specifically, $\Pi_m = \frac{\mu-1}{\mu}(1-\alpha-\beta)\,Y_d p_d$, where $Y_d p_d$ is increasing in Y_d.

[19]Our model also implies that privatizing upstream SOEs without eliminating their monopoly does not help.

3.1.3 Capital Subsidy

It is well documented in the literature that SOEs receive loans more favorably than POEs (e.g., Song, Storesletten and Zilibotti, 2011). Consequently, one may naturally ask what would happen if credit subsidies to SOEs are also introduced into the model as a second source of potential distortion.[20]

To formally investigate this question, we extend our baseline model above by assuming that the upstream SOE receives a credit subsidy at a rate of τ, that is, the upstream SOE faces a subsidized rental price of capital, $R(1-\tau)$. The credit subsidy expenditure is financed by a lump-sum income tax imposed equally on all households, so the total tax revenue required is $T = \tau R K_m$, where K_m is the aggregate amount capital used to produce intermediate good m. An agent's budget constraint becomes $p_n c_n + p_d c_d \leq I - T$, where $I \in \{I_s, I_p\}$.

It is easy to verify (see the proof in the appendix) that in equilibrium the upstream SOE's profit Π_m and the total GDP (per capita) Y are still given by (20) and (21) respectively, but the total industrial employment is revised as

$$\hat{L}(A_n, A, A_m, K, \tau) \equiv \hat{\varkappa}^{\xi} \frac{(1-\gamma)(1-\alpha-\beta)+\beta\mu}{\frac{\gamma}{1-\tau}(1-\alpha-\beta)+\alpha\mu} \left[\frac{\left(A_m^{1-\alpha-\beta} A\right)^{\epsilon-1}}{A_n^{\epsilon}} \right]^{\xi} K^{1-\xi}, \tag{22}$$

where

$$\hat{\varkappa} \equiv \frac{\frac{\gamma}{1-\tau}(1-\alpha-\beta)+\alpha\mu}{\mu} \left\{ \frac{\left[\frac{\mu}{\gamma^{\gamma}(1-\gamma)^{1-\gamma}}(1-\tau)^{\gamma}\right]^{1-\alpha-\beta}}{\alpha^{\alpha}\beta^{\beta}(1-\alpha-\beta)^{1-\alpha-\beta}} \right\}^{1-\epsilon}, \tag{23}$$

and ξ is still given by (17). Note that the above results obtain only when the labor endowment L is large enough so that in equilibrium every agent consumes a positive amount of good n. To ensure that, we must require:

$$L > \frac{\mu - \gamma(1-\alpha-\beta) - \alpha\mu}{(1-\gamma)(1-\alpha-\beta)+\beta\mu} \hat{L}(A_n, A, A_m, K, \tau). \tag{24}$$

It is straightforward to show that $\hat{L}(A_n, A, A_m, K, \tau)$ changes non-monotonically with τ. More specifically, $\hat{L}$ strictly increases with τ when $\tau < \tau^* \equiv 1 - \frac{1}{\mu}$, reaches its maximum when $\tau = \tau^*$, and then strictly decreases with τ when $\tau > \tau^*$. It implies that, given the existence of upstream SOE monopoly with an endogenous markup μ given by (9), total SOE profit and aggregate GDP will both also first strictly increase with the credit subsidy rate and then decrease with it. Thus

Nothing would change in the model if the upstream SOE is now replaced by a politically-connected private monopolist firm. An effective way to reform is to dismantle entry barriers to upstream industries and create a level playing field.

[20] Observe that the key mechanism of upstream SOEs benefiting from upstream industries remains valid if no capital is needed for production ($\alpha = \gamma = 0$).

we have the following proposition.

Proposition 4 *Suppose labor is sufficiently abundant so that (24) is satisfied. Given the existence of upstream SOE monopoly with an endogenous markup μ (given by (9)), there exists a unique optimal capital subsidy rate $\tau^* = 1 - \frac{1}{\mu}$, at which total GDP Y, industrial employment $\hat{L}$ and the upstream SOE's profit Π_m are all maximized. In other words, total GDP, industrial employment and SOE profit under this optimal capital subsidy rate are all strictly higher than their counterparts with no capital subsidy. Nevertheless, the total GDP and industrial employment under the optimal subsidy rate remain strictly lower than the first-best levels with no upstream monopoly.*

See the appendix for the proof. Proposition 4 shows that in the presence of the upstream monopoly distortion, introducing another distortion—the provision of a capital subsidy to the upstream industry—can actually improve welfare. Of course, the subsidy should not be too high, and indeed there exists a unique optimal level of subsidy which offsets the markup exactly (i.e., τ^* satisfies $(1 - \tau^*)\mu = 1$). The underlying mechanism is that providing subsidies to upstream industries could alleviate the under-supply problem of upstream industries and thus improve welfare. However, since providing a capital subsidy *per se* is still a distortion (on the factor market) on top of the monopoly distortion, the first-best efficiency under no monopoly can never be achieved. Proposition 4 may help us better understand the well-documented fact that SOEs receive more favorable loans than POEs in China. The capital subsidy to the upstream SOE may act as a mechanism to partially counteract the efficiency loss caused by the upstream monopoly.[21]

3.2 Open Economy

Now we extend our analysis to study how international trade affects the profit of the upstream SOE through the vertical structure. Trade globalization is particularly relevant to China's reforms and development, especially after its accession to the WTO in 2001.[22]

Consider a world with two countries, home (H) and foreign (F). The home economy is China, identical to the one specified in Section 3.1. For simplicity, we focus on the case without credit subsidies to SOEs. Country F is a developed economy populated with a continuum of identical households with a measure equal to unity. Each household is endowed with L^* units of labor and has the same preferences as households in country H, given by (3). For simplicity, we assume that all

[21] Observe that the provision of cheap credit to upstream SOEs may in part be a market behavior response (besides a deliberate arrangement by the government). Specifically, if the financial market is plagued by contracting frictions with collateral constraints akin to Bernanke and Gertler (1989) and Kiyotaki and Moore (1997), then the more profitable upstream SOEs would enjoy advantages over downstream private firms in obtaining more favorable loans, *ceteris paribus*. In other words, factor market discrimination can be the consequence, rather than the cause, of the high profitability of SOEs.

[22] See, e.g., Khandelwal, Schott and Wei (2013) and Brandt et al. (2017).

firms in country F are private and that no capital or intermediate goods are needed in production. Each foreign firm has free access to the following constant-returns-to-scale technologies: one unit of foreign labor, interpreted as a composite of raw labor and associated human capital, can produce either A^* units of good n or one unit of good d. All markets are perfectly competitive in country F. Trade is free between the two countries. Observe that it is a hybrid of Ricardian and Heckscher-Ohlin trade models, so the comparative advantage depends on both the relative productivity and relative factor abundance. Without loss of generality, A_n is normalized to unity.

To make our analysis relevant for China, we focus mainly on the case in which country H has comparative advantage in good d, which may be interpreted as a composite of manufacturing goods. Specifically, country H exports d and imports good n, interpreted as agricultural products. Moreover, the labor endowment in country H is sufficiently large so that, in equilibrium, country H produces and consumes both good d and good n, and Country F also consumes both but only produces good n.[23] The necessary and sufficient conditions for this equilibrium pattern are given in Appendix C.

Lemma 2 *Under certain conditions (given in the appendix), in the free trade equilibrium, the upstream SOE's profit and total GDP in country H are given by*

$$\Pi_m = \frac{(1-\alpha-\beta)(\mu-1)}{(1-\gamma)(1-\alpha-\beta)+\beta\mu}\overline{\overline{L}}(A, A_m, K), \tag{25}$$

$$Y = \left[L + \frac{\alpha\mu + (1-\alpha-\beta)(\gamma+\mu-1)}{(1-\gamma)(1-\alpha-\beta)+\beta\mu}\overline{\overline{L}}(A, A_m, K)\right], \tag{26}$$

where $\overline{\overline{L}}(A, A_m, K)$ *is the total industrial employment in country H and is given by* $\overline{\overline{L}}(A, A_m, K) \equiv 2^{\xi}\overline{L}(1, A, A_m, K)$*, with* ξ *given by (17) and* $\overline{L}$ *given by (18).*

Compared with the autarky equilibrium (Proposition 1), the only difference is that now $\overline{L}(A_n, A, A_m, K)$ is replaced by $\overline{\overline{L}}(A, A_m, K)$ in the formulas, reflecting the fact that international trade scales up the total demand for (and hence the output of) the downstream good d. The comparative static results are also similar to those in Proposition 2. The comparison between autarky and open economy is formally summarized in Proposition 5.

Proposition 5 *The monopoly profit of the upstream SOE and the GDP in country H are larger in the free trade equilibrium than in autarky.*

[23] In reality, country F (e.g., the US) also exports manufacturing good d to China, but to allow for the within-industry trade would require a more sophisticated trade model. However, the key results for the open economy, as summarized in Proposition 5 below, would still remain robust in alternative models so long as the overall comparative advantage of country H lies in its manufacturing sector instead of the agriculture sector, which is consistent with what is observed in the real world.

This proposition explicitly states that trade openness boosts industrialization by absorbing more labor into the industrial sector as the industrial sector is consistent with China's comparative advantage. Therefore, trade facilitates structural change, which in turn generates higher demand for upstream goods and hence higher upstream profit. GDP also becomes larger because of more industrialization as implied by (26).

This simple model formalizes a novel mechanism for how the high profitability of SOEs in China depends on international trade. Entering WTO in 2001 facilitated China's downstream exports and hence increased the induced aggregate demand for the upstream goods and services monopolized by SOEs. Consequently, upstream SOE profits rose with trade liberalization.

Moreover, the analysis also suggests that a small change in external demand may cause a large change in the upstream SOE's profits due to the markup price effect. This is consistent with the data, which shows that SOE profitability increased disproportionately more than non-SOEs' profitability when exports expanded until 2007. SOE profitability dropped more dramatically than non-SOEs' profitability when confronted by negative external demand shocks in 2008 during the global financial crisis. This may explain why SOE profitability co-moves closely with the export-to-GDP ratio even though upstream SOEs do not directly participate in trade. If the economic structure were horizontal, then we would not be able to simultaneously explain all of the features observed in data.

4 Emergence of Vertical Structure

The benchmark model captures what happened after the vertical structure came into full shape following the massive privatization of downstream SOEs in the late 1990s. This subsection serves two purposes. One is to rationalize how the vertical structure endogenously emerged. The other is to explain why private firms outperformed SOEs in terms of profitability even more significantly before the vertical structure fully emerged in 2001, as shown in Figure 1.

Consider the same setting of autarky in Section 3.1, except that now the downstream good d is an aggregate of a continuum of differentiated goods:

$$c_d = \left(\int_0^1 c(i)^{\frac{\eta-1}{\eta}} di \right)^{\frac{\eta}{\eta-1}}, \text{ for } \eta > 1 \tag{27}$$

where $c(i)$ is consumption of differentiated good i, $i \in [0, 1]$, and η is the elasticity of substitution. A downstream industry i is called liberalized if entry to that sector is free, and SOEs and non-SOEs are engaged in perfect competition. The production function for a firm in the industry i is still given by (4) for each $i \in [0, 1]$, where $A = A_p$ if it is a private firm, and $A = A_s$ if it is a state firm. We assume $A_s < A_p$. Let ϕ denote the fraction of downstream industries that are liberalized. The remaining $1-\phi$ fraction of the industries are regulated such that each of them is monopolized by one state firm. From Section 2, we know that $\phi = 0$ holds before the downstream liberalization. $\phi = 1$ refers to the fully-blown vertical structure. Obviously, without subsidies, downstream SOEs are replaced by competitive private firms in the liberalized industries. In those regulated downstream industries, SOEs are delegated to different managers, so they are engaged in monopolistic competition. Suppose the state-affiliated agent group (SASAC in reality) maximizes the economy-wide total profits of all SOEs by choosing ϕ.

Proposition 6 *(Endogenous Vertical Structure) In equilibrium, the profit-maximizing state-affiliated group chooses to only monopolize the upstream industries and fully liberalizes the downstream industries ($\phi = 1$) when private firms are sufficiently more productive than state firms:*

$$\frac{A_p}{A_s} > \left(\frac{\eta-1}{\eta}\right)\left[\frac{\eta-1}{\eta} + \frac{\mu}{\eta\left(\mu-1\right)\left(1-\alpha-\beta\right)}\right]^{\frac{1}{\eta-1}}.$$

The intuition is as follows. When a downstream industry is liberalized, the SOE in that industry will lose profit. On the other hand, this liberalized downstream industry will have a larger demand for upstream input than before, which increases the upstream SOE's profit. In addition, the profit of the remaining monopolist SOEs in the downstream industries will be reduced due to the cross-industry substitution effect. It turns out that when $\frac{A_p}{A_s}$ is sufficiently large, the indirect profit gain in the upstream industry from downstream liberalization dominates the direct SOE profit loss in all the downstream industries. Thus, it pays to liberalize all downstream industries. This explains the endogenous emergence of the vertical structure (upstream SOE monopoly plus downstream private competition with free entry).

As Figure 1 shows, the profitability gap between SOEs and non-SOEs was substantially larger before 2001 than the later period. The period between 1998 and 2001 witnessed massive privatization of downstream SOEs and consolidation of upstream SOEs (the "three-year battle" mentioned in Section 2), and the profitability gap shrunk significantly after 2001. We argue that this phenomenon is due to the gradual liberalization of downstream industries in the 1990s, a process through which the vertical structure gradually emerged. As documented in Section 2, the market-oriented economic reform accelerated after 1992 and the openness to foreign direct investment (FDI) and trade also deepened. With the entry and expansion of high-productivity non-SOEs, domestic or foreign, in liberalized downstream sectors, SOEs and non-SOEs competed in a horizontal structure, and many SOEs had to rely on subsidies from the government or other SOEs to survive. This drove down the average profitability of SOEs. During the period of massive SOE privatization in the downstream industries, most of the money-losing SOEs exited from the competitive downstream industries, and therefore, the average profitability of SOEs started to rise. The vertical structure came into full shape around 2001, and the average profitability of SOEs increased further.

5 Quantitative Analysis

In this section, we quantitatively assess the welfare implications of eliminating distortions in the autarky model with vertical structure and SOE credit subsidies.

5.1 Calibration

Recall that the sector producing good n is the agriculture sector, and the sector that exhibits the vertical structure (the upstream industries producing good m and the downstream industries producing good d) is the industrial sector. Due to severe data limitations for China's service sector, our calibration will focus on these two sectors. Our primary data source for the industrial sector is the Annual Survey of Industrial Enterprises (ASIE) in China. We categorize all firms into upstream and upstream industries following the industry classification shown in Table A1. To ensure our two-sector model consistent with the data, we compute the sum of real GDP in the primary and secondary sectors from the data provided by China's National Bureau of Statistics. This is the value of "total GDP" for our model economy.

Since our model is static, we calibrate it to year 2005 for expositional clarity. This benchmark year represents a fully established vertical structure, sits at the midpoint of the relevant sample period from 2002 to 2007,[24] and effectively captures the interaction between upstream monopoly and credit subsidies.

Without loss of generality, we set the agricultural good n as the numeraire ($p_n = 1$) and normalize labor endowment $L = 1$. We then calibrate the remaining exogenous parameters: the share parameters in the production functions (4) and (5): $\{\alpha, \beta, \gamma\}$; the preference parameter ϵ; the credit subsidy rate τ; and the sectoral TFPs and factor endowment: $\{A_d, A_m, A_n, K\}$. The share parameters are set to their averages over 2002 to 2007, as factor shares are typically stable over a short period; all remaining parameters are calibrated to 2005 data. The calibration procedures are detailed in Appendix D, and Table 8 reports the parameter values used in our model.

[24]The ASIE covers 1998 to 2007. We focus on 2002 onward because it marks the full emergence of the vertical structure (see the pertinent discussion earlier). It ends at 2007 because it is the final year before the global financial crisis and the last year when the ASIE data quality is widely deemed as trustworthy. We show in Appendix D that our qualitative results remain unchanged when the calibration is repeated for every year between 2002 and 2007.

Table 8: Calibrated Parameters and Targets (Benchmark Year: 2005)

Parameter	Value	Interpretation	Target / Source
Share parameters			
α	0.12	Downstream capital share	From data analog (average 2002–2007)
β	0.25	Downstream intermediate input share	From data analog (average 2002–2007)
γ	0.42	Upstream capital share	From data analog (average 2002–2007)
Preference parameters			
μ	1.74	Upstream SOE markup	Inferred from accounting identities
ϵ	3.15	Price elasticity of demand	Implied by markup condition in the model
Policy parameter			
τ	0.50	Credit subsidy rate	Credit spread s relative to rental rate R
Productivity and endowment			
A_d	48.11	Downstream TFP	A_d and A_n are jointly determined to
A_n	79.59	Agriculture TFP	match agriculture share and GDP
A_m	11.87	Upstream TFP	Determined by normalizing p_m to 1
K	497.1	Capital endowment	Match rental rate of capital R

5.2 Counterfactual Analysis

We next conduct counterfactual analyses to quantitatively explore the consequences on total output and welfare when the two distortions (monopoly and credit subsidy to upstream SOEs) are eliminated. We compare the following four scenarios: (i) no reform, i.e., $\mu = \mu^0$ and $\tau = \tau^0$, where superscript 0 stands for the *status quo* value; (ii) complete removal of credit subsidy alone, i.e., $\mu = \mu^0$ and $\tau = 0$; (iii) complete removal of upstream SOE monopoly alone, i.e., $\mu = 1$ and $\tau = \tau^0$; and (iv) first best, namely, complete removal of both SOE monopoly and credit subsidy, i.e., $\mu = 1$ and $\tau = 0$.

The real GDP is calculated using the prices in the no-reform scenario:

$$\text{real GDP} = p_n^0 y_n + p_d^0 y_d,$$

where p_n^0 and p_d^0 are the *status quo* prices for the agriculture and industry sectors, respectively. Using such invariant sectoral prices helps avoid underestimating real GDP purely due to the elimination of monopoly pricing.

We also translate output gains into consumption-equivalent welfare changes. Despite non-homothetic preferences, welfare can still be summarized by the proportional increase in consumption that makes households indifferent between the status quo and the counterfactual allocation. Specifically, we compute the percentage gain λ such that

$$u((1+\lambda)\, c_n^0, (1+\lambda)\, c_d^0) = u(c_n^1, c_d^1),$$

where (c_n^0, c_d^0) is the *status quo* consumption bundle and (c_n^1, c_d^1) denotes the counterpart after reforms.

Table 9: Counterfactual Output and Welfare (Benchmark Year: 2005)

Scenario	GDP Change	Welfare Change (λ)
Status quo	0.00%	0.00%
Remove subsidy	−1.15%	−1.15%
Remove markup	5.52%	4.03%
First best	7.58%	5.78%

Table 9 reports the changes in real GDP and consumption-equivalent welfare under alternative policy scenarios. Several findings emerge. First, removing the upstream monopoly alone raises GDP by 5.52%, suggesting that monopoly power is a quantitatively important source of output distortion and explains a large share of the total loss. Second, while eliminating the upstream monopoly increases GDP, eliminating the credit subsidy alone actually *reduces* GDP by 1.15%. This result indicates that the credit subsidy to SOEs partially mitigates the under-supply problem created by upstream monopolistic SOEs. Thus, removing the credit subsidy in isolation would exacerbate, rather than alleviates, the output distortion, an underappreciated finding in the existing literature.[25] Third, removing both distortions simultaneously raises GDP by 7.58%, exceeding the sum of the two individual effects ($5.52\% - 1.15\% = 4.37\%$). This pattern arises also because credit subsidies and upstream monopolies partially offset each other: once the monopoly is eliminated, the subsidy loses its corrective role and becomes purely distortionary. The welfare results display a highly consistent pattern.

Next, we conduct two policy reform experiments to illustrate how the sequencing of reforms matters. In policy reform I, we first gradually eliminate the monopoly (i.e., μ decreases from the *status quo* value to one) and then reduce the credit subsidy (i.e., τ declines from the *status quo* value to zero). In policy reform II, we switch the order of the two reforms.

Figure 3 illustrates how the welfare gain (in terms of the percentage change in consumption) changes as the distortion is gradually eliminated in policy reform I. The left panel shows that, given the existence of a credit subsidy, as the markup μ decreases, the welfare gain first increases, and reaches the peak when μ is approximately 1.1, and then decreases. This non-monotonic change can be understood as follows: When the upstream SOE markup decreases from a sufficiently high level, the under-supply problem is gradually mitigated, so the welfare improves relative to the *status quo*; when the markup μ reaches 1.1, the under-supply tendency of monopoly is just exactly offset by the credit subsidy, so the welfare gain reaches the maximum; when the markup continues to decline, the given level of credit subsidy is more than necessary to eliminate the effect of the monopoly, and

[25] Liu (2019) is an exception.

(a) Eliminate Markup First (b) Remove Credit Subsidy Next

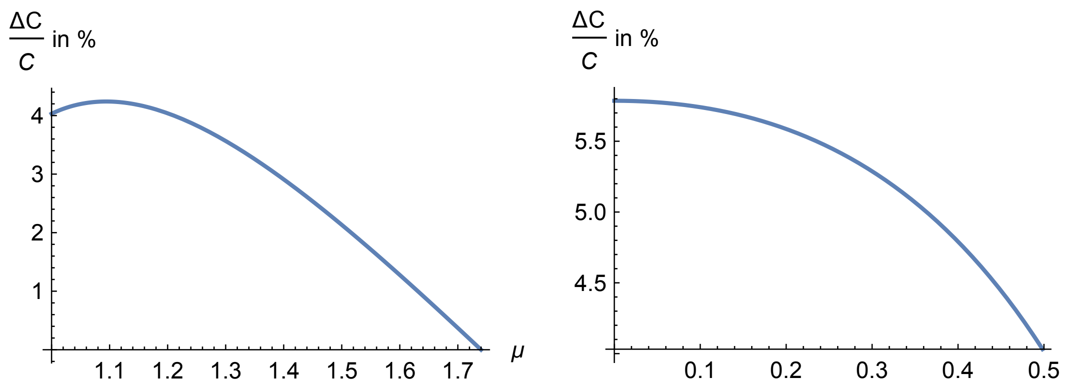


Figure 3: Welfare Change with Policy Reform I

therefore, the smaller the markup, the greater the welfare loss caused by the distortion from the credit subsidy. The right panel shows that, after the markup is completely eliminated, the credit subsidy becomes the only distortion to the economy, so the welfare increases monotonically as the credit subsidy rate τ decreases.

Figure 4 exhibits the welfare consequences of policy reform II. Specifically, the left panel shows that, given the existence of upstream SOE monopoly, the social welfare first increases as the credit subsidy τ decreases from the value of 0.5, and the welfare gain reaches its peak when τ is equal to 0.43, and then the welfare starts to decline as τ continues to decrease. In fact, the welfare level would be even lower than the initial level when τ is lower than 0.34. The reason is similar to the previous case. Reducing credit subsidy from a high enough level first reduces the distortion and increases the output, and when τ is equal to 0.43, the negative impact of monopoly is most effectively offset by the credit subsidy. When the credit subsidy is reduced further, it becomes too weak to undo the monopoly effect, so the welfare gain decreases as τ decreases until τ reaches the value of 0.34, beyond which the credit subsidy becomes too low to even sustain the initial welfare level. The right panel shows that, once the credit subsidy is completely eliminated, reducing the markup would monotonically improve the welfare.

As a robustness check, we repeat the full calibration and counterfactual analysis for each year from 2002 to 2007. All qualitative conclusions remain unchanged. In particular, removing the credit subsidy alone leads to small or even negative welfare effects, reflecting its complementary role in mitigating the monopoly distortion. In contrast, eliminating the upstream monopoly alone consistently generates large welfare gains, and removing both distortions yields even larger improvements. The complete year-by-year results are reported in Appendix D.

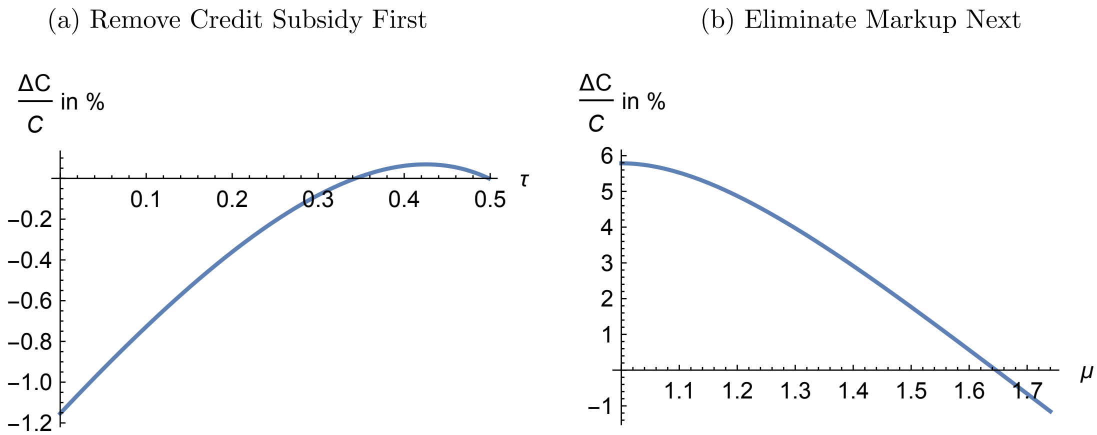


Figure 4: Welfare Change with Policy Reform II

5.3 Upstream Monopoly and State Ownership: A Decomposition

The vertical structure exhibits two salient features: the high markup of upstream industries, a universal tendency worldwide, and the high prevalence of state ownership within these sectors, a feature more specific to China. This contrast raises a central question: to what extent does state ownership amplify upstream monopoly? Put differently, how much of the observed upstream markup reflects inherent market structure, and how much is attributable to state ownership?

Addressing this question requires disentangling two drivers of upstream monopoly: the portion attributable to "natural monopoly," which would exist regardless of ownership, and the additional portion driven specifically by SOEs. Separating these components allows us to decompose the resulting output loss into their respective contributions.

This section proceeds in two steps. First, we use firm-level data to document additional evidence on firm markups, industry upstreamness, and state ownership. Second, we combine these empirical estimates with the model to quantify the contribution of state ownership to overall output loss.

Upstreamness, Ownership, and Markups. We begin by examining how industry upstreamness and state ownership shape firm markups. To measure markups, we employ the method of Loecker and Warzynski (2012), which infers firm-level markups from production data under the assumption of cost minimization. Unlike accounting-based measures, this approach does not rely on reported profits or marginal costs, which are often unavailable for individual firms or too noisy to be informative at such granularity. Instead, it connects markups to estimated production elasticities and observed input cost shares. While conceptually consistent with the accounting-based approach employed in Section 5.1, this method offers much finer granularity, allowing us to effectively capture markup heterogeneity across firms.

We conduct extensive regression analyses on firm markups (see Appendix D.3.1), yielding three robust findings. First, upstream firms exhibit persistently higher markups, particularly after 2001. We find that firms in upstream industries have significantly higher markups than those in downstream industries. This markup gap, already pronounced in the pre-2001 period, widens further after 2001, suggesting that upstream industries gained increasing monopoly power over time.

Second, SOEs charge higher markups on average, but only in upstream industries. In upstream industries, SOEs show no significant markup premium relative to non-SOEs, indicating that state ownership reinforces market power, but only in sectors where upstream structure already grants firms a dominant position.

Third, both upstreamness and state ownership contribute to market power, but upstreamness plays the dominant role. When both indicators are included in the same regression, each remains positive and generally significant, yet formal F-tests confirm that the effect of being upstream is significantly larger than the effect of state ownership.

Taken together, these findings highlight that upstreamness is the primary driver of markups, with state ownership reinforcing market power mainly in upstream industries. To assess the economic significance of this amplification, we next turn to a quantitative decomposition of the output loss.

Decomposing Output Loss. To quantify how much SOEs contribute to the amplification of upstream monopoly power, we construct a counterfactual in which all upstream SOEs are hypothetically converted into POEs. If SOEs systematically charge higher markups than comparable POEs, aggregate markups would fall under full privatization. Using regression-based estimates of the SOE markup premium together with observed SOE cost shares, we impute the counterfactual markup μ^c that would prevail if all SOEs were replaced by POEs (see Appendix D.3.3). This approach allows us to isolate the contribution of SOEs to upstream market power, relative to the natural monopoly that would exist regardless of ownership.

Because credit subsidies can also influence output responses, we consider two scenarios: (i) the absence of subsidies ($\tau = 0$), and (ii) the status quo credit policy ($\tau = \tau^0$). Let $Y(\mu, \tau)$ denote total output under markup μ and credit subsidy τ. In Scenario 1 (no subsidy), the total output loss from upstream monopoly power is $Y(\mu^0, 0) - Y(1, 0)$, where μ^0 is the observed markup and $\mu = 1$ corresponds to the perfectly competitive benchmark. The share of this loss attributable to SOEs is then

$$\frac{Y(\mu^0, 0) - Y(\mu^c, 0)}{Y(\mu^0, 0) - Y(1, 0)},$$

where μ^c is the counterfactual markup if all SOEs were replaced by POEs. In Scenario 2 (status quo), with subsidies in place, the analogous measure is

$$\frac{Y(\mu^0, \tau^0) - Y(\mu^c, \tau^0)}{Y(\mu^0, \tau^0) - Y(1, \tau^0)}.$$

We apply this decomposition to the 2005 benchmark year, using the same modeling framework and calibration as in the previous subsections. The firm-level regressions serve solely to construct μ^c. Under both credit regimes, SOEs account for roughly 8.5%–15.5% of the total output loss from upstream monopoly, where the low and high bounds are derived from alternative empirical specifications to provide a credible interval. The bulk of the loss stems from the structural features of upstream industries themselves. Results for the full sample period from 2002 to 2007 are reported in Appendix Figure D3; the 2005 estimates are consistent with the broader time-series pattern.

Our results indicate that upstream natural monopoly accounts for a substantial share of the distortion. Market power can emerge not only through formal state ownership but also from the structural position of industries in the production network, upstreamness, which may be driven by informal political ties or related market imperfections (Guo et al., 2014). This finding highlights the broader conceptual importance of vertical structure, offering insights that extend beyond the Chinese SOE–POE context to the general role of upstream bottlenecks in shaping market outcomes.

At the same time, our estimates likely understate the true impact of state ownership on upstream monopoly. In reality, administrative monopoly power often extends beyond firms with formal state ownership. For example, many non-SOEs maintain close ties with SOEs or government entities and thus benefit from similar privileges, such as regulatory protection, preferential access to resources, or implicit guarantees. As a result, these firms can exert comparable market power, even without being state-owned. This broader entanglement is not captured by our counterfactual scenario due to data limitation. Therefore, the estimated 8.5%–15.5% contribution of SOEs should be interpreted as a conservative lower bound on the total distortion arising from state influence in upstream markets.

6 Conclusion

We develop a simple model of China's vertical structure, in which upstream industries are monopolized by SOEs while downstream industries are largely liberalized and operate under private competition. This framework not only resolves the specific puzzle regarding the relative profitability of SOEs versus non-SOEs in China but also provides a novel lens through which to understand other important aspects of China's economic development, including structural change, sectoral linkages, international trade, credit subsidies, SOE reforms, and their welfare implications. We hope that this simple model of vertical structure can be easily extended to explore various other important issues in China or even serve as a useful tool for analyzing similar development challenges in other emerging markets.

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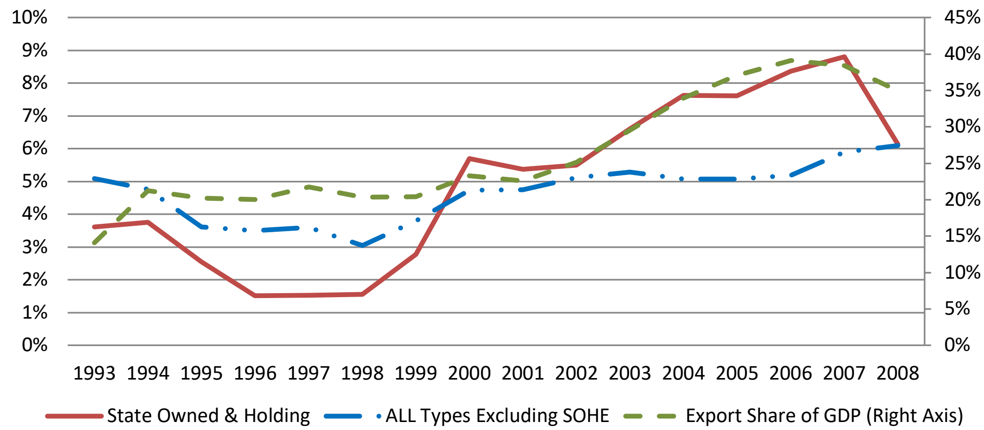
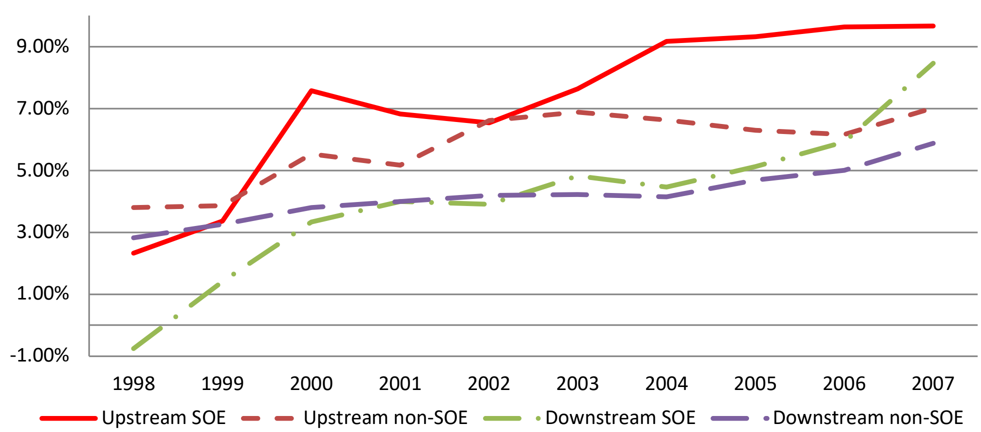
Online Appendix

A Additional Figures and Tables



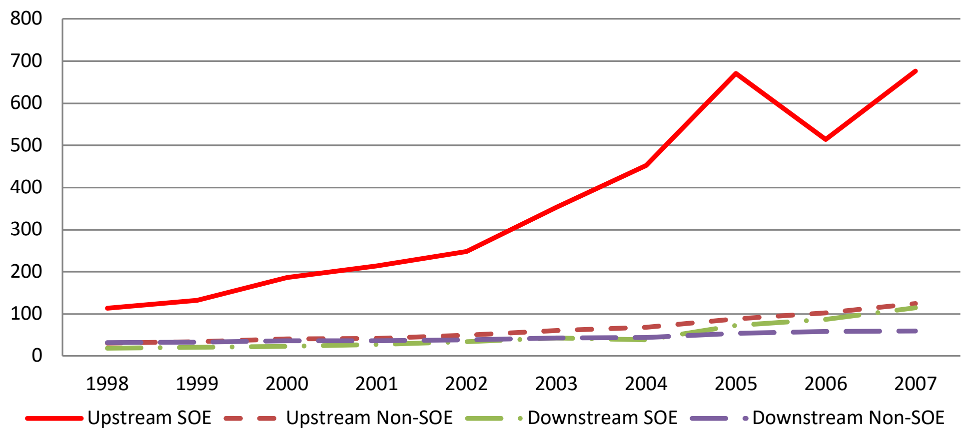
Note: We use CEIC (Table CN.BF: Industrial Financial Data: By Enterprise Type) to obtain total profit to sales revenue. In this table, CEIC categorizes industrial enterprises into state owned & holding, private, HMT & foreign, collective owned, shareholding corporations, foreign funded, and Hong Kong, Macau & Taiwan funded. We divide all the industrial enterprises into state owned & holding and the rest.

Figure A1: Total profit to sales revenues of Chinese enterprises in the industrial sector



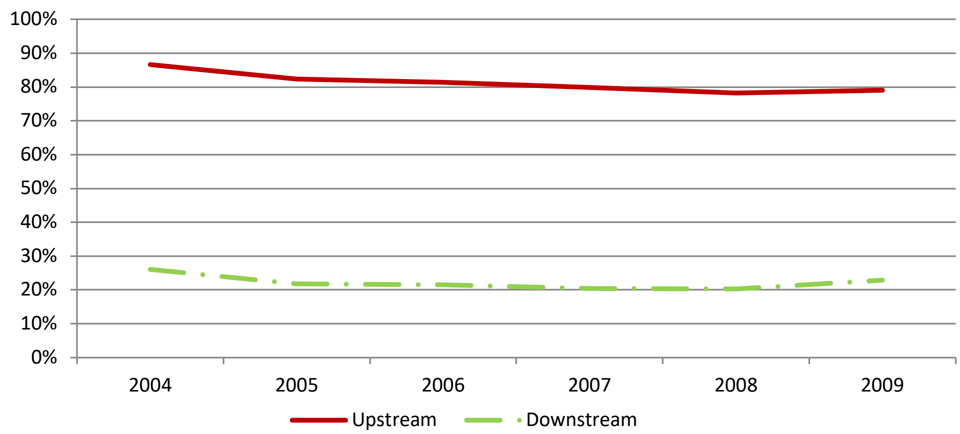
Note: We use NBS industrial enterprises data to obtain total profit to sales revenue and divide all the industrial enterprises into state owned & holding and the rest.

Figure A2: Total profit to sales revenue of Chinese enterprises in the industrial sector

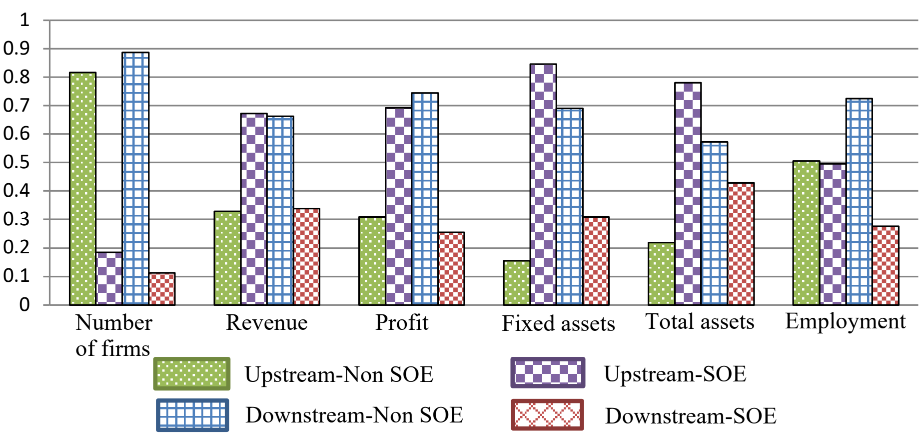


Note: Data Source: NBS.

Figure A3: Average total revenue per enterprise for 1998-2007 (million RMB)



(a) SOE share of investment in fixed assets from aggregate data for all sectors



(b) SOE share of various variables from NBS enterprise level data for all sectors, 2008

Note: Figure A4a reports the investments in fixed assets in urban areas by ownership for all sectors using data from the following tables of National Bureau of Statistics (NBS) of China: Investment in Urban Area by Sector, Source of Funds, Jurisdiction of Management and Registration Status. Note that NBS has changed the column title of state related ownership over time. NBS uses "state-owned and state-controlled" in Tables 6-14 of 2004; "state-owned and state-holding" in Tables 6-14 of 2005; "state-holding" in Tables 6-14 of 2006; and "state-holding" in Tables 5-14 of 2007-2008. Before year 2004, data for the state enterprises are not available. Figure A4b reports for various variables using NBS enterprise level all sector data available for 2008.

Figure A4: SOE share of all sectors

Table A1: Stream Classification for Industrial Sectors

Ind #	Industries	2007 Stream Score	Profit Margin	Export Exposure	Herfindahl-Hirschman Index
	Upstream				
1	Coal	5.64	0.0613	0.0175	0.0096
2	Petroleum and Natural Gas	5.83	0.1589	0.0103	0.1016
3	Ferrous Metal Ores	5.60	0.0733	0.0086	0.0065
4	Non-Ferrous Metal Ores	5.60	0.0654	0.0092	0.0081
6	Other Ores	4.23	0.0296	0.0077	0.2250
17	Paper and Paper Products	4.42	0.0207	0.0386	0.0031
20	Petroleum, Nuclear fuel	4.91	0.0228	0.0072	0.0200
21	Raw chemical materials	4.71	0.0251	0.0979	0.0024
27	Smelting Ferrous Metals	4.58	0.009	0.048	0.0099
28	Smelting and Pressing of Non-ferrous Metals	4.58	0.0172	0.0478	0.0045
38	Electric Power and Heat Power	5.22	0.0045	0.0375	0.0111
39	Gas	5.83	-0.0284	0.0106	0.0224
	Average across all enterprises in upstream		0.0257	0.0554	0.0065
	Middle Stream				
5	Nonmetal Ores	4.23	0.0353	0.0075	0.0042
34	Communication Equipment, computer	4.22	0.012	0.0276	0.0057
29	Metal Products	4.11	0.0223	0.017	0.0008
16	Furniture	3.43	0.0251	0.0665	0.0026
33	Electrical Machinery and Equipment	3.35	0.0313	0.0227	0.0029
30	General Purpose Machinery	3.09	0.0224	0.0449	0.0014
31	Special Purpose Machinery	3.09	0.0039	0.0454	0.0020
15	Wood, Bamboo, Rattan etc.	3.43	0.0208	0.0662	0.0025
22	Medicines	3.38	0.0097	0.005	0.0038
40	Water	3.71	-0.0504	0.0023	0.0082
	Average across all enterprises in midstream		0.0153	0.0324	0.0024
	Downstream				
8	Food from Agricultural Products	2.57	-0.0026	0.2555	0.0013
9	Foods	2.57	-0.0126	0.4934	0.0028
10	Beverages	2.57	-0.0304	0.4935	0.0060
13	Textile Wearing Apparel	2.48	0.0209	0.5405	0.0010
14	Leather, Fur, etc.	2.48	0.0217	0.5376	0.0018
18	Printing, Media	2.48	-0.0045	0.0289	0.0019
19	Articles for culture, education	1.22	0.0201	0.0474	0.0024
26	Non-metallic Mineral Products	3.03	0.0162	0.0244	0.0005
32	Transport Equipment	2.75	0.0068	0.0705	0.0086
35	Machinery	3.09	0.0004	0.0465	0.0067
36	Artwork and other manufacturing	2.66	0.0177	0.0575	0.0045
37	Recycling	2.58	0.0162	0.0589	0.0032
	Average across all enterprises in downstream		0.0073	0.2188	0.0028

Note: Stream scores are calculated by following Antràs et al. (2012) using China's IO table. More details are available upon request as to how various adjustments are appropriately made. Data Source: NBS.

Table A2: Stream Classification for All Sectors

Ind #	Industries	2008 Stream Score
	Upstream	
7	Extraction of petroleum and natural gas	5.83
8	Mining and processing of ferrous metal ores	5.60
44-45	Production and distribution of electric power and heat power and gas	5.22
43	Recycling and disposal of waste	5.16
25	Processing of petroleum, coking, processing of nuclear fuel	4.91
26/29	Manufacture of chemical raw materials and chemical products / Manufacture of rubber	4.71
33	Smelting and processing of non-ferrous metals	4.58
22/23 /24	Manufacture of paper and paper production / Printing and recorded / Manufacture of articles for culture, education and sport activity media	4.42
10	Mining and processing of nonmetal ores	4.23
34	Manufacture of metal products	4.11
	Middle Stream	
46	Production and distribution of tap water	3.71
51-55, 57-58	Railway transport / Road transport / Urban public transport / Water transport / Air transport / Loading/unloading, removal, and other transport services / Storage	3.63
68-71	Banking / Securities / Insurance / Other financial activities	3.62
73	Leasing	3.60
59	Postal services	3.44
20-21	Processing of timber, manufacture of wood, bamboo, rattan, palm, and straw products / Manufacture of furniture	3.43
39	Manufacture of electrical machinery and equipment	3.35
1	Farming	3.17
35-36, 41	Manufacture of general purpose machinery / Manufacture of special purpose machinery / Manufacture of measuring instruments and machinery for cultural activity and office work	3.09
31	Manufacture of non-metallic mineral products	3.03
	Downstream	
63-65	Wholesale trade / Retail trade	2.94
37	Manufacture of transport equipment	2.75
66-67	Accommodation / Catering	2.67
42	Manufacture of artwork and other manufacturing	2.66
60-62	Telecommunications and other information transfer services / Computer services / Software	2.62
82-83	Resident services / Other services	2.58
13-15	Processing of food from agricultural products / Manufacture of foods / Manufacture of beverages	2.57
18-19	Manufacture of textile, apparel, footwear, and caps / Manufacture of leather, fur, feather and related products	2.48
92	Entertainment	2.48
72	Real estate	1.76
47-50	Construction of buildings, and civil engineering / Renovation / Decoration / Other construction	1.06

Note: There are various adjustments. For example, some industries are deleted because there is no match from I/O table or they are non-commercial sectors, which are not relevant for this paper. Details are available upon request.

Table A3: Chinese Exports by Enterprise Ownership

Year	Total Exports	Exports by Ownership		Share of export from SOEs (%)	Gross Industrial Output from SOEs (%)
		SOEs	non-SOEs		
1994	121.01	84.94	36.06	70.20	37.34
1995	148.78	99.25	49.53	66.71	33.97
1996	151.05	86.04	65.01	56.96	36.32
1997	182.79	102.74	80.05	56.21	31.62
1998	183.81	96.85	86.96	52.69	49.63
2000	249.20	116.45	132.76	46.73	47.34
2002	325.60	122.85	202.75	37.73	40.78
2004	593.33	153.58	439.75	25.88	34.81
2006	968.94	191.33	777.60	19.75	31.24
2008	1430.69	257.48	1173.21	18.00	28.37

Note: Exports are in billions of US dollars. The data come from China Customs. Data for some years are missing.

Table A4: Does downstream firm TFP or export tariff affect upstream firm profits (Upstream and midstream firms)

	Dependent Variable = Change in Log(Profit)					
	(1)	(2)	(3)	(4)	(5)	(6)
ΔTFP_t	0.8128***		0.7826***	0.8128***		0.7826***
	(0.0476)		(0.0481)	(0.2802)		(0.2744)
$\Delta \text{Tariff}_{t-1}$		-18.1167***	-15.7881***		-18.1167**	-15.7881**
		(1.9993)	(2.0050)		(6.7609)	(5.9187)
Observations	381,450	376,946	376,946	381,450	376,946	376,946
Adjusted R^2	0.0218	0.0214	0.0220	0.0218	0.0214	0.0220
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Firm	Firm	Firm	Industry	Industry	Industry

Note: Both upstream and midstream firms are included in the analysis. All regressions include control variables as well as year fixed effects. Standard errors are clustered at either the firm or the industry level. *** p<0.01, ** p<0.05, * p<0.1.

B Further Empirical Evidence

B.1 Alternative Profitability Measures

We test the robustness of our findings using alternative profitability measures, including profit per employee and return on assets. We re-estimate Equation (2) using these alternative outcomes under our baseline SOE definition (SOE 3), and report the results in Table B1. Across specifications, SOEs are consistently less profitable than non-SOEs. At the same time, SOE profitability improves significantly relative to non-SOEs after 2001, as indicated by the positive and significant coefficient on the SOE×Post2001 interaction. However, in all cases, the magnitude of this positive coefficient is smaller than that of the negative coefficient on the SOE indicator itself, implying that SOEs remain less profitable even after 2001.

These results are consistent with the main findings in Table 5 and with the broader literature such as Allen et al. (2024). For our purpose, the central point is not the absolute profitability level, but the relative change: SOEs experience a significant relative improvement in profitability after 2001, even if they remain less profitable overall.

Table B1: Different Profitability Measures

Dependent variable	Profit/Employee (1)	Return on Assets (2)
SOE	-13.04***	-0.0362***
	(2.298)	(0.0036)
SOE×Post2001	4.814**	0.0091*
	(2.067)	(0.0044)
Observations	1,801,306	1,801,306
Adjusted R^2	0.2472	0.2829
Year FE	Yes	Yes
City FE	Yes	Yes
Industry FE	Yes	Yes
Controls	Yes	Yes
Weighted	Yes	Yes

Note: All regressions include control variables as well as year, city, and industry fixed effects, and are weighted by firm employment and total asset, respectively. Standard errors are clustered at the firm and year levels. *** p<0.01, ** p<0.05, * p<0.1.

B.2 Comparison with Aggregate Data

We examine whether the aggregate patterns documented in Figures 1–2 are robust when using the firm-level data. Because the ASIE data begins in 1998, the time coverage is shorter, but we find that the main trends remain highly consistent with those of the aggregate data.

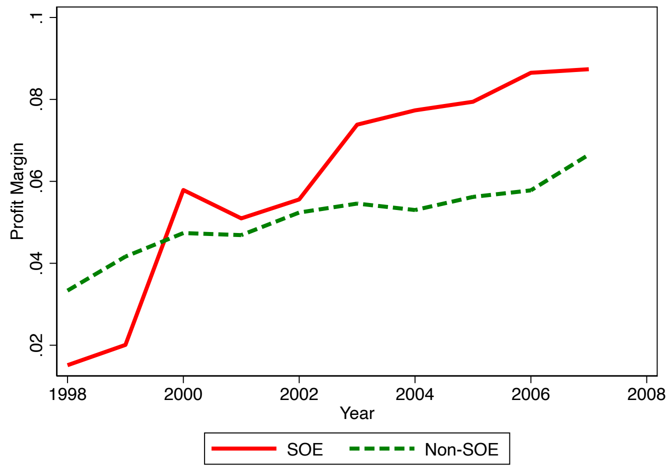


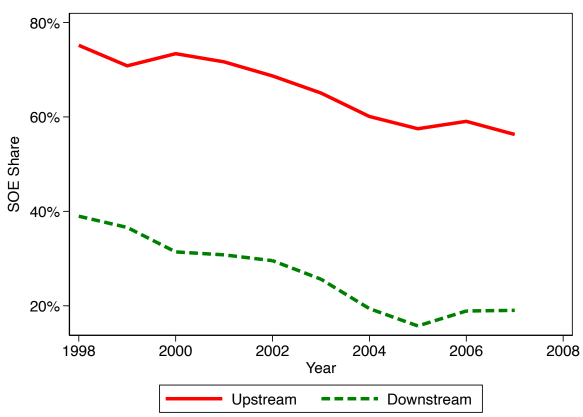
Figure B1: Operating profit to sales revenues of Chinese enterprises in the industrial sector using the enterprise level data

As shown in Figure B1, under our baseline SOE definition (SOE 3), SOE profit margins[26] were initially below those of non-SOEs but later surpassed them. The timing of this crossover and the overall trajectories closely mirror those in Figure 1. Moreover, the levels of profit margins during the overlapping period are highly consistent across the two data sources of NBS aggregate data and the ASIE firm level data, with both profit margins in Figure 1 and B1 rising from below 2% to nearly 9%.

Figure B2 replicates Figure 2 using the firm-level data. The results confirm that SOEs accounted for a much larger share of value added in the upstream industries. Although SOE shares decline over time, the decline is much slower in the upstream industries, where SOEs continue to account for more than half of total value added.

[26]We use operating profits instead of total profits to better capture firms' earnings from core activities. The two measures are highly correlated and visually indistinguishable at the aggregate level.

(a) SOE Share (Value-Added)



(b) Normalized SOE Share (Year 1998=100%)

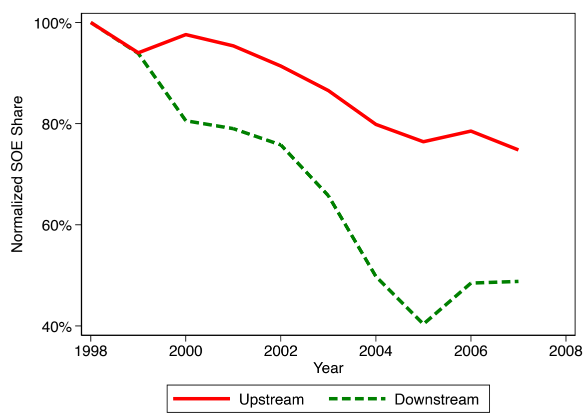


Figure B2: SOE share in the industrial sector using the enterprise level data

C Mathematical Proofs

Proofs of Lemma 1, Propositions 1-2, and Corollary 1: The proofs are straightforward based on the discussion in the main text and hence are omitted.

Results Under Horizontal Structure: This is to show that SOE profit is hurt by an increase in the TFP of private firms under horizontal structure, which is opposite to the prediction in the vertical structure. For ease of comparison, we adopt a horizontal-structure setup similar to Song, Storesletten and Zilibotti (2011). Suppose households' utility function is a strictly increasing function of the aggregate consumption. The final output Y is produced by "horizontally" combining the output of the private firm product Y_p and that of the SOE product Y_s in a CES form with substitution elasticity σ:

$$Y = (Y_p^{\frac{\sigma-1}{\sigma}} + Y_s^{\frac{\sigma-1}{\sigma}})^{\frac{\sigma}{\sigma-1}}, \sigma > 1.$$

Suppose labor is the only input and the technologies are given by

$$Y_p = A_p L_p; Y_s = A_s L_s.$$

Furthermore, assume perfect competition and free entry in the private sector but a monopoly market structure in the sector that produces Y_s. Labor market clears in this autarky general equilibrium

$$L_p + L_s = L,$$

where L is the total labor endowment. It can be shown that the profit of the SOE is given by

$$\Pi = \frac{WL}{\sigma\left[\left(\frac{A_s}{A_p}\frac{\sigma-1}{\sigma}\right)^{1-\sigma} + 1\right] - 1}.$$

Suppose we normalize wage to be unity. Clearly, $\frac{\partial \Pi}{\partial A_p} < 0$. That is, an increase in private TFP hurts the monopoly profit of the SOE when private firms and the SOE are producing horizontally differentiated goods. The intuition is that the demand for the SOE product declines as the private good becomes cheaper due to its productivity increase, hence the SOE profit goes down. It is drastically different from the prediction under vertical structure ($\frac{\partial \Pi_m}{\partial A} > 0$), as highlighted in Proposition 2.

Suppose, instead, we choose the final output as the numeraire, then we have

$$W = \left[\left(\frac{1}{A_s}\frac{\sigma}{\sigma-1}\right)^{1-\sigma} + \left(\frac{1}{A_p}\right)^{1-\sigma}\right]^{-\frac{1}{1-\sigma}},$$

and therefore

$$\Pi = \frac{\left[\left(\frac{1}{A_s}\frac{\sigma}{\sigma-1}\right)^{1-\sigma} + \left(\frac{1}{A_p}\right)^{1-\sigma}\right]^{-\frac{1}{1-\sigma}} L}{\sigma\left[\left(\frac{A_s}{A_p}\frac{\sigma-1}{\sigma}\right)^{1-\sigma} + 1\right] - 1}.$$

We can show that $\frac{\partial \Pi}{\partial A_p} < 0$ holds whenever $\sigma \geq 2$. It also holds when $\sigma \in (1, 2)$ and

$$\frac{A_s}{A_p} > \frac{\sigma}{\sigma - 1}\left[\frac{(\sigma-1)^2}{\sigma(2-\sigma)}\right]^{\frac{1}{1-\sigma}}. \tag{28}$$

The intuition is as follows. When A_p increases, it has a positive income effect on the demand for SOE product, which increases the SOE profit. On the other hand, it also has a negative substitution effect on the demand for the SOE product, which reduces the SOE profit. When the substitution elasticity between the SOE product and the private product is sufficiently large ($\sigma \geq 2$), the substitution effect dominates, so $\frac{\partial \Pi}{\partial A_p} < 0$. When $\sigma \in (1, 2)$, the productivity of private firms has to be sufficiently small (that is, (29) is satisfied) so that the substitution effect still dominates the income effect.

Proof of Proposition 3: One set of sufficient conditions is that the upstream technology is sufficiently capital intensive whereas the downstream technology is sufficiently labor intensive. More precisely, $\gamma = 1$, $\alpha > 0$, and β is sufficiently large such that

$$\left[1 + \frac{1}{(1-\alpha-\beta)(\epsilon-1)}\right]^{\alpha} < \left(1 + \frac{\frac{\alpha}{1-\beta}}{(1-\alpha-\beta)(\epsilon-1)}\right)^{1-\beta}. \tag{29}$$

The key results (i.e., predictions for upstream and downstream prices, total industrial employment, industrial output, welfare, etc.) also hold when capital is not needed for production at all, namely, $\gamma = \alpha = 0$, even though now the rental price is always $R = 0$.

Now we provide the proof for the above claim and also the characterization for the general case. Consider the general case in which everything is identical to the setting in Section 3.1 except that the upstream industry has N symmetric SOEs, where N can be any positive integer. In particular, when $N = 1$, it returns to the original setting with only one firm monopolizing the upstream industry. When $N \to \infty$, the upstream becomes perfectly competitive. It is straightforward to show that for any arbitrary N the markup μ is now given by

$$\mu \equiv \frac{N\left[(1-\alpha-\beta)(\epsilon-1)+1\right]}{N\left[(1-\alpha-\beta)(\epsilon-1)+1\right]-1},$$

which obviously decreases with N. For Proposition 3, it suffices to compare the two cases when

$N = 1$ and $N = \infty$. To avoid the trivial cases, we always assume that the upstream intermediate input is crucial for downstream production, i.e., $1 - \alpha - \beta > 0$.

[1] We can show that R strictly decreases with μ if and only if $\alpha > 0$ or $\gamma > 0$ or both. So R strictly increases after upstream liberalization. $R = 0$ always holds if $\alpha = \gamma = 0$.

[2] We can show that p_m strictly increases with μ when $\alpha > 0$ or $1 > \gamma > 0$, or both. More precisely,

$$p_m = p_n \cdot \frac{\mu \varkappa^{\xi\gamma} A_n^{1-\gamma} A_m^{-1}}{\gamma^\gamma (1-\gamma)^{1-\gamma}} \propto \mu \varkappa^{\xi\gamma} \propto [\gamma(1-\alpha-\beta) + \alpha\mu]^{\xi\gamma} \mu^{[(1-\alpha-\beta)(1-\epsilon)-1]\xi\gamma+1}$$

so $\frac{\partial p_m}{\partial \mu} > 0$ if and only if

$$\xi\gamma\alpha\mu + [\gamma(1-\alpha-\beta) + \alpha\mu] \left\{ \frac{\alpha(\epsilon-1) + 1 - \gamma}{1 + \alpha(\epsilon-1) + \gamma(1-\alpha-\beta)(\epsilon-1)} \right\} > 0,$$

which is always true when $\alpha > 0$ or $1 > \gamma > 0$, or both. For binary comparison, p_m becomes strictly smaller after the full liberalization of the upstream if and only if

$$\begin{aligned} [\gamma(1-\alpha-\beta) + \alpha\mu]^{\xi\gamma} \mu^{[(1-\alpha-\beta)(1-\epsilon)-1]\xi\gamma+1} &> [\gamma(1-\alpha-\beta) + \alpha]^{\xi\gamma}, \\ [\gamma(1-\alpha-\beta) + \alpha\mu]^{\xi\gamma} \mu^{\frac{1-\gamma+\alpha(\epsilon-1)}{1+\alpha(\epsilon-1)+\gamma(1-\alpha-\beta)(\epsilon-1)}} &> [\gamma(1-\alpha-\beta) + \alpha]^{\xi\gamma} \end{aligned}$$

which is always true except when $1 - \gamma = \alpha = 0$. It is also true when $\alpha = \gamma = 0$, because in that case p_m drops from $\mu \frac{A_n}{A_m} p_n$ to $\frac{A_n}{A_m} p_n$.

[3] We can show that p_d becomes strictly smaller after the full liberalization of the upstream industry if and only if

$$\left[\frac{(1-\alpha-\beta)(\epsilon-1)+1}{(1-\alpha-\beta)(\epsilon-1)} \right]^{\alpha+(\gamma-1)(1-\alpha-\beta)} < \left[\frac{\gamma(1-\alpha-\beta) + \alpha + \frac{\alpha}{(1-\alpha-\beta)(\epsilon-1)}}{\gamma(1-\alpha-\beta)+\alpha} \right]^{\alpha+\gamma(1-\alpha-\beta)}. \quad (30)$$

In particular, it holds when $\gamma = 1$, $\alpha > 0$, and β is sufficiently large ($\frac{1-\beta}{\alpha}$ is sufficiently small) such that

$$\left[1 + \frac{1}{(1-\alpha-\beta)(\epsilon-1)} \right] < \left[1 + \frac{\frac{\alpha}{1-\beta}}{(1-\alpha-\beta)(\epsilon-1)} \right]^{\frac{1-\beta}{\alpha}}.$$

In addition, p_d also becomes strictly smaller after the full liberalization when $\alpha = \gamma = 0$, because $p_d = \frac{W^\beta p_m^{1-\beta}}{A\beta^\beta (1-\beta)^{1-\beta}}$, where p_m decreases and W remains constant (equal to $A_n p_n$).

[4] Downstream industrial output in equilibrium strictly decreases with p_d. So the total output for downstream good d strictly increases after the full liberalization of the upstream if and only if (29) is true.

[5] Total industrial employment is given by

$$
\begin{aligned}
& \overline{L}(A_n, A, A_m, K) \\
\propto \quad & [\gamma(1-\alpha-\beta)+\alpha\mu]^{\xi-1}\,\mu^{[(1-\alpha-\beta)(1-\epsilon)-1]\xi}\,[(1-\gamma)(1-\alpha-\beta)+\beta\mu] \\
= \quad & [\gamma(1-\alpha-\beta)+\alpha\mu]^{-\frac{\alpha(\epsilon-1)+\gamma(1-\alpha-\beta)(\epsilon-1)}{1+\alpha(\epsilon-1)+\gamma(1-\alpha-\beta)(\epsilon-1)}}\,\mu^{\frac{\alpha-(1-\gamma)(1-\alpha-\beta)}{1+\alpha(\epsilon-1)+\gamma(1-\alpha-\beta)(\epsilon-1)}(\epsilon-1)}\left[\frac{(1-\gamma)(1-\alpha-\beta)+\beta\mu}{\mu}\right],
\end{aligned}
$$

which becomes strictly larger after the upstream full liberalization if and only if

$$
\begin{aligned}
& \left[\frac{(1-\alpha-\beta)(\epsilon-1)+1}{(1-\alpha-\beta)(\epsilon-1)}\right]^{\alpha+(\gamma-1)(1-\alpha-\beta)}\left[1-\frac{\frac{(1-\gamma)(1-\alpha-\beta)}{(1-\gamma)(1-\alpha-\beta)+\beta}}{1+(1-\alpha-\beta)(\epsilon-1)}\right]^{\frac{1+\alpha(\epsilon-1)+\gamma(1-\alpha-\beta)(\epsilon-1)}{(\epsilon-1)}} \\
< \quad & \left[\frac{\gamma(1-\alpha-\beta)+\alpha+\frac{\alpha}{(1-\alpha-\beta)(\epsilon-1)}}{\gamma(1-\alpha-\beta)+\alpha}\right]^{\alpha+\gamma(1-\alpha-\beta)}.
\end{aligned}
$$

In particular, the above inequality is equivalent to (29) when $\gamma = 1$ and $\alpha > 0$. When $\alpha = \gamma = 0$, $\overline{L}(A_n, A, A_m, K) \propto \mu^{(1-\beta)(1-\epsilon)-1}[(1-\beta)+\beta\mu]$, which strictly decreases with μ, so it becomes strictly larger after full liberalization.

[6] GDP (per capita) Y strictly increases with $\frac{\alpha\mu+(1-\alpha-\beta)(\gamma+\mu-1)}{(1-\gamma)(1-\alpha-\beta)+\beta\mu}\overline{L}(A_n, A, A_m, K)$, or

$$
\left[\frac{\gamma(1-\alpha-\beta)+\alpha\mu}{\mu}\left\{\mu^{1-\alpha-\beta}\right\}^{1-\epsilon}\right]^{\xi}\frac{(1-\beta)\mu-(1-\alpha-\beta)(1-\gamma)}{\gamma(1-\alpha-\beta)+\alpha\mu},
$$

which becomes strictly larger after full liberalization if and only if

$$
\begin{aligned}
& \left[\frac{\gamma(1-\alpha-\beta)+\alpha\mu}{\mu}\left\{\mu^{1-\alpha-\beta}\right\}^{1-\epsilon}\right]^{\xi}\frac{(1-\beta)\mu-(1-\alpha-\beta)(1-\gamma)}{\gamma(1-\alpha-\beta)+\alpha\mu} \\
< \quad & [\gamma(1-\alpha-\beta)+\alpha]^{\xi-1}[(1-\beta)-(1-\alpha-\beta)(1-\gamma)],
\end{aligned}
$$

which is equivalent to (29) when $\gamma = 1$ and $\alpha > 0$. However, Y becomes smaller after full liberalization when $\alpha = \gamma = 0$, because, without capital, we have $Y = WL + \Pi_m$, where W stays unchanged but Π_m becomes zero after upstream liberalization.

[7] Welfare. We can derive the welfare of an average household (assuming equal income across all the agents after lump-sum transfer from the state-affiliated agents to the private agents):

$$
\begin{aligned}
u(c_n, c_d) \quad = \quad & c_n + \frac{\epsilon}{\epsilon-1}c_d^{\frac{\epsilon-1}{\epsilon}} = \frac{WL+RK+\Pi_m}{p_n} - \left(\frac{p_n}{p_d}\right)^{\epsilon-1} + \frac{\epsilon}{\epsilon-1}\left[\left(\frac{p_n}{p_d}\right)^{\epsilon}\right]^{\frac{\epsilon-1}{\epsilon}} \\
= \quad & A_nL + \frac{\varkappa^{\xi}\left[(1-\alpha-\beta)(\mu-1)+\frac{\mu}{\epsilon-1}\right]}{\gamma(1-\alpha-\beta)+\alpha\mu}\left[A_n^{\alpha+\gamma(1-\alpha-\beta)-1}A_m^{1-\alpha-\beta}AK^{\alpha+\gamma(1-\alpha-\beta)}\right]^{\xi(\epsilon-1)},
\end{aligned}
$$

which becomes strictly larger after full liberalization when γ and α are not both zero if and only if

$$\begin{aligned}\frac{\left[(1-\alpha-\beta)(\mu-1)+\frac{\mu}{\epsilon-1}\right]}{\gamma(1-\alpha-\beta)+\alpha\mu} &< \frac{\frac{1}{\epsilon-1}}{\gamma(1-\alpha-\beta)+\alpha},\\ (1-\alpha-\beta)(\epsilon-1)+1 &< \frac{\alpha}{\gamma(1-\alpha-\beta)+\alpha},\end{aligned}$$

which is never possible.

The welfare of a representative private agent is given by

$$\begin{aligned}& A_nL+\frac{\varkappa^{\xi}\left[(1-\alpha-\beta)(\mu-1)+\frac{\mu}{\epsilon-1}\right]}{\gamma(1-\alpha-\beta)+\alpha\mu}\left[A_n^{\alpha+\gamma(1-\alpha-\beta)-1}A_m^{1-\alpha-\beta}AK^{\alpha+\gamma(1-\alpha-\beta)}\right]^{\xi(\epsilon-1)}-\frac{\Pi_m}{p_n}\\ =\;& A_nL+\frac{\varkappa^{\xi}\left[(1-\alpha-\beta)(\mu-1)+\frac{\mu}{\epsilon-1}\right]}{\gamma(1-\alpha-\beta)+\alpha\mu}\left[A_n^{\alpha+\gamma(1-\alpha-\beta)-1}A_m^{1-\alpha-\beta}AK^{\alpha+\gamma(1-\alpha-\beta)}\right]^{\xi(\epsilon-1)}\\ & -\frac{(1-\alpha-\beta)(\mu-1)}{(1-\gamma)(1-\alpha-\beta)+\beta\mu}\overline{L}(A_n,A,A_m,K)A_n\end{aligned}$$

which strictly increases with

$$[\gamma(1-\alpha-\beta)+\alpha\mu]^{-\frac{\alpha+\gamma(1-\alpha-\beta)}{1+\alpha(\epsilon-1)+\gamma(1-\alpha-\beta)(\epsilon-1)}}\,\mu^{\frac{\alpha+(\gamma-1)(1-\alpha-\beta)}{1+\alpha(\epsilon-1)+\gamma(1-\alpha-\beta)(\epsilon-1)}},$$

which becomes strictly larger after full liberalization when γ and α are not both zero iff

$$[\gamma(1-\alpha-\beta)+\alpha\mu]^{-[\alpha+\gamma(1-\alpha-\beta)]}\,\mu^{\alpha+(\gamma-1)(1-\alpha-\beta)}<[\gamma(1-\alpha-\beta)+\alpha]^{-[\alpha+\gamma(1-\alpha-\beta)]}$$

or

$$\left[1+\frac{1}{(1-\alpha-\beta)(\epsilon-1)}\right]^{\alpha+(\gamma-1)(1-\alpha-\beta)}<\left[1+\frac{\frac{\alpha}{\gamma(1-\alpha-\beta)+\alpha}}{(1-\alpha-\beta)(\epsilon-1)}\right]^{\alpha+\gamma(1-\alpha-\beta)},$$

which is equivalent to (29) when $\gamma=1$ and $\alpha>0$. When $\alpha=\gamma=0$, the private-agent welfare also becomes strictly larger after full liberalization because their income remains constant but p_d becomes strictly lower.

On the other hand, the welfare of a representative state-affiliated agent becomes strictly worse off after upstream liberalization because each earns income $WL+RK+\frac{\Pi_m}{\theta}$, which is strictly larger than average income Y whenever $\Pi_m>0$. We can derive the welfare of a household with the average income level Y is given by

$$\begin{aligned}u(c_n,c_d) &= c_n+\frac{\epsilon}{\epsilon-1}c_d^{\frac{\epsilon-1}{\epsilon}}=\frac{WL+RK+\Pi_m}{p_n}-\left(\frac{p_n}{p_d}\right)^{\epsilon-1}+\frac{\epsilon}{\epsilon-1}\left[\left(\frac{p_n}{p_d}\right)^{\epsilon}\right]^{\frac{\epsilon-1}{\epsilon}}\\ &= A_nL+\frac{\varkappa^{\xi}\left[(1-\alpha-\beta)(\mu-1)+\frac{\mu}{\epsilon-1}\right]}{\gamma(1-\alpha-\beta)+\alpha\mu}\left[A_n^{\alpha+\gamma(1-\alpha-\beta)-1}A_m^{1-\alpha-\beta}AK^{\alpha+\gamma(1-\alpha-\beta)}\right]^{\xi(\epsilon-1)},\end{aligned}$$

which becomes strictly smaller after full liberalization when γ and α are not both zero iff

$$(1-\alpha-\beta)(\epsilon-1)+1>\frac{\alpha}{\gamma\left(1-\alpha-\beta\right)+\alpha},$$

which is always true. So the welfare loss of a state-affiliated agent is even larger after full liberalization. When $\alpha=\gamma=0$, the welfare of each of the state-affiliated households also becomes strictly smaller after full liberalization when θ is sufficiently small, because their income drops too much despite the decrease in p_d.

Proof of Proposition 4: With credit subsidy, we have $p_m=\mu\frac{(R(1-\tau))^{\gamma}W^{1-\gamma}}{A_m\gamma^{\gamma}(1-\gamma)^{1-\gamma}}$, $L=D_m\frac{\partial\frac{(R(1-\tau))^{\gamma}W^{1-\gamma}}{A_m\gamma^{\gamma}(1-\gamma)^{1-\gamma}}}{\partial W}+D_d\frac{\partial p_d}{\partial W}+D_n\frac{1}{A_n}$, and $K=D_m\frac{\partial\frac{(R(1-\tau))^{\gamma}W^{1-\gamma}}{A_m\gamma^{\gamma}(1-\gamma)^{1-\gamma}}}{\partial(R(1-\tau))}+D_d\frac{\partial p_d}{\partial R}$. By combining these, we obtain a result similar to that in Lemma 1, but with an updated $\varkappa$ as in (23). Industrial employment changes to (22). By collecting all terms regarding τ in $\hat{L}$, we have

$$\hat{L}(A_n,A,A_m,K)\propto\left[(1-\alpha-\beta)\,\frac{\gamma}{1-\tau}+\alpha\mu\right]^{\xi-1}\cdot(1-\tau)^{-\gamma(1-\alpha-\beta)(\epsilon-1)\xi},$$

where $\xi\equiv\frac{1}{1+\alpha(\epsilon-1)+\gamma(1-\alpha-\beta)(\epsilon-1)}$. The first-order condition with respect to τ is

$$\frac{\partial\hat{L}}{\partial\tau}=(\xi-1)\left[(1-\alpha-\beta)\left(\gamma x\right)+\alpha\mu\right]^{-1}+(\epsilon-1)\,\xi x^{-1}=0,$$

where $x=\frac{1}{1-\tau}$. So we have $x=\mu$ or $\frac{1}{1-\tau^{*}}=\mu$. Moreover, the second-order condition is $\frac{\partial^2\hat{L}}{\partial\tau^2}<0$.

Note that $e\equiv p_dc_d$ is the total output of the industrial sector. We find the factor shares: $\hat{L}W=e\cdot\left[(1-\alpha-\beta)\,(1-\gamma)\,\frac{1}{\mu}+\beta\right]$, $KR=e\cdot\left[(1-\alpha-\beta)\,\frac{\gamma/\mu}{1-\tau}+\alpha\right]$, and $\Pi_m=e\cdot\left[(1-\alpha-\beta)\,\frac{\mu-1}{\mu}\right]$.

To ensure that the private agents also consume good n, it requires $p_dc_d\le I_p-T$. Let $\tilde{L}$ be the threshold of L to have $p_dc_d=I_p-T$. Using $e\equiv p_dc_d$, $I_p=W\tilde{L}+RK$ and $T=\tau RK_m$, it follows $e=\left(W\tilde{L}+RK\right)-\tau RK_m$. Because $KR=e\cdot\left[(1-\alpha-\beta)\,\frac{\gamma/\mu}{1-\tau}+\alpha\right]$ and $K_mR=e\cdot\left[(1-\alpha-\beta)\,\frac{\gamma/\mu}{1-\tau}\right]$, we have $W\tilde{L}=e\cdot(1-[(1-\alpha-\beta)\,\gamma/\mu+\alpha])$, which implies (24).

Proof of Lemma 2: The necessary and sufficient conditions for this equilibrium pattern are the following:

$$A^{*1-\epsilon}<\frac{\mu\overline{\overline{L}}(A,A_m,K)}{2\left[(1-\gamma)\,(1-\alpha-\beta)+\beta\mu\right]},\tag{31}$$

$$\frac{\mu\overline{\overline{L}}(A,A_m,K)}{2\left[(1-\gamma)\,(1-\alpha-\beta)+\beta\mu\right]}<L^{*}A^{*},\tag{32}$$

and

$$L>\frac{\frac{\mu}{2}-\gamma\,(1-\alpha-\beta)-\alpha\mu}{(1-\gamma)\,(1-\alpha-\beta)+\beta\mu}\overline{\overline{L}}(A,A_m,K),\tag{33}$$

where $\overline{\overline{L}}(A, A_m, K)$ is the total industrial employment in country H and is given by

$$\overline{\overline{L}}(A, A_m, K) \equiv 2^{\xi} \overline{L}(1, A, A_m, K), \tag{34}$$

where ξ is given by (15).

Condition (31) ensures that country H has a comparative advantage in producing good d so that only country H produces good d and country F only produces and exports good n. Condition (32) ensures that country F consumes both good n and downstream good d. Condition (33) guarantees that each agent in country H, even the private agents, consumes a positive amount of good n (i.e., $I_p > p_n^{\epsilon} p_d^{1-\epsilon}$). For simplicity, assume the following is true:

$$(\epsilon - 3)(1 - \alpha - \beta) + 1 \leq 0, \tag{35}$$

in which case condition (33) automatically implies $L > \overline{\overline{L}}(A, A_m, K)$, ensuring that country H produces a positive amount of good n in equilibrium.

To ensure the trade pattern in equilibrium as described earlier, we require that $\frac{p_d}{p_n} < A^*$, or equivalently

$$\frac{1}{A\alpha^{\alpha}\beta^{\beta}(1-\alpha-\beta)^{1-\alpha-\beta}}\left(\frac{\mu}{A_m\gamma^{\gamma}(1-\gamma)^{1-\gamma}}\right)^{1-\alpha-\beta}\left(\frac{K}{2b}\right)^{\frac{-[\alpha+\gamma(1-\alpha-\beta)]}{1+\alpha(\epsilon-1)+\gamma(1-\alpha-\beta)(\epsilon-1)}} < A^*,$$

where $b \equiv \left[A_m^{(1-\alpha-\beta)} A\right]^{\epsilon-1} \varkappa$. The positive production of good n in country H requires $L > \overline{\overline{L}}$, where $\overline{\overline{L}} \equiv 2^{\frac{1}{1+\alpha(\epsilon-1)+\gamma(1-\alpha-\beta)(\epsilon-1)}} \overline{L}(1, A, A_m, K)$. $\overline{\overline{L}}$ is the total industrial employment in country H. Positive consumption of good n in country F requires $D_n^* = A^* L^* - \frac{p_d D_d^*}{W} > 0$,or equivalently

$$A^*L^* - \left(A\alpha^{\alpha}\beta^{\beta}(1-\alpha-\beta)^{1-\alpha-\beta}\left(\frac{A_m\gamma^{\gamma}(1-\gamma)^{1-\gamma}}{\mu}\right)^{1-\alpha-\beta}\left(\frac{K}{2b}\right)^{\frac{[\alpha+\gamma(1-\alpha-\beta)]}{1+\alpha(\epsilon-1)+\gamma(1-\alpha-\beta)(\epsilon-1)}}\right)^{\epsilon-1} > 0.$$

The individual consumption in country H is given by

$$
\begin{aligned}
c_n^s &= L + (\frac{K}{2b})^{\frac{-1}{1+\alpha(\epsilon-1)+\gamma(1-\alpha-\beta)(\epsilon-1)}} \cdot K + \frac{[\frac{1}{A\alpha^\alpha\beta^\beta(1-\alpha-\beta)^{1-\alpha-\beta}}]^{1-\epsilon}}{[\frac{\mu}{A_m\gamma^\gamma(1-\gamma)^{1-\gamma}}]^{(1-\alpha-\beta)(\epsilon-1)}} \\
&\cdot (\frac{K}{2b})^{\frac{\alpha(\epsilon-1)+\gamma(1-\alpha-\beta)(\epsilon-1)}{1+\alpha(\epsilon-1)+\gamma(1-\alpha-\beta)(\epsilon-1)}} \cdot [\frac{1}{\theta}\frac{2(1-\alpha-\beta)}{(1-\alpha-\beta)(\epsilon-1)+1} - 1], \\
c_n^p &= L + (\frac{K}{2b})^{\frac{-1}{1+\alpha(\epsilon-1)+\gamma(1-\alpha-\beta)(\epsilon-1)}} \cdot K - \frac{[\frac{1}{A\alpha^\alpha\beta^\beta(1-\alpha-\beta)^{1-\alpha-\beta}}]^{1-\epsilon}}{[\frac{\mu}{A_m\gamma^\gamma(1-\gamma)^{1-\gamma}}]^{(1-\alpha-\beta)(\epsilon-1)}} \cdot \\
&\cdot (\frac{K}{2b})^{\frac{\alpha(\epsilon-1)+\gamma(1-\alpha-\beta)(\epsilon-1)}{1+\alpha(\epsilon-1)+\gamma(1-\alpha-\beta)(\epsilon-1)}}, \\
c_d^j &= \left\{\frac{1}{A\alpha^\alpha\beta^\beta(1-\alpha-\beta)^{1-\alpha-\beta}}(\frac{\mu}{A_m\gamma^\gamma(1-\gamma)^{1-\gamma}})^{1-\alpha-\beta}(\frac{K}{2b})^{\frac{-[\alpha+\gamma(1-\alpha-\beta)]}{1+\alpha(\epsilon-1)+\gamma(1-\alpha-\beta)(\epsilon-1)}}\right\}^{-\epsilon}, \\
\forall j &\in \{s, p\}.
\end{aligned}
$$

The aggregate consumption of the numeraire good in country H is

$$
\begin{aligned}
C_n &= L + (\frac{K}{2b})^{\frac{-1}{1+\alpha(\epsilon-1)+\gamma(1-\alpha-\beta)(\epsilon-1)}} \cdot K + \frac{[\frac{1}{A\alpha^\alpha\beta^\beta(1-\alpha-\beta)^{1-\alpha-\beta}}]^{1-\epsilon}}{[\frac{\mu}{A_m\gamma^\gamma(1-\gamma)^{1-\gamma}}]^{(1-\alpha-\beta)(\epsilon-1)}} \\
&\cdot (\frac{K}{2b})^{\frac{\alpha(\epsilon-1)+\gamma(1-\alpha-\beta)(\epsilon-1)}{1+\alpha(\epsilon-1)+\gamma(1-\alpha-\beta)(\epsilon-1)}} [\frac{2(1-\alpha-\beta)}{(1-\alpha-\beta)(\epsilon-1)+1} - 1].
\end{aligned}
$$

For completeness, the total (or individual) consumption in country F is given by

$$
c_n^* = A^*L^* - [\frac{1}{A\alpha^\alpha\beta^\beta(1-\alpha-\beta)^{1-\alpha-\beta}}]^{1-\epsilon}[\frac{\mu}{A_m\gamma^\gamma(1-\gamma)^{1-\gamma}}]^{(1-\alpha-\beta)(1-\epsilon)}(\frac{K}{2b})^{\frac{\alpha(\epsilon-1)+\gamma(1-\alpha-\beta)(\epsilon-1)}{1+\alpha(\epsilon-1)+\gamma(1-\alpha-\beta)(\epsilon-1)}}
$$

and

$$
c_d^* = \left\{\frac{1}{A\alpha^\alpha\beta^\beta(1-\alpha-\beta)^{1-\alpha-\beta}}(\frac{\mu}{A_m\gamma^\gamma(1-\gamma)^{1-\gamma}})^{1-\alpha-\beta}(\frac{K}{2b})^{\frac{-[\alpha+\gamma(1-\alpha-\beta)]}{1+\alpha(\epsilon-1)+\gamma(1-\alpha-\beta)(\epsilon-1)}}\right\}^{-\epsilon}.
$$

The second condition guarantees that $c_n^* > 0$. The total GDP in country F is $I^* = L^*W^* = L^*A^*W$. To ensure that even the private agents in country H consumes a positive amount of good n, we require $RK + WL > p_n^\epsilon p_d^{1-\epsilon}$, which is equivalent to $L > \frac{\frac{\mu}{2}-\gamma(1-\alpha-\beta)-\alpha\mu}{(1-\gamma)(1-\alpha-\beta)+\beta\mu}\overline{\overline{L}}(A, A_m, K)$. Therefore, condition $\frac{\frac{\mu}{2}-\gamma(1-\alpha-\beta)-\alpha\mu}{(1-\gamma)(1-\alpha-\beta)+\beta\mu} \geq 1$ means that $(1-\alpha-\beta)(\epsilon-3)+1 \leq 0$. The capital market clearing condition implies

$$
R = p_n \cdot \left[A_m^{(1-\alpha-\beta)}A\right]^{\frac{(\epsilon-1)}{1+\alpha(\epsilon-1)+\gamma(1-\alpha-\beta)(\epsilon-1)}} (\frac{K}{2\varkappa})^{\frac{-1}{1+\alpha(\epsilon-1)+\gamma(1-\alpha-\beta)(\epsilon-1)}}.
$$

Observe that R is still given by (11) except that K is replaced by $\frac{K}{2}$. To understand why, first notice that the demand functions for good d are identical in the two countries ($D_d = D_d^* = \left(\frac{p_n}{p_d}\right)^\epsilon$, due to the lack of income effect implied by the quasi-linear utility function), so the monopolist SOE charges the same markup as in the autarky case. As the world total demand for good d doubles the domestic demand in country H, the demand for the intermediate good is also scaled up (recall that good d is produced only in country H). Labor is abundant in country H but only half of the capital endowment is used to serve domestic demand for good d, plus the fact that all the technologies are constant returns to scale, so in equilibrium K is replaced by $\frac{K}{2}$. Similarly, we have

$$p_m = p_n \cdot \frac{\mu}{A_m \gamma^\gamma (1-\gamma)^{1-\gamma}} \left[A_m^{(1-\alpha-\beta)} A\right]^{\frac{(\epsilon-1)\gamma}{1+\alpha(\epsilon-1)+\gamma(1-\alpha-\beta)(\epsilon-1)}} \left(\frac{K}{2\varkappa}\right)^{\frac{-\gamma}{1+\alpha(\epsilon-1)+\gamma(1-\alpha-\beta)(\epsilon-1)}},$$

The same is true for the price of downstream good d:

$$p_d = p_n \cdot \left\{ \frac{\left[\frac{\mu}{\gamma^\gamma (1-\gamma)^{1-\gamma}}\right]^{1-\alpha-\beta}}{\alpha^\alpha \beta^\beta (1-\alpha-\beta)^{1-\alpha-\beta}} \right\} \left[A_m^{(1-\alpha-\beta)} A\right]^{\frac{-1}{1+\alpha(\epsilon-1)+\gamma(1-\alpha-\beta)(\epsilon-1)}} \left(\frac{K}{2\varkappa}\right)^{\frac{-[\alpha+\gamma(1-\alpha-\beta)]}{1+\alpha(\epsilon-1)+\gamma(1-\alpha-\beta)(\epsilon-1)}}.$$

Proof of Proposition 5: The proof is straightforward based on the discussion in the main text.

Proof of Proposition 6: Consider any industry j that is monopolized by an SOE. This firm faces the following demand function $D(j) = \left(\frac{p_n}{P}\right)^\epsilon \left[\frac{p(j)}{P}\right]^{-\eta}$, where $p(i)$ denotes the market price of good $i \in [0,1]$ and the price index P is defined as $P \equiv \left(\int_0^1 p(i)^{1-\eta} di\right)^{\frac{1}{1-\eta}}$. The aggregate price P and p_n are taken as given by the SOE, so it would choose $p(j) = \frac{\eta}{\eta-1} \frac{R^\alpha W^\beta {p_m}^{1-\alpha-\beta}}{A_s \alpha^\alpha \beta^\beta (1-\alpha-\beta)^{1-\alpha-\beta}}$. On the other hand, $p(j') = \frac{R^\alpha W^\beta {p_m}^{1-\alpha-\beta}}{A_p \alpha^\alpha \beta^\beta (1-\alpha-\beta)^{1-\alpha-\beta}}$ for any liberalized industry j', so the aggregate price level

$$\begin{aligned} P &= \left(\int_0^1 p(i)^{1-\eta} di\right)^{\frac{1}{1-\eta}} \\ &= \left((1-\phi)\left[\frac{\eta}{\eta-1}\frac{1}{A_s}\right]^{1-\eta} + \phi\left[\frac{1}{A_p}\right]^{1-\eta}\right)^{\frac{1}{1-\eta}} \frac{R^\alpha W^\beta {p_m}^{1-\alpha-\beta}}{\alpha^\alpha \beta^\beta (1-\alpha-\beta)^{1-\alpha-\beta}}. \end{aligned} \tag{45}$$

The induced demand for the intermediate good from the SOE monopolist in industry j is $D(j)\frac{(1-\alpha-\beta)}{p_m}\frac{p(j)}{\frac{\eta}{\eta-1}}$. The total demand for the intermediate good is

$$\begin{aligned}
&\phi\frac{(1-\alpha-\beta)\,p(j')}{p_m}\left(\frac{p_n}{P}\right)^{\epsilon}\left[\frac{p(j')}{P}\right]^{-\eta}+(1-\phi)\left(\frac{p_n}{P}\right)^{\epsilon}\left[\frac{p(j)}{P}\right]^{-\eta}\frac{(1-\alpha-\beta)}{p_m}\frac{p(j)}{\frac{\eta}{\eta-1}} \\
= \quad & p_n^{\epsilon}\frac{(1-\alpha-\beta)}{p_m}\frac{\phi\left(\frac{1}{A_p}\right)^{1-\eta}+(1-\phi)\left[\frac{1}{A_s}\right]^{1-\eta}\left(\frac{\eta}{\eta-1}\right)^{-\eta}}{\left[(1-\phi)\left[\frac{\eta}{\eta-1}\frac{1}{A_s}\right]^{1-\eta}+\phi\left[\frac{1}{A_p}\right]^{1-\eta}\right]^{\frac{\epsilon-\eta}{1-\eta}}}\left[\frac{R^{\alpha}W^{\beta}{p_m}^{1-\alpha-\beta}}{\alpha^{\alpha}\beta^{\beta}(1-\alpha-\beta)^{1-\alpha-\beta}}\right]^{1-\epsilon},
\end{aligned}$$

so the total profit of the upstream SOE is

$$p_n^{\epsilon}\frac{\mu-1}{\mu}(1-\alpha-\beta)\frac{\phi\left(\frac{1}{A_p}\right)^{1-\eta}+(1-\phi)\left[\frac{1}{A_s}\right]^{1-\eta}\left(\frac{\eta}{\eta-1}\right)^{-\eta}}{\left[(1-\phi)\left[\frac{\eta}{\eta-1}\frac{1}{A_s}\right]^{1-\eta}+\phi\left[\frac{1}{A_p}\right]^{1-\eta}\right]^{\frac{\epsilon-\eta}{1-\eta}}}\left[\frac{R^{\alpha}W^{\beta}{p_m}^{1-\alpha-\beta}}{\alpha^{\alpha}\beta^{\beta}(1-\alpha-\beta)^{1-\alpha-\beta}}\right]^{1-\epsilon},$$

and the total revenue of the upstream SOE is

$$p_n^{\epsilon}(1-\alpha-\beta)\frac{\phi\left(\frac{1}{A_p}\right)^{1-\eta}+(1-\phi)\left[\frac{1}{A_s}\right]^{1-\eta}\left(\frac{\eta}{\eta-1}\right)^{-\eta}}{\left[(1-\phi)\left[\frac{\eta}{\eta-1}\frac{1}{A_s}\right]^{1-\eta}+\phi\left[\frac{1}{A_p}\right]^{1-\eta}\right]^{\frac{\epsilon-\eta}{1-\eta}}}\left[\frac{R^{\alpha}W^{\beta}{p_m}^{1-\alpha-\beta}}{\alpha^{\alpha}\beta^{\beta}(1-\alpha-\beta)^{1-\alpha-\beta}}\right]^{1-\epsilon}.$$

The total downstream SOE profit is

$$\begin{aligned}
&(1-\phi)\left(\frac{p_n}{P}\right)^{\epsilon}\left[\frac{p(j)}{P}\right]^{-\eta}\left(\frac{\eta}{\eta-1}-1\right)\frac{R^{\alpha}W^{\beta}{p_m}^{1-\alpha-\beta}}{A_s\alpha^{\alpha}\beta^{\beta}(1-\alpha-\beta)^{1-\alpha-\beta}} \\
= \quad & p_n^{\epsilon}\frac{(1-\phi)\left[\frac{\eta}{\eta-1}\frac{1}{A_s}\right]^{-\eta}\left(\frac{1}{\eta-1}\right)\frac{1}{A_s}}{\left((1-\phi)\left[\frac{\eta}{\eta-1}\frac{1}{A_s}\right]^{1-\eta}+\phi\left[\frac{1}{A_p}\right]^{1-\eta}\right)^{\frac{\epsilon-\eta}{1-\eta}}}\left[\frac{R^{\alpha}W^{\beta}{p_m}^{1-\alpha-\beta}}{\alpha^{\alpha}\beta^{\beta}(1-\alpha-\beta)^{1-\alpha-\beta}}\right]^{1-\epsilon},
\end{aligned}$$

and the total downstream SOE revenue is

$$\eta p_n^{\epsilon}\frac{(1-\phi)\left[\frac{\eta}{\eta-1}\frac{1}{A_s}\right]^{-\eta}\left(\frac{1}{\eta-1}\right)\frac{1}{A_s}}{\left((1-\phi)\left[\frac{\eta}{\eta-1}\frac{1}{A_s}\right]^{1-\eta}+\phi\left[\frac{1}{A_p}\right]^{1-\eta}\right)^{\frac{\epsilon-\eta}{1-\eta}}}\left[\frac{R^{\alpha}W^{\beta}{p_m}^{1-\alpha-\beta}}{\alpha^{\alpha}\beta^{\beta}(1-\alpha-\beta)^{1-\alpha-\beta}}\right]^{1-\epsilon}.$$

Therefore, the aggregate profit of SOE is

$$\left[\frac{(\mu-1)(1-\alpha-\beta)}{\mu}\frac{\phi\left(\frac{1}{A_p}\right)^{1-\eta}+(1-\phi)\frac{\eta-1}{\eta}\left[\frac{\eta}{\eta-1}\frac{1}{A_s}\right]^{1-\eta}}{\left[(1-\phi)\left[\frac{\eta}{\eta-1}\frac{1}{A_s}\right]^{1-\eta}+\phi\left[\frac{1}{A_p}\right]^{1-\eta}\right]^{\frac{\epsilon-\eta}{1-\eta}}}+\frac{\frac{1}{\eta}(1-\phi)\left[\frac{\eta}{\eta-1}\frac{1}{A_s}\right]^{1-\eta}}{\left((1-\phi)\left[\frac{\eta}{\eta-1}\frac{1}{A_s}\right]^{1-\eta}+\phi\left[\frac{1}{A_p}\right]^{1-\eta}\right)^{\frac{\epsilon-\eta}{1-\eta}}}\right]$$
$$\cdot p_n^{\epsilon}\left[\frac{R^{\alpha}W^{\beta}{p_m}^{1-\alpha-\beta}}{\alpha^{\alpha}\beta^{\beta}(1-\alpha-\beta)^{1-\alpha-\beta}}\right]^{1-\epsilon},$$

which is maximized when $\phi=1$ if $\frac{A_p}{A_s}>\left(\frac{\eta-1}{\eta}\right)\left[\frac{\eta-1}{\eta}+\frac{\mu}{\eta(\mu-1)(1-\alpha-\beta)}\right]^{\frac{1}{\eta-1}}$ given all the factor prices (R and W) and optimal price choice of upstream intermediate input p_m.

D Additional Quantitative Analyses

In Section 5, we calibrate the model to a single benchmark year, 2005. Although the ASIE covers 1998 to 2007, the relevant sample period is 2002 to 2007: 2002 marks the full emergence of the vertical structure (see the pertinent discussion earlier), and 2007 is the final year before the global financial crisis and its data quality is widely deemed as trustworthy. This appendix provides details of the calibration procedures described in Section 5.1 and then repeats the counterfactual analysis and loss decomposition for every year from 2002 to 2007, confirming that the qualitative conclusions are robust to the choice of benchmark year.

D.1 Calibration Details

Table D1 reports the year-specific moments used in the calibration exercises that follow.

Table D1: Year-Specific Data Moments for Calibration

Year	2002	2003	2004	2005	2006	2007
μ	1.23	1.74	1.48	1.74	1.63	1.49
R	0.0947	0.0971	0.0959	0.0905	0.1022	0.1207
s	0.0377	0.0725	0.0342	0.0451	0.0423	0.0411
Agri. Share	0.257	0.238	0.245	0.224	0.208	0.202

Share Parameters. Our model implies that the intermediate input share of the downstream production is given by $1-\alpha-\beta$, which can be directly computed as the fraction of the after-tax value-added in the upstream industries in the total value-added of the industrial sector net of tax[27].

[27] Our two-layer production structure is a parsimonious way to capture the key insights without getting into the details of the more complicated production network.

That is,

$$(1-\alpha-\beta) = \frac{(\text{VA}_{up} - \text{Tax}_{up})}{(\text{VA}_{up} - \text{Tax}_{up}) + (\text{VA}_{down} - \text{Tax}_{down})},$$

where all the variables on the right hand side can be directly obtained from the data for each year. For simplicity, we assume α and β are time-invariant, so we calculate the simple average across years, which yields that $\alpha+\beta = 0.37$. To impute β, we use the fact that

$$\frac{\beta}{\alpha+\beta} = \text{Labor Income Share}_{down}. \tag{36}$$

A common issue with the ASIE data set is that the labor income share is too low, so we follow Hsieh and Klenow (2009) to make the same adjustment. We first calculate the average wage rate for the industrial sector at year t

$$\text{Average Wage}_t = \frac{\text{Total VA}_t \times \text{Labor Income Share}_t}{\text{Total Employment}_t}, \tag{37}$$

where the total value-added, labor income share, and total employment of the whole industry sector at year t are all directly provided by the National Bureau of Statistics. This share is significantly higher than the raw labor income share directly calculated from ASIE. Then we use this average wage rate to calculate upstream and downstream labor income:

$$\text{Labor Income}_{s,t} = \text{Average Wage}_t \times \text{Employment}_{s,t}, \quad s = \text{up or down}.$$

The total net income in sector s at year t can be decomposed into three additive components:

$$\underbrace{\text{VA}_{s,t} - \text{TAX}_{s,t}}_{\text{Value Added excluding Tax}} = \underbrace{W_t \times L_{s,t}}_{\text{Labor Income}} + \underbrace{(R^n_{s,t} \times K_{s,t} + \delta \times K_{s,t})}_{\text{Rental Income of Capital}} + \underbrace{\Pi_{s,t}}_{\text{Economic Profit}},$$

where $R^n_{s,t}$ denotes the net ROA in sector s at year t and δ is the depreciation rate. As $\text{VA}_{s,t}$ and $\text{TAX}_{s,t}$ are directly observed in the data, and the labor income has been imputed, we obtain the adjusted labor income share for sector s at year t as follows:

$$\text{Adjusted Labor Income Share}_{s,t} = \frac{\text{Labor Income}_{s,t}}{\text{VA}_{s,t} - \text{TAX}_{s,t}}.$$

Based on the above information, we compute the year average of labor income share in the downstream industries and then plug it into (36), which, together with $\alpha+\beta = 0.37$, yields that $\alpha = 0.12$ and $\beta = 0.25$.

To obtain $(1-\gamma)$, note that we should use labor cost share instead of labor income share for the upstream industries because of positive monopoly profits ($\Pi_{up,t} > 0$):

$$(1-\gamma)_t = \frac{W_t \times L_{up,t}}{W_t \times L_{up,t} + (R^n_{up,t} + \delta) \times K_{up,t}} = \frac{\text{Labor Income}_{up,t}}{(\text{VA}_{up,t} - \text{TAX}_{up,t}) - \Pi_{up,t}}.$$

We have already obtained the upstream labor income, and we also know the value of δ and $K_{up,t}$ from the data, so it remains to determine $R^n_{up,t}$ to pin down $(1-\gamma)_t$. Recall that our model implies that $\Pi_{down,t} = 0$ and $R^n_{down,t} = R^n_t$. Thus, the market credit cost can be calculated from the data with the following formula:

$$R^n_t = \frac{\text{VA}_{down,t} - \text{TAX}_{down,t} - W_t \times L_{down,t} - \delta \times K_{down,t}}{K_{down,t}}. \tag{38}$$

Note that R^n_t is essentially the net ROA and also the financing cost (or the credit cost) of the downstream industries.

For the upstream industries, we have

$$\text{VA}_{up,t} - \text{TAX}_{up,t} - W_t \times L_{up,t} - \delta \times K_{up,t} = \underbrace{R^n_{up,t} \times K_{up,t} + \Pi_{up,t}}_{\text{Net Accounting Profit}},$$

where all the four terms on the left side are directly reported in the data and $R^n_{up,t} = R^n_{down,t} - s_t = R^n_t - s_t$, as implied by our model. Substituting it back into the previous equation, we have

$$\Pi_{up,t} = \text{VA}_{up,t} - \text{TAX}_{up,t} - W_t \times L_{up,t} - \delta \times K_{up,t} - (R^n_t - s_t) \times K_{up,t}, \tag{39}$$

where neither the subsidy rate s_t nor the economic profit $\Pi_{up,t}$ are directly observable. To uncover $\Pi_{up,t}$ or the gross markup μ_t, one has to know the value for s_t. In our model, s_t is equal to the credit spread between upstream SOE and downstream POEs:

$$s_t = i_{down,t} - i_{up,t},$$

where $i_{down,t}$ and $i_{up,t}$ denote the interest rate on borrowing for the downstream and upstream industries at year t, respectively. We directly uncover the credit spread s_t from data—for each sector and each year, we compute the interest rate using the aggregate interest payment divided by the aggregate debt and then compute the difference.[28] With s_t, we calculate $\Pi_{up,t}$ from the

[28] Our estimates of credit spread are mostly around 4% (see Table D2). These estimates align with findings in the literature, albeit on the conservative end. For example, Bai, Lu and Tian (2018) use the ASIE data and find that the mean interest rate spread between SOE and POE is 5% for 1999 and 6% for 2007. It is worth noting that a larger credit spread would further bolster our quantitative results in the counterfactual analysis.

accounting identity (39) together with (38), so we can impute the gross markup μ_t by

$$\mu_t = \frac{\mathrm{VA}_{up,t} - \mathrm{TAX}_{up,t}}{W_t \times L_{up,t} + (R_t^n - s_t + \delta) \times K_{up,t}},$$

which implies that μ_t strictly increases with the credit subsidy s_t, *ceteris paribus*. In other words, the credit subsidy and the markup are interwined within our framework. Note that, because of positive monopoly profits, we should use the labor cost share instead of labor income share to determine upstream labor cost share $1 - \gamma$:

$$\text{Labor Cost Share}_{up,t} = \frac{W_t \times L_{up,t}}{W_t \times L_{up,t} + (R_t - s_t + \delta) \times K_{up,t}}.$$

We take the year average and obtain $\gamma = 0.42$.

Preference Parameter. By rearranging (9), we can derive ϵ from the gross markup μ for each year, with α and β known.

Policy Parameters. The rental price of capital is given by $R = R^n + \delta$, where net capital return of the downstream industries R^n is already obtained and the depreciation rate δ is computed from the ASIE data. The imputed value of δ slightly varies across years and sectors, but we choose 4%, its year average value, and assume for simplicity that it is invariant for all years and all sectors. Then, $\tau \equiv \frac{s}{R}$ can be computed.

Productivity and Endowment. Total population L is normalized to one for all years. The level of capital stock K is determined by equating the model-implied rental price of capital and the data. Observe that our model yields the same capital allocation across the upstream and downstream industries because both the markup and credit subsidy rate are obtained from the data. With Cobb-Douglas production functions, the TFP levels A_m and A_d only determine the quantities of m and y_d. The values of these output quantities *per se* are unimportant because we can always rescale them by changing the unit. Note that scaling m up has the same effect as scaling A_d up, so the value for A_m can be chosen freely. Without loss of generality, we choose A_m such that $p_m = 1$, which gives

$$A_m = \frac{\mu(1-\tau)^\gamma R^\gamma A_n^{1-\gamma}}{(1-\gamma)^{1-\gamma}\gamma^\gamma}.$$

However, A_d affects output level y_d and c_d; thus, it will affect the relative size of the agriculture sector and the industry sector. Recall our model implies that A_n is equal to the wage rate, as seen in (11), so the value of A_n is empirically determined by (37). A_d is chosen such that $\frac{A_d}{A_d}$ generates the output share of the agriculture sector in the model economy consistent with the data.

Table D2 summarizes the calibrated parameter values for each year. Because the model is static, each year is calibrated independently with its own normalization (e.g., $L = 1$, $p_m = 1$), so the levels of time-varying parameters are not directly comparable across years. In particular, parameters such as A_d and K fluctuate substantially; these fluctuations reflect the calibration procedure rather than meaningful economic dynamics and should not be interpreted as year-over-year changes in underlying fundamentals. Within each year, however, the counterfactual GDP and welfare comparisons are unaffected, as they depend only on the relative changes across policy scenarios.

Table D2: Parameter Values

Year	2002	2003	2004	2005	2006	2007
	Share parameters (constant over time)					
α	0.12					
β	0.25					
γ	0.42					
	Preference parameters					
ϵ	7.90	3.15	4.31	3.15	3.52	4.24
	Policy parameters					
τ	0.40	0.75	0.36	0.50	0.41	0.34
	Productivity and endowment					
A_d	9.80	41.24	21.43	48.11	38.13	27.45
A_m	8.31	8.14	11.21	11.87	13.30	14.87
A_n	66.35	64.74	76.28	79.59	88.70	102.1
K	374.6	621.7	385.3	497.1	467.6	440.1

D.2 Counterfactual Output and Welfare

This subsection reports the full year-by-year counterfactual results that complement the benchmark 2005 analysis in Section 5.2. The four policy scenarios and the definitions of real GDP and consumption-equivalent welfare change λ are identical to those in the main text. For ease of comparison, real GDP in 2002 is normalized to 100.

Table D3 reports the real GDP levels under the four scenarios for each year from 2002 to 2007. The key findings from the 2005 benchmark are confirmed across all years. Removing the upstream monopoly alone consistently yields a larger GDP gain than removing the credit subsidy alone. Moreover, eliminating the credit subsidy alone actually reduces GDP for 2004 through 2007, confirming that the subsidy partially mitigates the under-supply problem caused by upstream

Table D3: Real GDP (All Years)

	2002	2003	2004	2005	2006	2007	Average
Status quo	100	110	123	137	152	171	132.16
Remove subsidy	100.14	111.11	122.29	135.42	150.55	169.91	131.57
Remove markup	100.54	113.40	126.77	144.56	159.34	176.89	136.92
First best	101.42	121.32	127.73	147.39	161.25	178.16	139.55

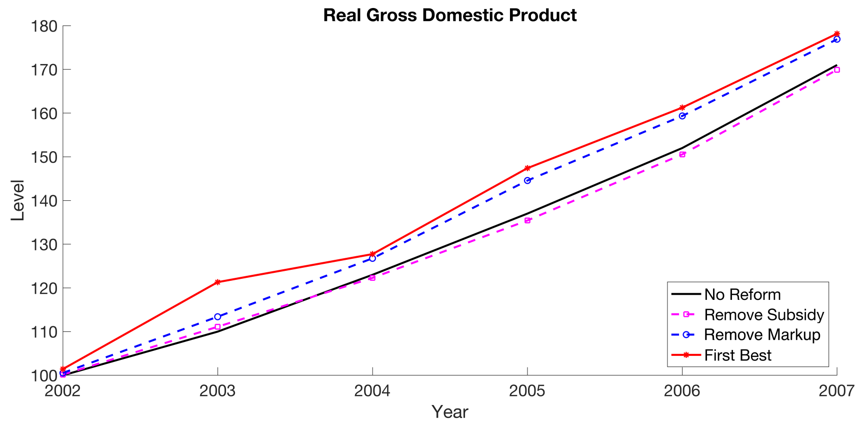


Figure D1: Real GDP (All Years)

monopoly. The year 2002 is the only exception: both distortions are relatively small ($\mu = 1.23$, $\tau = 0.40$; see Table D2), so all reform scenarios yield modest positive gains and the offsetting interaction between the two distortions is limited. These results are also plotted in Figure D1.

Table D4: Consumption Equivalent Welfare Change (All Years)

	2002	2003	2004	2005	2006	2007	Average
Status quo	0	0	0	0	0	0	0
Remove subsidy	0.15%	1.01%	−0.58%	−1.15%	−0.96%	−0.64%	−0.36%
Remove markup	0.43%	1.96%	2.39%	4.03%	3.64%	2.70%	2.53%
First best	1.27%	8.05%	3.10%	5.78%	4.73%	3.36%	3.36%

Table D4 reports the consumption-equivalent welfare changes. The welfare results display the same pattern. Removing the upstream monopoly alone generates a sizable welfare gain in every year, while removing the credit subsidy alone leads to a welfare loss for 2004 through 2007, with the largest loss occurring in the benchmark year 2005 (−1.15%). The results are also shown in Figure D2.

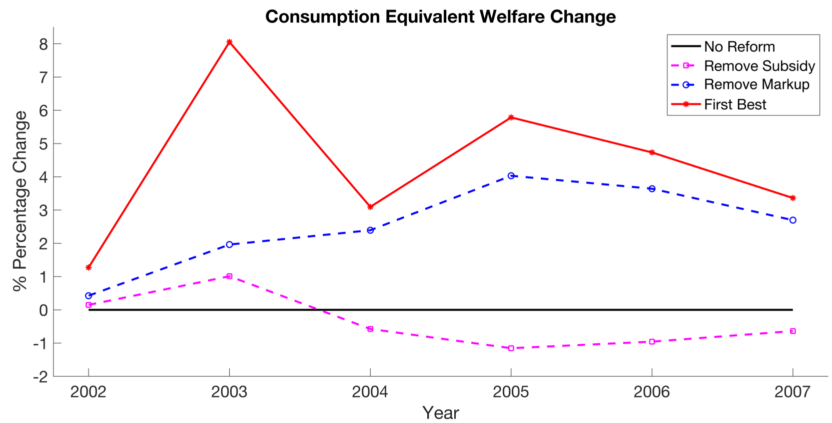


Figure D2: Consumption Equivalent Welfare Change (All Years)

D.3 Loss Decomposition

D.3.1 Evidence from Firm-level Markups

Now we turn to firm-level regressions of markups to shed light on how upstreamness and state ownership shape market power. Markups are measured using the method of Loecker and Warzynski (2012), which infers firm-level markups from production data under the assumption of cost minimization.

Do upstream industry firms have more market power? We begin by testing whether firms in upstream industries systematically charge higher markups than others. To do so, we regress log markups on an upstream indicator, controlling for firm characteristics, city fixed effects, and year fixed effects:

$$\log(\text{Markup})_{it} = \alpha + \beta \text{Upstream}_{it} + \gamma \mathbf{X}_{it} + \delta_c + \delta_t + \epsilon_{it},$$

where i indexes firms and t indexes years. The binary indicator Upstream_{it} equals one if firm i operates in an upstream industry in year t. The control vector $\mathbf{X}_{it}$ includes firm size, age, export share, and capital intensity, same as all previous firm-level regressions. We also control for city fixed effects (δ_c) and year fixed effects (δ_t).

In reporting the results, we consider four alternative samples to ensure robustness. The *All* sample includes the full set of firms in the data. The *No Mid* sample excludes the midstream industries, allowing for a cleaner contrast between the upstream and upstream industries. The *Balanced* sample restricts attention to firms that are present in every year of the panel, thereby controlling for potential biases from firm entry and exit. Finally, the *Balanced, No Mid* sample combines both restrictions, focusing only on continuously observed firms in either upstream or downstream industries.

Table D5 Panel A reports the results. Across all specifications, upstream firms exhibit significantly higher markups, and the interaction terms show that this gap widened further after 2001. This confirms that upstreamness is a persistent and growing source of market power.

Does being in upstream industries induce more market power after 2001? To test whether the upstream premium increased after the SOE reform and the WTO accession, we extend the specification to include an interaction with the post-2001 period:

$$\log(\text{Markup})_{it} = \alpha + \beta_0 \text{Upstream}_{it} + \beta_1(\text{Upstream}_{it} \times \text{Post2001}_t) + \gamma \mathbf{X}_{it} + \delta_c + \delta_t + \epsilon_{it},$$

As shown in Table D5 Panel B, both the baseline upstream coefficient and the interaction term are positive and significant, indicating that not only do upstream firms have higher markups, but this gap widened significantly after 2001.

Table D5: Do upstream industry firms have more market power?

	Dependent Variable = Log(Markup)			
Sample	All (1)	No Mid (2)	Balanced (3)	Balanced, No Mid (4)
	Panel A: No Interaction Term			
Upstream	0.1457***	0.1599***	0.1381***	0.1700***
	(0.0249)	(0.0178)	(0.0168)	(0.0189)
Observations	1,149,863	726,129	187,773	116,290
Adjusted R^2	0.3675	0.3733	0.3671	0.3975
	Panel B: Interaction with Post2001			
Upstream	0.0705***	0.0824***	0.0472***	0.0667***
	(0.0105)	(0.0095)	(0.0131)	(0.0140)
Upstream×Post2001	0.0888**	0.0919***	0.1147***	0.1313***
	(0.0288)	(0.0198)	(0.0178)	(0.0160)
Observations	1,149,863	726,129	187,773	116,290
Adjusted R^2	0.3676	0.3740	0.3689	0.4020
Year FE	Yes	Yes	Yes	Yes
City FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Weighted	Yes	Yes	Yes	Yes

Note: All regressions include control variables as well as year and city fixed effects, and are weighted by firm value added. Industry fixed effects are excluded because they would absorb the upstream indicator. Standard errors are clustered at the firm and year levels. *** p<0.01, ** p<0.05, * p<0.1.

Do SOEs have more market power? Next, we examine whether state ownership itself is associated with higher markups. We estimate the following equation:

$$\log(\text{Markup})_{it} = \alpha + \beta \text{SOE}_{it} + \gamma \mathbf{X}_{it} + \delta_c + \delta_s + \delta_t + \epsilon_{it},$$

where SOE_{it} is a binary indicator using our baseline SOE definition (SOE 3), and δ_s represents industry fixed effects.

As shown in Table D6, SOEs on average display higher markups, but the effect is highly asymmetric across sectors. The markup premium is strong and significant in upstream industries, but statistically insignificant in downstream industries. This suggests that state ownership amplifies market power only when coupled with upstream position.

Table D6: Do SOEs have more market power?

	Dependent Variable = Log(Markup)					
Sample	Full Sample			Balanced Panel		
Group	All (1)	Upstream (2)	Downstream (3)	All (4)	Upstream (5)	Downstream (6)
SOE	0.0641*** (0.0099)	0.1055*** (0.0090)	0.0077 (0.0106)	0.0576*** (0.0098)	0.0800*** (0.0098)	0.0158 (0.0164)
Observations	1,149,863	272,028	454,097	187,773	46,139	70,148
Adjusted R^2	0.4970	0.5316	0.5069	0.5113	0.5626	0.5179
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
City FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Weighted	Yes	Yes	Yes	Yes	Yes	Yes

Note: All regressions include control variables as well as year, city, and industry fixed effects, and are weighted by firm value added. Standard errors are clustered at the firm and year levels. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Which one drives market power more, being in upstream industries or a SOE? To compare their relative importance, we include both upstream and SOE indicators in the same regression:

$$\log(\text{Markup})_{it} = \alpha + \beta_0 \text{SOE}_{it} + \beta_1 \text{Upstream}_{it} + \gamma \mathbf{X}_{it} + \delta_c + \delta_t + \epsilon_{it}.$$

Table D7 shows that both coefficients remain positive, but the upstream effect is consistently larger and more robust. Formal F-tests confirm that upstreamness explains more of the markup variation than state ownership.

Table D7: Which one drives market power more, being in upstream industries or a SOE?

	Dependent Variable = Log(Markup)			
Sample	All	No Mid	Balanced	Balanced, No Mid
	(1)	(2)	(3)	(4)
SOE	0.0412***	0.0346**	0.0413**	0.0242
	(0.0108)	(0.0139)	(0.0127)	(0.0159)
Upstream	0.1426***	0.1577***	0.1350***	0.1683***
	(0.0249)	(0.0182)	(0.0169)	(0.0194)
Observations	1,149,863	726,129	187,773	116,290
Adjusted R^2	0.3675	0.3733	0.3671	0.3975
Year FE	Yes	Yes	Yes	Yes
City FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Weighted	Yes	Yes	Yes	Yes

Note: All regressions include control variables as well as year and city fixed effects, and are weighted by firm value added. Industry fixed effects are excluded because they would absorb the upstream indicator. Standard errors are clustered at the firm and year levels. *** p<0.01, ** p<0.05, * p<0.1.

D.3.2 Year-Specific Markup Premiums

For the purpose of calibration, we also estimate year-specific coefficients on the SOE indicator. These regressions allow us to track how the SOE markup premium evolves over time and to provide credible inputs for our counterfactual calculations. Specifically, we estimate:

$$\log(\text{Markup})_i = \alpha + \beta \text{SOE}_i + \gamma \mathbf{X}_i + \delta_c + \delta_s + \epsilon_i,$$

where the specification mirrors the baseline regressions but is estimated separately by year.

Table D8 presents the results for two samples: (i) the full set of upstream firms, and (ii) the upstream firms from a balanced panel that follows the same firms over time. Across both samples, the SOE coefficient is positive, statistically significant, and persistent across all years, though the magnitude varies somewhat. Importantly, comparing the two sets of coefficients provides a more credible range for the true SOE markup premium: the full sample offers broader coverage, while the balanced panel mitigates concerns about composition effects from firm entry and exit. We draw on this range in the subsequent decomposition exercise.

D.3.3 Counterfactual Markups

What would the markups be if all upstream SOEs were instead POEs? To isolate the effect of state ownership on market power, we construct counterfactual upstream markups under a hypothetical

Table D8: SOE Coefficients by Year

	Dependent Variable = Log(Markup)					
Year	2002 (1)	2003 (2)	2004 (3)	2005 (4)	2006 (5)	2007 (6)
	Panel A: All Upstream Firms					
SOE	0.1256*** (0.0064)	0.1384*** (0.0067)	0.1458*** (0.0072)	0.1355*** (0.0067)	0.1413*** (0.0065)	0.1522*** (0.0066)
Observations	24,138	25,164	25,098	40,241	44,138	49,407
Adjusted R^2	0.4894	0.4682	0.4855	0.4621	0.4629	0.4649
	Panel B: Balanced Panel					
SOE	0.1101*** (0.0120)	0.1032*** (0.0128)	0.1094*** (0.0129)	0.0985*** (0.0134)	0.0877*** (0.0139)	0.1031*** (0.0138)
Observations	5,027	5,030	5,222	5,182	5,182	5,161
Adjusted R^2	0.5389	0.4831	0.4927	0.4640	0.4639	0.4631
City FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Weighted	Yes	Yes	Yes	Yes	Yes	Yes

Note: Only firms from the upstream industries are included. All regressions include control variables as well as industry and city fixed effects, and are weighted by firm value added. Robust standard errors are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

scenario where all upstream firms are private. The key idea is to combine observed aggregate markups with regression-based estimates of the SOE markup premium to impute what markups would be under full privatization. The formal procedures are outlined below:

- Note that the aggregate markup is calculated as:

$$\mu^{\text{agg}} = \frac{\sum_i \text{revenue}_i}{\sum_i \text{cost}_i} = \sum_i \left(\frac{\text{cost}_i}{\sum_j \text{cost}_j} \times \frac{\text{revenue}_i}{\text{cost}_i} \right) = \sum_i \text{cost-share}_i \times \mu_i,$$

  where i can index firms, sectors, or ownership types (e.g., SOE or POE). We can derive the cost term once we know the markup: $\text{cost}_i = \text{revenue}_i / \mu_i$.

- Therefore, the observed aggregate markup from the data is:

$$\mu^0 = \mu^{\text{SOE}} \times \text{share}^{\text{SOE}} + \mu^{\text{POE}} \times \text{share}^{\text{POE}},$$

  and our goal is to impute the counterfactual markup $\mu^c = \mu^{\text{POE}}$, under the hypothetical scenario where all firms are POEs.

- From firm-level regressions, we estimate the markup gap:

$$\beta = \log\left(\frac{\mu^{\text{SOE}}}{\mu^{\text{POE}}} \right).$$

  Substituting it into the equation for μ^0, we have:

$$\mu^0 = \mu^{\text{POE}} \times \exp(\beta) \times \text{share}^{\text{SOE}} + \mu^{\text{POE}} \times \text{share}^{\text{POE}}.$$

- Thus, the counterfactual markup is:

$$\mu^c = \mu^{\text{POE}} = \frac{\mu^0}{\exp(\beta) \times \text{share}^{\text{SOE}} + \text{share}^{\text{POE}}}.$$

The final equation allows us to uncover counterfactual markup using three observable inputs: the aggregate markup μ^0, the estimated markup gap β, and the SOE cost share. We follow this procedure and obtain the key parameters, which are summarized in Table D9.

D.3.4 Loss Decomposition

Using the quantitative framework developed in Section 5.3, Figure D3 summarizes the decomposition for years 2002 to 2007 by plotting the share of output loss from upstream monopoly attributable to SOEs under both credit regimes. Each panel reports a range of estimates, with the low and high

Table D9: SOE Share and Parameter Estimates by Year

Year	2002	2003	2004	2005	2006	2007
SOE Cost Share (%)	52.27	48.93	47.06	46.46	48.78	44.71
β low	0.110	0.103	0.109	0.099	0.088	0.103
β high	0.126	0.138	0.146	0.136	0.141	0.152
μ^c low	1.159	1.652	1.404	1.660	1.560	1.421
μ^c high	1.150	1.622	1.378	1.630	1.518	1.388

Note: The estimates of β come from Table D8. A higher β implies a greater markup premium for SOEs, and thus a lower counterfactual markup under full privatization.

bounds derived from alternative empirical specifications to provide a credible interval. Across both scenarios, SOEs account for roughly 10–25% of the total loss (except in 2002), while the bulk of the loss stems from the structural features of upstream industries themselves.

(a) Scenario 1 (No subsidy)

(b) Scenario 2 (*Status quo*)

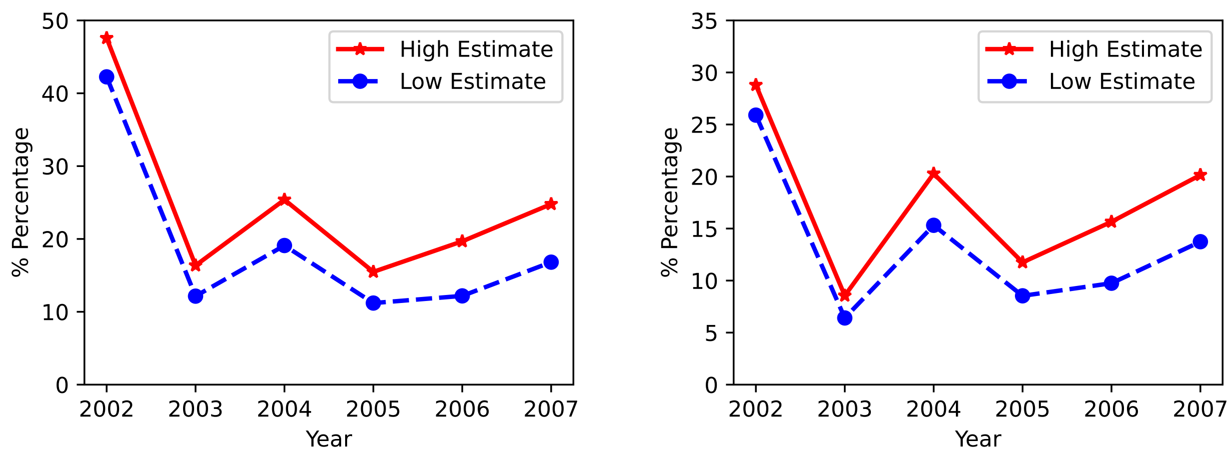


Figure D3: Share of Output Loss Attributable to Upstream State Ownership