Social Network and Industrial Policy: Japan's Camphor Monopoly in Colonial Taiwan*

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Abstract

This paper inspects how firm-official connectivity impacts the policy treatments assigned to firms in contexts of industrial policies. We digitalize the micro-level data from Japan's Camphor Monopoly System in Taiwan for 1902-1918, and compile firm-official connectivities from a social network constructed from the data archive of the official gazette during 1896-1918. We first propose an estimation framework based on control function approach to identify firm productivities, and inspect how the implementation of the monopoly system affects productivity growth. Using a shock design based on shift-share approach, we then estimate the impact of connectivities on the production quota and compensation granted to the firm by the authority under the monopoly system. Our estimation suggests that favoritism played a crucial role for the policy treatments. We then construct a counterfactual model to mimic the ideally implemented monopoly system, such that the authority aims to maximize its profit given its connection to firms. We simulate the model and compare with the empirical allocations. Our counterfactual simulation suggests that favoritism towards large Japanese conglomerates are at play, as empirically these conglomerates receive disproportionately more production sites while being less productive than the other firms compared with model prediction. Such a favoritism leads to a reduction in the authority's profit rate by approximately 16 percentage points, and is equivalent to a loss of efficiency in generating government profit by 35%.

Key Words: Industrial Policy, Social Network, Firm-Official Connectivity, Government Monopoly, East Asia, Camphor

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1 Introduction

Many countries are known to use industrial policies to promote the performances of selected sectors. In East Asian countries such as South Korea, Japan, Taiwan, and China, the policies frequently feature picking winners. A small number of bureaucrats identifies sectors as "strategic industries", and implements policy treatments such as subsidies, low-interest loans or even new technology of production to firms in these industries. The performances of the firms are then promptly reviewed by the bureaucrats. The best performing firms are considered as "winners", which are provided with even more policy treatments to facilitate their development. In contrast, poorly performing firms face cuts to their policy treatments, and can even be forced to exit the market by the bureaucrats. This mode of industrial policy has cultivated several superstar firms in the global market, and are generally thought of as the driving force behind the East Asian miracle of economic development.

More often than not, the winners in such policy arrangements are oftentimes firms with strong political connections to the bureaucrats. Scholars such as Peter Evans (1995) argue that such a political connection is a key for a successful industrial policy, as an intimate and concrete link between the state officials and entrepreneurs provides a foundation for these social groups to share a joint goal for economic transformation. The official's familiarity to the entrepreneurs facilitates the authority's decision making, including identifying strategic industries, assignment of policy treatments and evaluations to firm performances. However, this argument always cast doubts regarding the arrangements of industrial policies. Specifically, are firms receiving favorable policy treatments because, based on the official's familiarity to them, they are efficient and potential? Or are they treated more favorably simply out of pure favoritism by the officials? Which of the two aspects is more dominant in shaping the configuration of an industrial policy? To our knowledge, no empirical researches have been conducted to address these related questions on industrial planning.

This paper aims to unravel the roles of firm-official connectivity in the allocation of policy treatments across firms by the authority, and the effects of the resulting resource (mis)allocation on the outcome of industry planning. One of the major challenges to study this issue is to obtain a dataset with detailed information on firm-level input, output, and the government's firm-specific treatments out of industrial planning purpose. Moreover, gauging firm-official connectivity is never an easy task as interactions between them are hardly observable to a large scale. The Camphor Monopoly System in Taiwan during the earlier years of Japanese Colonial Period (1902-1918) provides an invaluable opportunity to study the issue in interest while addressing the two major challenges owing to its institutional design.

Camphor was an strategic intermediate input before the end of World War II, and was mostly produced in Taiwan since it had the largest natural habitat of camphor trees in the world. To exploit the potential benefits, the Japanese government implemented the Camphor Monopoly System soon after its colonization to Taiwan. The system features active government intervention. In particular, this system has a **monopsony** aspect that features active participation of entrepreneurs in the upstream crude camphor sector in its early stage (1899-1918). During this period, firms need to submit detailed production plans for the government's approval. Upon approval, the firm can produce camphor within the production allowance (quota) given by the government, and is required to exclusively sell these outputs back to the government for refining and distribution. The government tracks the performance of firms, and rewards best performing firms with additional production quota, and punishes poorly performed firms by forcing them to reduce their production scales or even terminating their production permissions. Because of this institutional background, a detailed panel data is publicly available nowadays, which includes detailed information for each permitted firms such as their names, permitted years, production quota, input, output and government discretion. We design a framework to estimate the production function and firm-level TFPs of permitted firms by exploiting the timing of the monopoly system.

The number of participating firms are manageable owing to the permission-based institutional design. By combining the list of firms and various historical archives such as the list of government officials, *Who's Who*, and various biographies, we obtain a comprehensive list of agents directly or indirectly involved in camphor monopoly. Then we recursively construct a social network between all of these agents based on their interactions disclosed by news reports on *Taiwan Daily News (*臺灣日日新報*)*, which further allows us to gauge the connectivities between agents by the "edge counting" approach as has been standard in network analysis. By utilising the exogenous nature of adjustments in bureaucratic system, we measure changes in firm-level connectivities to various ranks of officials by aggregating up individual level connectivities with a shock design similar to shift-share construction. Then we estimate how such changes in connectivities impact the changes in policy treatments received by the firm, such as production quota and the authority's purchasing price. We also inspect how these changes in connectivities affect the productivities of firms.

We attempt to inspect whether firm-official connectivity leads to appropriate resource allocation a la Peter Evans, or simply entails distortive favoritism. For this purpose, we design a counterfactual model that mimics Japan's Camphor Monopoly System wherein the government aims to maximize its expected profit by assigning the *right* firms accounting for the connectivities and productivity potentials that are heterogeneous across firms. In this model each firm determines its efficiency of production by an initial innovation effort, and then engages in bilateral bargaining against the government on the profit from production. The bargaining power of the firm is modeled as its share to the profit, and our quantitative analysis shows that a tighter connection with the government entails a greater profit share for the firm. The government thus faces a tradeoff: choosing firms with better connection requires the government to shift a greater proportion of profit to the firm, but at the same time it may incentivise the firm for better production efficiency and in turn entails a higher profit to the government. We calibrate this model using our data, and compare the model predicted winning probabilities and productivities of firms with their empirical counterparts. As the government make efficient decisions in maximizing its profit, the differences between model prediction and empirical observations thus reflects the size of distortive favoritism, which can be further summarized by the profit rate of the government from this system.

Our quantitative analysis suggests that the Camphor Monopoly System tend to exhibit favoritism to Japanese, especially *zaibatsu* and the larger Japanese firms. Our estimation to productivities find that firms with **more** Taiwanese shareholders are more productive in terms of quantity than Japanese firms. In contrast, the upper-right tail of revenue productivity is occupied by Japanese firms, indicating that they are better compensated by the authority than Taiwanese firms. We also find that both Suzuki and Mitsui zaibatsu performed poorly and fall on the very left-tail of both productivity distributions. Our empirical analysis also shows that firms with better connectivities with officials at Head-of-Government rank obtain more production quota, and firms that are more connected to Head-of-Ministry officials receive higher compensation prices for their output under the monopsony arrangement.

We calibrated the bargaining power of firms as profit shares predicted from our connectivity estimation, and compute the empirical winning rate of firms as the fractions of permitted production sites. By considering all permitted firms after 1910 as potential entrants, our simulation finds that the fitness of winning probability of firms exhibits a clustered pattern. The empirical winning rates for large Japanese firms and zaibatsu are disproportionately higher than model counterparts. In contrast, firms with highest empirical productivities are predicted to see winning rates much higher than empirically observed. Relative to the firm with the highest empirical productivity, the productivities of big Japanese firms and zaibatsu are way below model prediction. We further perform the same simulation at regional level to account for prefectural heterogeneities. Our simulation suggest that the model prediction to be more similar to empirical observation in regions where zaibatsu and large Japanese firms do not present. Overall, our model suggests that Camphor Monopoly System exhibits favoritism towards big Japanese conglomerates. By comparing the Monopoly Bureau's empirical profit rate with model prediction, our simulation suggests that such a favoritism hinders the government's financial objective by an approximately 35% of reduction in generating government profit.

Our work is closely related to the literature on firm-politician connection such as Akcigit, Baslandze, and Lotti (2023), Bai, Hsieh, Song, and Wang (2021), and Nian and Wang (2023). Akcigit et al. (2023) and Nian and Wang (2023) both inspect how political connection impacts a firm's performances, and proposes measurements to the degree of connection. Akcigit et al. (2023) directly observe whether a firm formally employs a politician or candidate, and identify the connectivity effect using electoral outcome as shocks. Nian and Wang (2023) defines connection of a firm operating in a given province by whether the current province official used to work in the province where the firm's headquarter is located. Then they identify the effects by the exogenous turnover of offical. Our work complements with these literature in two aspects. First of all, we focus on how connectivity affects the authority's decisions in a context of industrial policy, then we attempt to disentangle favoritism and evaluate its implication on the outcome of an industrial policy. Second, we construct firm-official connectivity by directly observing interactions between relevant agents in a large entrepreneur-official network.

Our work also contributes to studies on industrial policies. We are mostly reminiscent to the work Barwick, Kalouptsidi and Zahur (2021), who focus on the optimal policy instrument by studying the Chinese shipbuilding during 1998-2013. In particular, they evaluate whether China's White List policy, which works in a similar manner to Japan's camphor monopoly, is properly implemented to promote the production efficiency in the industry by simulation, finding that nearly half of the firms should not have been selected by the authority. Our study complements with their paper by further incorporating the role of firm-official connectivities based on the large social network. This allows us to estimate the effect of connectivities on policy treatments received by firms, and perform counterfactual simulation based on our empirical findings.

Our paper relates to the growing literature on estimating the impacts of industrial policies. Recent studies include place-based policy (e.g. Lu, Wang and Zhu 2019; Criscuolo et al., 2019), subsidies to promote investment (Aghion et al., 2015), to gain global market share (Barwick, Kalouptsidi and Zahur, 2019), or to foster new technological industries (Lane, 2019). We focus on the winner-picking strategy within a narrowly defined industry, a strategy that is common in East Asia. Our data provide an unique opportunity to gauge the impacts of such industrial planning on industry aggregates. In contrast with the findings of Foster, Haltiwanger, and Syverson (2008) that market mechanism in the USA tends to select firms with higher "revenue productivity" to survive, we find that in the camphor industry Japanese planners tend to select firms with higher "physical output" as winners and in turn caused the aggregated growths of total factor productivity in quantity (TFP).

Our project is also connected to the control function approach in the Empirical IO literature (e.g. Olley and Pakes, 1996; Levinsohn and Petrin, 2003; Ackerberg, Caves, and Frazer, 2015, henceforth ACF; and Gandhi, Navarro, and Rivers, 2020). To address econometric issues raised by ACF (functional dependency of Olley and Pake's estimator) and GNR (ACF's alternative estimator overestimating firm heterogeneity) we extend OP's method by utilizing the unique institutional setting in the colonial Taiwan.

Finally, studies on Taiwanese camphor industry are qualitative, and mainly focus on general history of development (Tavares 2004, 王學新 2012), case studies to entrepreneur (何鳳嬌 2013), and cultural studies (陳政哲 2008). Surprisingly, there are no known quantitative analysis to Taiwanese camphor industry to the best of our knowledge, inspite of its importance to the economy and public revenue. Our study contributes to the literature by providing the very first quantitative analysis through the lens of economics.

This paper is organized as follows. In Section 2 we detail the historical background and the data archive where we retrieve the key variables for our analysis. In Section 3 we estimate firm-level TFPs of firms participating the camphor monopoly system with an estimation framework based on ACF. In Section 4 we detail the construction of social network from the news archive. Then we detail our identification strategy in estimating the effect of connectivities on policy treatments and present the results. Section 5 details a counterfactual model to study how how firms' connectivities and production efficiencies interplay to affect government's decisions in allocating production permission under an ideally implemented monopoly system that aims to generate government profit. We quantify the model and perform counterfactual simulations to gauge the impact of distortions due to purely favoritism on the outcome of the monopoly system. These results are presented in Section 6. Section 7 concludes our analysis.

2 Background and Data

2.1 Institutional Background

As a chemical with strong aroma, camphor serves as the main intermediate product to produce *celluloid*, the first invented thermoplastics (Durham 1932). The celluloid industry experienced a rapid growth in the 19th century and the early 20th century following the development of celluloid products, such as camera films, dentures, toys, nitrocellulose lacquer, and even explosives. As the key component to the industry, the demand of camphor expanded accordingly.

There were two ways of manufacturing camphor: natural camphor and artificial camphor. To produce natural camphor, manufacturers need to distill woods of camphor trees (*Cinnamomum camphora*) which have been abundant in sub-tropical areas. Based on the level of refinement, the natural camphor is further distinguished into the (1) *crude camphor* (粗製樟脳,[1] and (2) the *refined camphor* (精製樟脳) which is the processed product of the crude camphor. The production of natural camphor is subjected to the distribution of camphor trees. According to Hashimoto (1932), 77% of wild camphor trees are found in Taiwan, 15% in mainland Japan (内地), and the remaining 8% in Southern China. Natural camphor from Taiwan during the Japanese Colonial Period once accounted for more than 60% market share in the United States and 90% of global market share (Grunge 1939). The US and several European countries attempted to plant camphor trees for "Import substitution" but none of them had ever succeeded.[2]

To produce artificial camphor, is by synthesis using turpentine and hydrochloric gas, so it is also called *synthetic camphor*.[3] The technology to produce camphor by synthesis had been invented as early as in 1870s, and was greatly improved by the German firm Schering in 1905.[4] Initially, it only accounted for a mall share to the world camphor market due to its higher price than natural camphor.[5] Overall, synthetic camphor did not threat the role of natural camphor before the end of the First World War, after which the technology of synthetic camphor become more advanced and widespread. In short, for a very long time, natural camphor is the only cost-efficient material to produce celluloid, and most of the natural stock inhabit within Japanese territory, especially Taiwan.

Given the crucial role camphor played in chemical industry, the Japanese colonial government soon implemented a public monopoly system of camphor in 1899, and imposed hands-on supervision. The downstream refining, retailing and international distribution are monopolized by the Monopoly Bureau.[6] For the **upstream crude camphor** production, interestingly, the system exhibits a **monop-**

[1]Crude camphor is also known as *mountain camphor* 山製樟脳) as it was mainly manufactured in remote mountains in Qing Taiwan and colonial Taiwan.

[2]There were attempts to plant camphor trees in California, Florida, Louisiana and Texas in the US. Several attempts of plantation also took place in Australia, Ceylon, Egypt, Italy, Java, Mauritius, and Spain. All these attempts failed. See Strain (1946) p.197-8.

[3]See Strain (1946) p.198-9 for more details.

[4]See Kobrak (2002) p.44-5.

[5]As we will mention later, the camphor monopoly system in Taiwan allowed the Japanese government to control the world camphor market by underselling its natural camphor.

[6]The exports was handled by the British firm Samuel & Co. But the Governor-General is dissatisfied since Samuel & Co. typically sold the camphor to foreign downstream firms instead of Japanese firms. Its contract was terminated in 1908, and the contract was given to the Japanese *zaibatsu* Mitsui thereafter. Chapter 4 and 5 of Matsushida (1924) and Chapter 3 of Tavares (2004) provide in-depth reviews to the monopoly system. We will focus on the regulations and

sony aspect that features active participation by private firms and entrepreneurs during 1899-1918. Firms join the crude camphor sector on the Monopoly Bureau's approval, and the resulting output must be sold exclusively to the Monopoly Bureau at pre-declared prices. These outputs, with some of them being refined by the Monopoly Bureau's factory, were exported to the refineries and celluloid manufacturers all over the world by a contracted trading company.

To obtain production permissions for crude camphor, the firms were required to submit their production plans for the year, including the locations of production sites, the number of camphor stoves (脳灶) of each site, the planned quantity of production for both camphor crystal (樟脳) and oil (樟脳油), etc. The production plans were reviewed by the Monopoly Bureau, and the permissions were approved on the Monopoly Bureau's discretion.[7] For each permitted case, all changes of the production plan were required to be submitted for further approvals.

Upon approval, production allowance on outputs (許可額, which we refer to as *quota* henceforth) will be granted to the firm by the Monopoly Bureau. The authority then kept tight monitoring on the production of crude camphor, and flexibly adjusts the quota granted to the firms on its discretion. Typically the Monopoly Bureau considers the quota as a production target, and evaluates the firm's performance by the extent that the firm's actual output meets the production target while accounting for impacts of exogenous events such as production disruptions due to natural disasters, rebellions, and aborigine raids. Firms that fall far behind the quota is considered as poorly performed, and will face cuts in its production quota or even termination of businesses. In contrast, firms with good achievement rate or even exceeding the quota are considered as good performers, and will be rewarded with additional quota.[8] For example, in 1907 the permitted quantities of producers in Douliu prefecture were cut because they were unable to hire enough workers to perform their operations; while the producer in Taoyuan prefecture was deemed with additional production allowances since its output had surpassed the given goal for the year.[9]

The crude camphor produced by the producers must be exclusively sold to the Monopoly Bureau at the purchasing prices (補償金, literally *compensation*) determined and publicly declared by Taiwan Government-General (臺湾総督府). The prices depended on location of operation, quality, and product type, and were flexibly adjusted from time to time. As documented in Matsushida (1924, pp.176-197), there were 30 major adjustments in prices during 1904-18. These adjustments were frequently specific to prefectures and even production sites, and claimed to reflect remoteness and working conditions in the region. The prices were mostly adjusted upwards, and downwards adjustments tend to be small in magnitudes. Moreover, prefectures with more Japanese producers tend to experience more upward adjustments. For example, the prices in nowadays Taipei experienced several waves of upwards adjustments during 1905-07 wile the prices in Taichung Prefecture remains unchanged. But during this period the Taiwanese producers in Taipei region were gradually replaced by Japanese producers, while the producers in Taichung were still owned by local Taiwanese business-

managements on crude camphor production, which are the main interest of this project.

[7]Clause 6 of Monopoly Law of Crude Camphor Crystal and Oil (粗製樟脳樟脳油専売法), 1903. For the complete law please refer to Matsushida (1924) p.72-6.

[8]See Yearbook of Taiwan Government-General Monopoly Bureau, 7th Year (1910), p.28.

[9]See Yearbook of Taiwan Government-General Monopoly Bureau, 7th Year (1910), p.30-31.

men. Another example is that the prices for crude camphor produced in nowadays Jiji and Zhushan regions (was Douliu Prefecture before 1909, and become a part of Nantou Prefecture afterwards) started to experience upwards adjustments since 1909, right after the Japanese businessmen taken over the production sites originally owned by Taiwanese producers while the Government-General claimed that the adjustments are to reflect the remoteness of these production sites. Similar situation also happened in Chiayi Prefecture, wherein the compensation price experienced a one-year hike in 1909, right before the business jointly owned by the Lin Family and several Taiwanese businessmen being taken over by a former Japanese official. The prices in Southern and Eastern Taiwan were also become nearly 50% higher than other regions after several waves of price adjustments. While these regions were considered to be remote, all of the businesses were also owned by Japanese.

In a nutshell, the camphor monopoly during 1899-1918 can be viewed as an industrial policy where the government claimed pick the efficient firms. The major policy treatments include both the production quota and the compensation price. The quota captures the government's *confidence* towards the firm, and in an ideal setting the governments update their confidence and shift the quota from less efficient firms to more efficient firms. The compensation price can be viewed as a reward for efficient production and development of hard-to-access production sites. Nevertheless, these policy treatments could also reflect the government's favoritism towards specific firms following our discussions above.

2.2 Businessmen-Official Interaction

Given the institutional design, our discussion regarding the crude camphor monopsony suggest that favoritism is potentially at play for policy treatments received by firms. Such a favoritism could stem from the interactions between the entrepreneur and high ranked officials in charge of economy-related affairs, during which process the entrepreneur may affect Monopoly Bureau's decisions either directly or indirectly. These interaction include lobbying and private communications with the relevant officials. *Taiwan Daily News (臺灣日日新報)*, the largest newspaper in Taiwan and at the same time the government gazette of the Government-General, provides an opportunity for us to observe these interactions.

For example, a news published on May 30, 1901 reports that Ishizuka Eizo (石塚英蔵), the Director of Internal Affair, summoned Komatsu Kusuya (小松楠弥), the person in charge of crude camphor production for *Suzuki Zaibatsu*, to discuss plans on improving production efficiency of crude camphor.[10] An earlier news published on Jun. 17, 1898 also revealed that Nasu Yoshimoto (奈須義質), one of the major crude camphor producer in earlier years, organized a lobbying activity with various crude camphor producers at Nan-Zhuan against the Governor-General for a revision in the camphor tax system.[11] Lie-Tan Lin (林烈堂), one of the leaders of the Lin Clan, were also reported visiting high officials of Monopoly Bureau regarding his business in crude camphor production.[12] The Governor-General and other high officials were also frequently reported stopping by major crude

[10]製脳業者の石塚長官代理訪問, 19010530, Taiwan Daily News, Japanese Edition, p.2
[11]樟脳油税則改正の請願, 18980717, *Taiwan Daily News*, Japanese Edition, p.2
[12]林紳來北,19031027, *Taiwan Daily News*, Japanese Edition, p.3

camphor producers during their official visits to prefectures.[13]

The interactions out side the crude camphor industry may be equally important for entrepreneurs to link-up with relevant officials for their future leverage in all sorts of business activities. Indeed, the entrepreneur involving in crude camphor production were also frequently reported participating in social occasions with government officials. These occasions include festive activities,[14] joining organizations with official background,[15] holding parties for high officials,[16] and being invited as VIPs for banquets hold by officials.[17] By intensively interacting with the officials, the entrepreneurs may gradually expand their connection network in the bureaucratic system and gain familiarity to the officials (currently in seat or potential rising stars), in turn obtain influences on the government's decisions in economic-related policies.

2.3 Data

Our establishment-level dataset is mainly drawn from *Yearbooks of Taiwan Government-General Monopoly Bureau* (henceforth *YMB*), historical archives which had not previously been organized and digitized. We gather the available data in the yearbooks from 1902 to 1918. For the period to our interest, the yearbook recorded detailed establishment-level data, including output quotas for both camphor crystals and oil, input quota for producers' capital (camphor stoves), the number of camphor woods and fuel woods used in production (available after 1906), the output of both products, the annual revenue generated by each product (available after 1907) and thus we can imply the prices paid for both products per physical unit, the prefecture where the establishment cut trees and operated production, and the name of the owner of each establishment. Note that camphor crystal and oil are simultaneously produced by the same production process, and is challenging for production function estimation. Since camphor oil needs to be processed further to extract crystals, and Matsushida (1924, p.211 and p.267) documented that the transformation rate from oil to crystal is approximately 0.5. We therefore define the output quantity of a firm as the its *crystal-equivalent quantity* with the transformation rate.

[13]Examples include Governor-General Kodama Gentarou's visit to crude camphor producers at Douliu Prefecture (總督南巡（第四報）, 19060111, *Taiwan Daily News*, Taiwanese Edition, p.2), visits to Arai Taiji's camphor business in Southern Taiwan by Director of Monopoly Bureau Miyao Shunji (蕃薯寮製腦地近況, 19061109, *Taiwan Daily News*, Taiwanese Edition, p.3) and Governor-General Sakuma Samata (總督抵甲仙埔, 19071224, *Taiwan Daily News*, Taiwanese Edition, p.2).

[14]Examples include the celebration for Mikado's birthday (天長節夜會招待者, 19071106, *Taiwan Daily News*, Taiwanese Edition, p.3) and religious activities at Taiwan Shrine (臺灣神社祭典 記念祭と例祭, 19121030, *Taiwan Daily News*, Japanese Edition, p.7). Several businessmen such as Komatsu Kusuya along with high officials were found in the list of participants.

[15]For example, Lie-Tan Lin joined the Red Cross as a honored member (十字社特別社員, 19030715, *Taiwan Daily News*, Japanese Edition, p.4)

[16]For examples, the Lin Clan and other local elites hold a welcoming party for Goto Sinpei's visit to Taichung (臺中後藤男歡迎會（二十二日臺中電話）, 19121023, *Taiwan Daily News*, Japanese Edition, p.2), and the farewell party for Oosima Kumaji (大島久滿次) organized by Arai Taiji and other businessmen (招讌前方伯, 19100817, *Taiwan Daily News*, Taiwanese Edition, p.5) despite that Oosima was just being prosecuted due to corruption.

[17]There are several examples, such as Kada Ginsaburou (賀田金三郎) being invited to banquet by Governor-General Sakuma Samata (佐久間總督招宴（以上五日門司電）, 19141207, *Taiwan Daily News*, Japanese Edition, p.3), and that members of the Lin Clan and board members of Mitsui were invited to the banquet hold by the Director of Internal Affairs Shimomura Hiroshi at his official residence (督邸招宴, 19171215, *Taiwan Daily News*, Japanese Edition, p.5)

Because the yearbooks did not record labor inputs for each establishment, we match our establishment-level data with labor expenditure from the appendix of Matsushida (1924). This official publication on the camphor monopoly records annual input expenditure on firemen, porters, and other intermediate materials per physical unit of output at the product level of most camphor producers from 1911 to 1917. We recover most producers' total labor expenditure.[18] We construct labor inputs by deflating total labor expenditure by price index. However, the data of labor expenditure some small establishments are missing in the appendix of this book. It seems that the colonial officials only record labor expenditure for those bigger or more productive firms, causing a potential problem of sample selection. To take account those missing data, we impute missing observations of labor expenditure by taking average to the year right before and after the missing year. Then we estimate with the imputed labor expenditure. All the monetary data are deflated with PPI of base year 1914 compiled by Wu (1996).

We use Hanzen's *Taiwan Daily News (Taiwan Nichinichi Simpo; 臺灣日日新報)* Newspaper Archive to construct businessmen-official connectivity. The *Taiwan Daily News* was a semi-state-owned daily newspaper published during 1898–1944. It was merged from *Taiwan Daily (臺灣日報)* and *Taiwan News (臺灣新報)* in 1898, and soon become the government gazette of the Government-General 3 weeks after its establishment. It published a wide range of news, including activities of officials, entrepreneurs and VIPs, business and economy activities, government announcements, announcements from enterprises, interviews, and entertainment. For news about business and enterprises, it frequently discloses the annual meetings of enterprises in detail, which not only provides information on participants and changes in the managerial board, but also a list of major shareholders. The activities of officials, entrepreneurs, and VIPs are also frequently disclosed, including participating in private dinner parties, promotions, and other semi-public activities.

YMB provides the full list of permitted firms involved in the camphor monopoly system. For firms that operate in the form of partnership, the names of partners are mentioned in the introduction part of *YMB* for some years. For names of partners and shareholders not explicitly mentioned in *YMB*, we supplement with the news disclosed by *Taiwan Daily News*. The full list of all ranks of officials in the Government-General is retrieved from *Official Staff in Taiwan Government-General (臺灣総督府職員録)*, which is published annually by the Government-General and covers all formally employed officials from Governor-General to street-level police. Finally, we inspect the biographies of the involved businessmen to supplement for their identities, background and potential long-term relationships. For the Taiwanese businessman we use *Biographies of Taiwanese Gentries (臺灣列紳傳)* published by the Government-General in 1916 for Taiwanese businessmen, and for Japanese businessmen we use *Japanese Who's Who (人事興信録)* digitalized by Nagoya University.

[18]We construct labor expenditure per unit of each product by summing the expenditure on firemen and porters and next multiply unit labor expenditure and output of each product for each establishment.

3 Estimating Productivity

In this section we estimate establishment-level TFPs in the crude camphor industry. We develop an estimation framework based on the approach suggested by ACF, in which we identify TFP using the timing of Monopoly Bureau's adjustments to production quota at establishment-level. The estimation framework is detailed in Appendix A.

We estimate with the data during 1911–1917 as the labor expenditure are readily available in Matsushida (1924). The labor expenditure in Matsushida (1924) are missing for some establishments in some years, causing the panel data to become imbalanced. We impute the missing values of the same establishment by taking average to the values for the year right before and after the missing year. For missing years in the first or the last period we impute by the nearest year available. This imputation process provides additional 20 observations so that the total observations available are 143.

Table 1 presents each input's output elasticity. Both the coefficients of labor and camphor stove are highly significant. The coefficients of camphor wood and fuel wood inputs are positive but insignificant. Following our framework in Appendix A, the physical total productivity productivity (TFP) is defined as $TFP_{it} = e^{\omega_{it}+\varepsilon_{it}}$, which can be obtained as the residual of our estimation to the production function. As Foster, Haltiwanger, and Wolf (2016) mentioned, we can directly construct "revenue productivity", or TFPR_{it} by $\text{TFPR}_{it} = \text{TFP}_{it} \times \overline{p}_{it}$ without estimating the revenue function.

Table 1: Input Elasticity

β_l (labor)	0.715***
	(0.058)
β_w (camphor wood)	0.078
	(0.107)
β_m (fuel wood)	0.142
	(0.102)
β_k (stove)	0.158*
	(0.083)
Observations	143

Standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

We inspect how firm productivities relate to selection into the monopoly system by the colonial officials. Suppose that the colonial officials tend to select more efficient producers then we expect that conditional on the same year and the same prefecture, the entrants' physical productivity should be higher than the incumbents (survivors). Similarly, we can also examine if the officials select the less efficient firms out of the market. Since our data can distinguish between physical productivity and revenue productivity, we can also explore to which kind of productivity the officials paid attention. Formally, we run the following regression to explore the effect of selection on productivity evolution at firm-prefectur-level:

$$
\begin{aligned}
prod_{i,l,t} = &\gamma_0 + \gamma_1 Entry_{i,l,t} + \gamma_2 Exit_{i,l,t} + \gamma_3 ShrJp_{i,t} \\
&+ \gamma_4 Interaction_{i,l,t} \\
&+ Prefecture_l + Year_t
\end{aligned} \tag{1}
$$

where $prod_{i,lt}$ denotes TFP_{it} or $TFPR_{it}$ defined above, $Exit_{it}$ and $Entry_{it}$ denote the dummy variable of exit and entry, and is a continuous variable. The variable $ShrJp_{it}$ denotes the fraction of Japanese shareholders behind establishment *i*, which is computed based on shareholding relationships disclosed by *Taiwan Daily News* and *YMB*. The details of recovering this information is relegated to Steps 1 and 2 in Appendix B.3. The variables $Year_t$ and $Prefecture_l$ denote time trend and prefecture fixed effect. To allow for more flexible regression models, we also include the interaction term between $ShrJp_{it}$ and one of the entry and exit dummies $Interaction_{i,l,t}$. We do not include the interaction terms for both entry and exit simultaneously to avoid collinearity problem.

Table 2: Regression of Entry and Exit

	(1) TFP	(2) TFP	(3) TFP	(4) TFPR	(5) TFPR	(6) TFPR
$Entry_{i,l,t}$	0.330	0.620	0.308	0.004	-0.105	-0.018
	(0.325)	(6.686)	(0.330)	(0.145)	(0.530)	(0.151)
$Exit_{i,l,t}$	0.235	0.292	0.253	0.117	0.063	0.046
	(0.299)	(0.262)	(0.631)	(0.089)	(0.081)	(0.137)
$ShrJp_{i,t}$	-0.391*	-0.368*	-0.394*	0.105	0.035	0.039
	(0.159)	(0.215)	(0.204)	(0.056)	(0.069)	(0.066)
$ShrJp_{i,t} \times Entry_{i,l,t}$		-0.358			0.098	
		(6.954)			(0.595)	
$ShrJp_{i,t} \times Exit_{i,l,t}$			0.058			0.025
			(0.711)			(0.184)
Time Trend and Prefecture FEs	No	Yes	Yes	No	Yes	Yes
Observations	142	142	142	142	142	142

HC3 robust standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The result of estimation are given in Table 2. Columns 1 to 3 are regression results for TFP, and columns 4 to 6 are results for TFPR. The coefficient of $ShrJp_{it}$ is negative and significant throughout columns 1 to 3, indicating that the establishments owned by firms with more Japanese shareholders are less productive. The entry and exit dummies and their interaction terms with $ShrJp_{it}$ are insignificant, but positive for most part. The results suggest that firms composed of more Japanese shareholders tend to be less productive in terms of output, but potentially more productive in terms of revenue. As firm's revenue is determined by the Monopoly Bureau, this finding thus implies that favoritism towards Japanese firms could be at play.

We further inspect how the ethnicity structure of shareholders relates to firms' positions in the distributions of TFP and TFPR. Figure 1 illustrates the empirical cumulative distribution function (henceforth CDF) of both TFP and TFPR for the pooled sample in the upper and lower rows. We

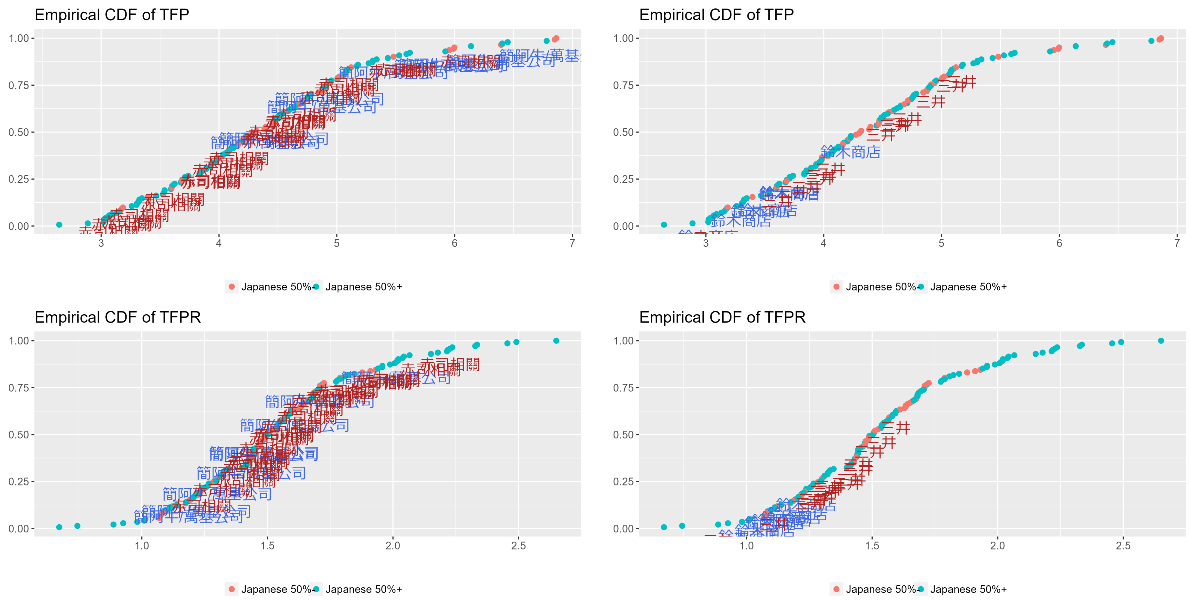

Figure 1: Empirical CDF of TFP and TFPR

distinguish the establishments by whether it is owned by firms with more than 50% of Japanese shareholders. We also mark the positions of establishments owned by more important firms according to ethnicity and scale of operation. For smaller but rapid-growing enterprises, we choose A-Niu Chien (簡阿牛) as the representative of local Taiwanese elite, and Akagi Hatsutaro (赤司初太郎) for Japanese businessmen. Both businessmen started their businesses from scratch, and expanded rapidly by cooperating with more developed enterprises in all fields. For large conglomerates, both of the dominant Zaibastsu Mitsui (三井) and Suzuki (鈴木) are labeled.

Figure 1 shows that, consistent with Table 2, the establishments owned by more Taiwanese shareholders are more concentrated in the middle to the upper right tail. Among the rapid-growing firms, establishments related by A-Niu Chien out performed those related to Akagi Hatsutaro, his Japanese counterpart. In contrast, the performance of Japanese Zaibatsu are surprisingly unsatisfying as their productivities are at best modest in the distribution, and are even outperformed by smaller Taiwanese and Japanese firms. Overall, the TFP distribution shows that Japanese firms tend to be more dispersed and on average less productive than Taiwanese firms.

Turning to TFPR, Figure 1 indicates a rather dispersed pattern for the Japanese firms. However, the top 20% of establishments are mainly owned by Japanese firms. In contrast, the TFPR of Taiwanese firms are concentrated right at the middle of the distribution. This finding suggests that some of the Japanese firms are better compensated than average firms, such that their TFPR dominates the best-performing Taiwanese. For example, among the rapid growing firms the TFPR of A-Niu Chien no longer stand out in the industry, while Akagi Hatsutaro becomes one of the best performing firms. Surprisingly, the performance of Zaibtsu in terms of TFPR remains on the left-tail of the distribution. Such a dispersion in TFPR of Japanese firms may also explain that the coefficients in columns 4 to 6 in Table 2 being insignificant.

The contrast in the distributions of TFP and TFPR potentially suggests favoritism by the bureaucrat, as productive Taiwanese establishments can receive compensation from the Monopoly Bureau less than those received by less productive Japanese establishments. This is consistent with various anecdotal evidence that the Taiwanese businessmen complaining that the Monopoly Bureau tend discriminate them to the Japanese firms by treating their output to be of low quality hence paying poorly. These findings suggest that the concerns on production efficiency and the Monopoly Bureau's favoritism / firm-official connectivity are both at play for firm selection in the Camphor Monopoly System. The two effects need to be disentangled in order to evaluate how this monopoly system has affected the performance of the industry, and whether it is efficient in generating government revenue.

4 Estimating Connectivity Effect

In this section we estimates the effect of firm-official connectivity on the policy treatments that the firm receives. For this purpose, we first construct the businessmen-official network and retrieve lists of government officials and the partners / shareholders of permitted firms. Such a network needs to cover not only the relevant businessmen and officials, but also the friends and family members of these agents to capture their interactions in contexts other than camphor monopoly. Second, we classify the officials into different ranks and define a connectivity measurement between individuals and these officials. Finally, we aggregate the individual-level connectivity up to firm-level by the list of shareholders following a shock design similar to shift-share construction, and then estimate how this connectivity impacts the compensation price and quota of the firm. We also inspect how shocks in connectivity relate to firms' TFPs. In what follows we provide an overview to the procedures above. The details are relegated to Appendix B.3.

4.1 Constructing Network and Distances

We start by a manual search in the *Taiwan Daily News* News Archive using the names of agents (firms, owners and shareholders in the camphor monopoly system) to retrieve a comprehensive list of newspaper appearance of these agents during 1898–1918. At the same time we also update the list of shareholders to businesses involved in camphor monopoly by their news appearances. For each news, we manually identify the type of interactions between the agents and other names appeared in the same news. For news that document interactions between agents and the government, or between agents and the private sector, we record the names appeared in the same news and consider them to be pair-wise connected by the event in the news. Aside from the news appearance, we also construct pair-wise connection between individuals using the partnerships documented in *YMB*. We also construct pair-wise connections among individuals belonging to the same family or have developed persistent relationships if such relationships are documented by the newspaper, *Biographies of Taiwanese Gentries* and *Japanese Who's Who Database.* We identify if an individual is a government official by referring to *Official Staff in Taiwan Government-General* during 1896-1918. We accumulate the network year-by-year on top of the long-term relationship network, and remove deceased individuals hence the relevant paths. This setting implies that connections between individuals persist permanently until deceased.

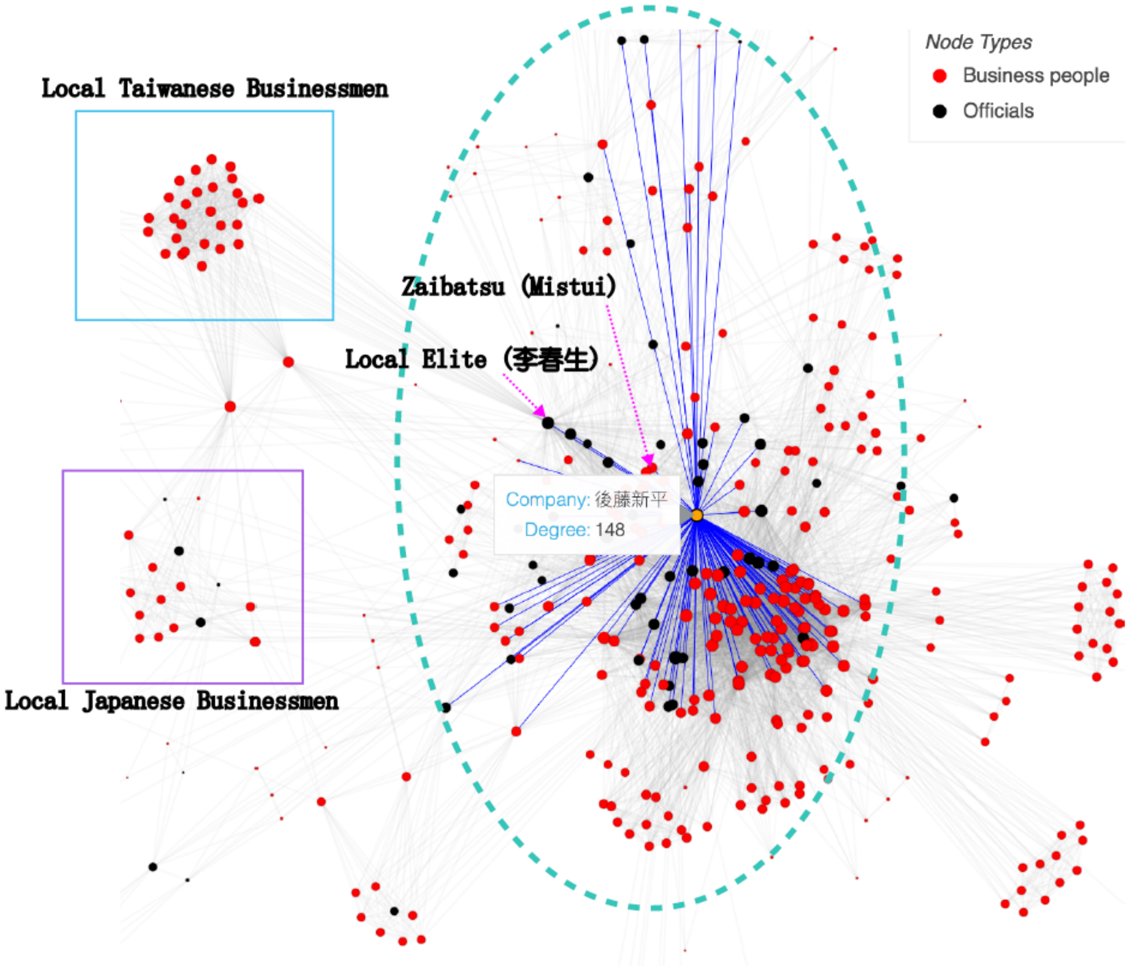

Figure 2: Network in 1899

Following our construction, the network involves in approximately 2600 individuals as of 1918. Figure 2 provides an illustration to the network structure using 1899 as an example. In the figure we inspect how individuals and firms link to Gotou Sinpei (後藤新平), the Director of Internal Affairs in Taiwan Government-General (analogous to primiere in modern bureaucratic structure). As we can see, several VIPs including local elites and Japanese conglomerates connect to Gotou directly. The more peripheral "local" Taiwanese and Japanese businessmen then link up with Gotou via their connections to the VIPs. How many intermediate nodes that a given individual needs to go through to link up with Gotou can thus be think of as the connectivity of this individual to the current Director of Internal Affairs.

As official turnover is externally determined by the bureaucratic system, whether Gotou will remain in the same position is beyond the control of these VIPs. Gotou's position as Director of Internal Affairs was handed to Iwai Tatsumi (祝辰巳) following his reassignment as the chairman of *South Manchuria Railway* in 1906. Such a turnover affects the connectivity of individuals and firms to the Director of Internal Affairs: the existing VIPs might no longer have direct connection to the Director as they are less familiar with Iwai, while the initially more peripheral businessmen could now have better connections with the Director if they have linked up with Iwai in less indirect manners.

Based on the illustration above, we compute the social distance between individuals by counting the number of *edges* required to connect the interested individuals, accounting for the frequencies of newspaper exposure for each of the edges involved. An edge involves in a **pair** of directly connected individuals, and indicate that the interactions between these individuals are disclosed by the news for at least once. More frequent newspaper exposure for an edge thus indicates that the involved individuals are more likely to be familiar with each other, meaning that this edge to be a more viable path for indirectly connected individuals to reach each other among all possible paths. We normalize the distances to be $[0,1]$ in order to avoid the infinite distance issue due to unconnected individuals. The technical details are relegated to Step 5 in Appendix B.3.

4.2 Identification Strategy

As we are interested in how firm's connectivity with officials impacts the policy treatment it receives, we first compute the distances between each individuals involved in camphor production with officials of a given rank. Then we aggregate these connections up to firm-level to obtain an index of firm-official connectivity. The variation will be stemming from the turnover of officials and the expansion of bureaucratic system. The effect of turnover is as discussed in the previous section, that whether a friend of the individual obtains or being removed from the official rank can lead to substantial churning in the social distances to the rank. The bureaucratic expansion entails a dilution effect, that a larger bureaucratic system involves in more officials for all rank levels, thus businessmen familiar with fewer officials experience reductions in their connectivities to each of the official ranks. Note that both of the changes are determined by the bureaucratic system, hence are irrelevant to efforts by individual businessmen.

Aggregating individual-level distances directly to firm-level by shareholder structure can be problematic. This is because connections between individuals hence officials are formed endogenously, and that businessmen become shareholders of firms endogenously. The turnover of officials could thus be anticipated by businessmen with their private knowledge and familiarity with the given officials. As a result, the businessmen could guide a firm to endogenously respond to the exogenous turnover of officials. To mitigate this endogeneity issue, we adopt a shock design that mimics shift-share construction for our firm-level connectivities. The central idea is to classify individuals into exogenous identity groups, and inspect how an average individual in an identity group connects to an average official at a given rank. Then we aggregate up the connectivities of average persons to firm-level using their fraction in the firm's shareholders. Let g be the official group and e denote the identity group, firm i's *change* in connectivity to rank g officials in year t is thus defined by

$$d_{i,t}^{g} \equiv \sum_{e} \underbrace{\omega_{i,e,t}}_{share} \underbrace{\frac{d_{e,t+1}^{g} - d_{e,t}^{g}}{d_{e,t}^{g}}}_{shift},$$

where $\omega_{i,e,t}$ is the fraction of group e to all shareholders at the current year and $d_{e,t}^{g}$ denotes group e's distance with rank g officials. The *shift* part eliminates the linear time-invariant endogeneities, and the share part captures firm heterogeneities.[19]

We classify individuals into four identity groups by their ethnicity-nobility combinations: Noble Japanese, Ordinary Japanese, Local Taiwanese Assistants, and Ordinary Taiwanese. The ethnicity is either Taiwanese or Japanese, which is obviously exogenous. Nobility for Japanese include individuals belonging to *Kazoku or Shizoku* family rank, holding nobility titles, or being a member of the royal family. These titles are given to individuals based on historical achievements and family background, hence are exogenous. For Taiwanese, its 「nobility equivalent」 is Local Taiwanese Assistants, which is defined by whether the individual is enrolled into the colonial government as an adviser (参事) or local executive (街庄區長) **before 1904**. To see the idea, first note that Japan faced heavy organized resistance against its rule in earlier years (1895-1902). In order to counter these resistance activities, the Japanese government entitle privileges to influential local elites in exchange for their assistance such as local peacekeeping, persuading resistant leaders to surrender, or even fight the resistance for the colonial government. As these Taiwanese gain their local influences due to their past efforts in local development well before Japan's arrival, and that their titles are granted by the Japanese out of political motives in these years, this 「nobility equivalent」 is thus more of exogenous.

For official ranks, we focus on officials in central Government-General in charge of economic-related affairs, directly or indirectly. We further classify them into three different ranks $G01$, $G02$ and $G03$. As an analogy to modern bureaucracy system, the $G01$ class is the top officials similar to president, premiere and parliament head, and $G02$ class are ministry heads in charge of economic, finance and development affairs. The $G03$ class are section heads right under the aforementioned ministries. The details are relegated to Appendix B.2.

Figure 3 illustrates the group-to-official distances for each of the identity groups. Not surprisingly,

[19] While shareholder composition changes over time, the share $\omega_{i,e,t}$ is nearly unaffected as most of the changes happen within the same identity group.

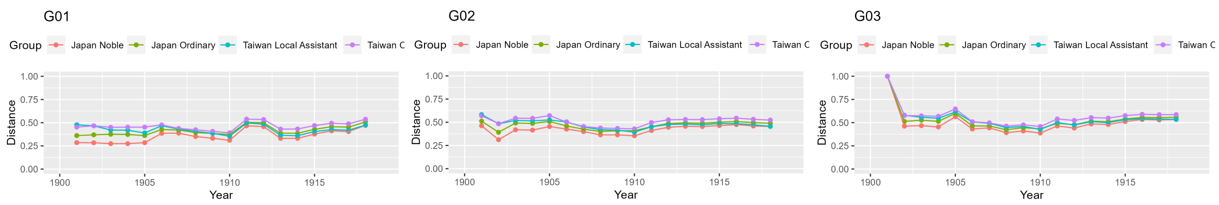

Figure 3: Time Series of Group-level Connectivity

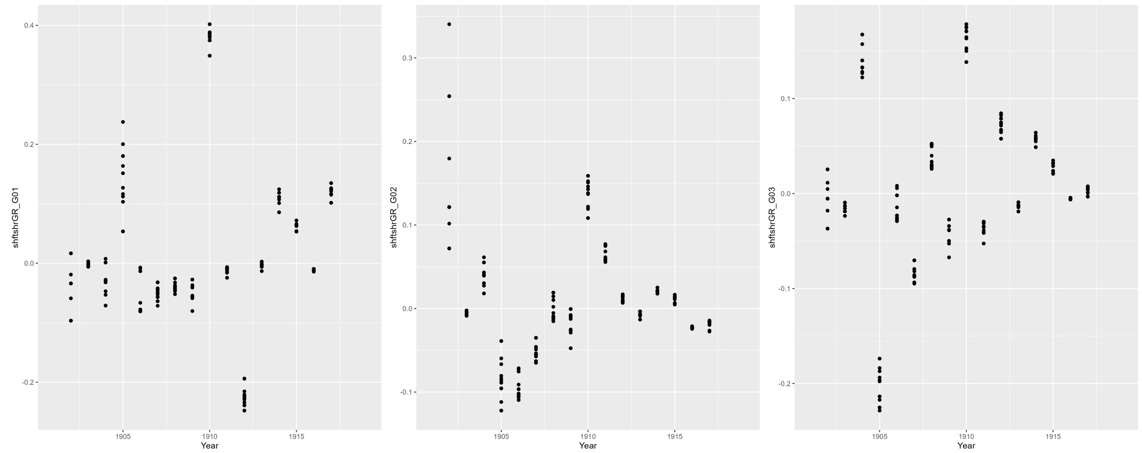

Figure 4: Shift-Share Connectivity

Japanese are more connected to all ranks of officials than Taiwanese. The Japanese Nobility group is particularly connected as the social distances are shortest compared with other identity groups. The Local Taiwanese Assistants group is distant from officials as other Taiwanese. But they gradually gain familiarity with the official and eventually become as connected to the officials as Japanese Nobility group.

We find that the fraction of ethnicity groups within firm to be rather fixed over time. Our data consists of 57 unique firms, but only 9 of them experienced changes in identity group composition, with the average number of such changes being approximately 2.44. Most of the firms are composed of single ethnicity: 20 of them are purely Japanese-owned, and 30 of them are owned by Taiwanese. For the Japanese firms, 6 out of them include shareholders with nobility titles; as for the Taiwanese firms, the Local Taiwanese Assistant group presents in nearly half of the firms at some time point. All of the 7 firms with mixed identity composition include shareholders belonging to at least one of the Japanese Nobility and Local Taiwanese Assistant groups. In short, the shareholder structure is rather constant over time, but quite variable across firms.

Figure 4 illustrates the time series of $d_{i,t}^{g}$ for each official rank, suggesting substantial variations between firms and years. As discussed, the variations come from official turnover, adjustments in bureaucratic structure, and the identity composition of firms. The connectivity changes for $G02$ and $G03$, are highly correlated. This suggests that businessmen connect to higher rank officials also link up with lower rank officials. Including multiple connectivity variables in our regression could thus be problematic due to collinearity.

We estimate how changes in firm i's connectivity affects the policy treatment it receives at location

l with the following specification

$$\dot{y}_{i,l,t} = \beta_0 + \sum_g \beta_g d^g_{i,t} + \gamma \mathbf{X} + Year_t + Prefecture_l,$$

where $\mathbf{X}$ is a vector of firm-location current year controls including fraction of Japanese shareholders and inputs including camphor wood, fuel wood and camphor stove; $Year_t$ denotes the linear time trend and $Prefecture_l$ be the location fixed effects. The dependent variable $\dot{y}_{i,l,t}$ is the rate of change in policy treatments, which we focus on changes in compensation price and quota. We also inspect if connectivity relate to a firm's productivities by estimating

$$\ln y_{i,l,t} = \beta_0 + \sum_g \beta_g d^g_{i,t} + \gamma \mathbf{X} + Year_t + Prefecture_l,$$

where $\ln y_{i,l,t}$ is log-TFP and log-TFPR. The sample size for estimation is subjected to data availability.

4.3 Estimation Results

Table 3 inspects how changes in connectivities impact the compensation prices applied to firms in different locations when only one connectivity variables is included. All of the coefficients are negative, indicating that a reduction in social distance entails an increase in compensation price. The connectivity with $G02$ officials is particularly significant under all specifications. In column (7) where the full set of controls are included, a reduction in social distance by a standard deviation (0.365%) leads to an increase in compensation price by 0.253%. The effects of $G03$ are significant except for the specification in column (7). Since the compensation prices vary across locations, this finding suggests that connectivity with $G03$ officials to be an unlikely channel for changes in compensation prices as it does not beat the location fixed effects.

Table 3: Compensation Price Changes: Single Connectivity

Compensation Price Changes	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Only $d^{G01}_{i,t}$	-0.106	-0.099	-0.088	-0.079	-0.095	-0.068	-0.053
	(0.090)	(0.086)	(0.087)	(0.092)	(0.089)	(0.090)	(0.099)
Only $d^{G02}_{i,t}$	-0.755**	-0.749**	-0.828***	-0.785**	-0.654**	-0.745**	-0.694*
	(0.305)	(0.297)	(0.314)	(0.324)	(0.312)	(0.324)	(0.365)
Only $d^{G03}_{i,t}$	-0.582**	-0.561**	-0.522**	-0.529**	-0.515*	-0.489*	-0.458
	(0.261)	(0.251)	(0.247)	(0.258)	(0.267)	(0.256)	(0.282)
Share of Japanese		Yes	Yes	Yes	Yes	Yes	Yes
Input					Yes	Yes	Yes
Time Trend			Yes	Yes		Yes	Yes
Prefecture FE				Yes			Yes
Observations	204	204	204	204	186	186	186

HC3 robust standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

In Table 4 we inspect the specifications where all connectivity variables are included. As discussed earlier, such a specification potentially suffers from collinearity problem. Nevertheless, the coefficient of $G02$ remains significant in some of the settings, including the most challenging setting in column (7), whereas other connectivity variables are insignificant throughout. This finding suggests that the connectivity to $G02$ official being a more robust channel in affecting the compensation prices than other connectivity variables.

Table 4: Compensation Price Changes: All Connectivities

Compensation Price Changes	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$d_{i,t}^{jG01}$	0.095	0.102	0.163	0.163	0.077	0.168	0.167
	(0.112)	(0.111)	(0.120)	(0.124)	(0.107)	(0.125)	(0.130)
$d_{i,t}^{jG02}$	-0.594	-0.640	-0.973**	-0.926*	-0.470	-0.923**	-0.857*
	(0.431)	(0.443)	(0.481)	(0.500)	(0.319)	(0.385)	(0.436)
$d_{i,t}^{jG03}$	-0.359	-0.317	-0.183	-0.187	-0.343	-0.158	-0.167
	(0.327)	(0.324)	(0.306)	(0.321)	(0.298)	(0.263)	(0.283)
Share of Japanese		Yes	Yes	Yes	Yes	Yes	Yes
Input					Yes	Yes	Yes
Time Trend			Yes	Yes		Yes	Yes
Prefecture FE				Yes			Yes
Observations	204	204	204	204	186	186	186

HC3 robust standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Tables 5 and 6 present the effects of connectivity on quota assigned to firms in each locations, with one and all connectivity variables respectively. Table 5 suggests that a better connectivity with $G01$ officials entails an increase in the quota assigned to a firm. In column (7), a standard deviation reduction (0.36%) in social distance leads to an increase in quota by 0.323%, which is nearly one-for-one in percentage points. The connectivity with $G02$ officials, while being negative, is much less significant throughout. The effect of $G03$ is not only insignificant but also less robust in its magnitude. In Table 6, the connectivity with $G01$ is significant for all specifications except for column (7). Considering the collinearity problem of these specifications, we conclude that $G01$ to be a plausible channel in affecting quota assigned to firms.

Tables 7 and 8 respectively inspect the effect of connectivities on log-TFP and log-TFPR when only one connectivity variable is included. For log-TFP, the only more significant variable is $G02$, but it does not survive when location fixed effect is controlled. For log-TFPR, none of the connectivity variables are significant. While we do not report the coefficients for Share of Japanese variable, it is negative and significant throughout in Table 7, and positive but being insignificant in Table 8. These findings are consistent with our earlier estimation in Table 2, wherein firms with more Japanese shareholders tend to be less productive in terms of output, but are better compensated such that the revenue productivities are not significantly different across firms. In other words, a firm's productivity tends to be more related to the ethnicity structure of its shareholders no matter how the firm gains familiarity with the authority. This could imply that firm productivity is not a criteria for the authority's decision in selecting firms.

In summary, our empirical finding suggests that a better connectivity with officials helps the firm

Table 5: Quota Changes: Single Connectivity

Quota Changes	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Only $d_{i,t}^{jG01}$	-1.199***	-1.227***	-1.153***	-1.188***	-1.177***	-1.005**	-0.896**
	(0.370)	(0.381)	(0.371)	(0.379)	(0.407)	(0.412)	(0.360)
Only $d_{i,t}^{jG02}$	-1.617*	-1.676*	-1.656*	-1.925*	-1.545	-1.362	-1.201
	(0.937)	(0.944)	(0.970)	(1.016)	(1.042)	(1.0801)	(1.206)
Only $d_{i,t}^{jG03}$	0.132	0.062	0.169	0.076	-0.169	0.064	0.183
	(0.791)	(0.798)	(0.865)	(0.924)	(0.843)	(0.934)	(1.039)
Share of Japanese		Yes	Yes	Yes	Yes	Yes	Yes
Input					Yes	Yes	Yes
Time Trend			Yes	Yes		Yes	Yes
Prefecture FE				Yes			Yes
Observations	211	211	211	211	195	195	195

HC3 robust standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 6: Quota Changes: Single Connectivities

Quota Changes	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$d_{i,t}^{jG01}$	-1.499**	-1.511**	-1.394**	-1.357**	-1.454*	-1.238*	-1.116
	(0.665)	(0.675)	(0.664)	(0.684)	(0.740)	(0.742)	(0.716)
$d_{i,t}^{jG02}$	-1.426	-1.395	-1.658	-2.099	-0.865	-1.159	-1.205
	(1.470)	(1.502)	(1.604)	(1.668)	(1.676)	(1.741)	(1.923)
$d_{i,t}^{jG03}$	2.815**	2.734**	2.835**	2.959**	2.121	2.230	2.195
	(1.348)	(1.368)	(1.422)	(1.494)	(1.428)	(1.473)	(1.467)
Share of Japanese		Yes	Yes	Yes	Yes	Yes	Yes
Input					Yes	Yes	Yes
Time Trend			Yes	Yes		Yes	Yes
Prefecture FE				Yes			Yes
Observations	211	211	211	211	195	195	195

HC3 robust standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 7: Log-TFP: Single Connectivity

log-TFP	(1)	(2)	(3)	(4)
Only $d_{i,t}^{jG01}$	0.267	0.327**	-0.038	-0.009
	(0.165)	(0.158)	(0.186)	(0.184)
Only $d_{i,t}^{jG02}$	-2.321***	-2.414***	-1.543*	-1.372
	(0.577)	(0.590)	(0.914)	(0.904)
Only $d_{i,t}^{jG03}$	-0.004	0.037	0.119	0.062
	(0.499)	(0.493)	(0.451)	(0.450)
Share of Japanese		Yes	Yes	Yes
Time Trend			Yes	Yes
Prefecture FE				Yes
Observations	142	142	142	142

HC3 robust standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 8: Log-TFPR: Single Connectivity

log-TFPR	(1)	(2)	(3)	(4)
Only $d_{i,t}^{G01}$	0.300	0.272	0.195	0.180
	(0.197)	(0.202)	(0.240)	(0.204)
Only $d_{i,t}^{G02}$	-0.824	-0.773	-0.119	-0.298
	(0.780)	(0.773)	(1.278)	(1.130)
Only $d_{i,t}^{G03}$	0.246	0.220	0.254	0.255
	(0.607)	(0.604)	(0.601)	(0.529)
Share of Japanese		Yes	Yes	Yes
Time Trend			Yes	Yes
Prefecture FE				Yes
Observations	142	142	142	142

HC3 robust standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

to acquire more quota and higher compensation prices. However, we do not find evidence as to that the authority actively use firm productivity as a criteria for firm selection.

5 A Model of Camphor Monopoly

In this section we develop a model that features firm heterogeneities in productivity potentials and connectivities to mimic the camphor monopoly system. The only concern of the government is to pick the **right firms** that maximize its financial return, thus the decisions made by the government is always efficient by the government's objective. We can therefore think of the model as the *ideally* implemented camphor monopoly system as claimed by Monopoly Bureau. Under this framework, we disentangle the roles of productivity potentials and connectivities on the Monopoly Bureau's permission granting decisions, firms' realized productivities, and the resulting government revenue. Then we use this model as a benchmark to evaluate the performance of the monopoly system.

In this model there is a continuum of locations suitable for producing camphor. For each location, the government grants the permission to one out of many potential entrants endowed with different levels of productivity potential and firm-official connectivity. Each of the potential entrants first exert costly investments to build-up its productivity. Once a firm is selected by the government, it becomes the sole producer that produces a distinct camphor variety at the location. The operating profit is then shared between the firm and the government, hence the government's income from camphor monopoly is given by aggregating its share to the operating profits. The model is detailed as follows.

5.1 Demand Structure

There is a unit mass of production sites of camphor (location). Each location n produces a distinct camphor variety q_n. Assume that the consumer's preference to camphor is characterised by CES as

$$U = \left(\int_0^1 q_n^{\frac{\sigma-1}{\sigma}} dn \right)^{\frac{\sigma}{\sigma-1}}.$$

The inverse demand function for each variety n is thus given by

$$p_n = \left(\frac{I}{P^{1-\sigma}} \right)^{\frac{1}{\sigma}} q_n^{-\frac{1}{\sigma}} \equiv A q_n^{-\frac{1}{\sigma}},$$

where I is the total expenditure, $P \equiv \left(\int_0^1 p_n^{1-\sigma} dn \right)^{\frac{1}{1-\sigma}}$ is the price index, and $\sigma > 1$ is the elasticity of substitution.

Note that I is exogenously given and the price index P is taken as given by all agents when making their decisions. The object $A \equiv I^{\frac{1}{\sigma}} P^{\frac{\sigma-1}{\sigma}}$ is hence an exogenously given demand shifter, and cannot be changed by individual firms and the government. In the rest of the analysis we focus on permissions at variety level. As we will see later, the firm decisions and government's expected income are symmetric across varieties. Focusing on variety level is sufficient as the varieties come in a unit mass.

5.2 Firm

There are N potential entrants competing for the production permission at each production site. A successful entrant i at a production site n thus produces the camphor variety using M inputs with the production technology

$$q_{i,n} = \varphi_{i,n} \prod_{j=1}^{M} m_{j,i,n}^{\alpha_j},$$

where $m_{j,i,n}$ denotes the amount of input j used by firm i, $\varphi_{i,n}$ represents firm i's productivity at location n, and the input intensities α_j are such that $\alpha_j \in (0,1)$ and $\sum_{j=1}^{M} \alpha_j = 1$. The factor markets are perfectly competitive, and the factor prices w_j are taken as given by all firms. The cost minimization problem of firms yields the production cost function

$$C(q_{i,n}) = B \left(\prod_{j=1}^{M} w_j^{\alpha_j} \right) \varphi_{i,n}^{-1} q_{i,n},$$

where $B \equiv \prod_{j=1}^{M} \alpha_j^{-\alpha_j}$.

Before obtaining any permissions, each entrant must exert costly innovation to acquire its productivity. The outcome of innovation depends on both the firm's innovation effort $\varphi_{0,i}$ and a firm-location-specific shock $z_{i,n}$. Specifically, we assume that the firm level productivity is given by

$$\varphi_{i,n} = \varphi_{0,i} z_{i,n},$$

where the random shock z_i follows a Frechet distribution common across all firms with c.d.f.

$$F\left(z_{i,n}\right) = e^{-z_{i,n}^{-\theta}},$$

and the tail index $\theta > 1$. Note that the expected productivity of firm i at location n is proportional to its innovation effort as $E\left(\varphi_{i,n}\right) = \varphi_{0,i}\Gamma\left(1 - \frac{1}{\theta}\right)$ where $\Gamma(.)$ is the gamma function.

We consider an infinite time horizon scenario, where the one-shot innovation effort $\varphi_{0,i}$ is made in the first period. In each follow-up periods the firm-location-specific productivity shock $z_{i,n}$ is drawn randomly from $F\left(z_{i,n}\right)$ so that the productivity level $\varphi_{i,n}$ in each period is realized. In each period, the firm chooses its output $q_{i,n}$ to maximize its operating profit given the realization of $\varphi_{i,n}$ for each location it obtains the permission. We denote the profit by $\pi_{f,i,n}\left(\varphi_{i,n}\right)$. Since the innovation outcome is random, the firm's innovation decision maximizes the present value of its expected profit given the innovation cost function $c\left(\varphi_{0,i}\right)$. For tractability, we assume that the innovation cost function is given by

$$c\left(\varphi_{0,i}\right) = \varphi_{0,i}^{\zeta},$$

where $\zeta > 1$. We further assume that the innovation efforts $\varphi_{0,i}$ are observable to all firms for simplicity.

5.3 Government Monopoly

In each period for each location, the government grants the permission of production to one of the firms upon observing the realized productivities of all potential firms. The permitted firm thus acts as a monopolist and then share the profit of producing the camphor variety with the government. The government's problem is then to choose the firm that generates the highest government income for each location. Each permission lasts for one period only, hence the the assignment process of permissions is repeated in each period.

Suppose that the permission at a location is given to firm i upon the realization of its productivity $\varphi_{i,n}$, the operating profit is then

$$\pi_{i,n}\left(\varphi_{i,n}\right) = Aq_{i,n}^{1-\frac{1}{\sigma}} - B\left(\prod_{j=1}^{M} w_j^{\alpha_j}\right)\varphi_{i,n}^{-1}q_{i,n}.$$

The profit is split between the government and the firm, which we assume that the government obtains a share $\beta_i \in (0,1)$ of the profit. The profit of firm i and the government are respectively

$$\begin{aligned}\pi_{f,i,n} &= \left(1-\beta_i\right)\pi_{i,n}\left(\varphi_{i,n}\right)\\ \pi_{G,i,n} &= \beta_i\pi_{i,n}\left(\varphi_{i,n}\right).\end{aligned}$$

The government's objective is to choose the firm that yields the highest $\pi_{G,i,n}$ given β_i the realization of $\varphi_{i,n}$ for each firm.

The profit share β_i can be thought of as the government's bargaining power to firm i, and depends on how well firm i and the government are connected. Our estimation in 4 finds that official favoritism is at play, that firms with better firm-official connectivities tend to be better compensated by the government. Such a favoritism is characterized as a smaller β_i, that the government is willing to take a smaller portion of the profit. As connectivities vary from firms to firms, the bargaining power β_i is thus heterogeneous between firms. We take an agnostic stand regarding how firm-official connectivities and the bargaining powers are determined. In the rest of the modeling we treat β_i as *de facto*, and is a common knowledge to all players. The modeling of the formation of β_i is beyond the scope of our paper.

The timing of the model is as follows:

1. In the initial period, each firm makes a one-shot innovation effort φ_0 that maximizes its expected present value.

2. In each infinitely repeated follow-up period, the government grants permission and production takes place in the following manner:

Permission Stage: Firm-site-specific shocks $z_{i,n}$ are independently realized and observed. For each site n the government grants a permission that last for the current period to a firm that maximizes its return from the site $\pi_{G,n}$ based on the observations to $\{\beta_i, \varphi_{i,n}\}$.

Production Stage: In each location the permitted firm, say firm i, chooses the level of output $q_{i,n}$, and the profit is realized and split between the firm and the government. The permission ends upon the realization of profit.

5.4 Equilibrium

The model structure is stationary in the sense that each of the follow-up periods are similar. It is sufficient to study the equilibrium outcome in one period, and then construct the present value of expected profit in the first period.

We solve the model backwards for each of the follow-up period. In the Production Stage the permitted firm chooses $q_{i,n}$ to maximize its operating profit $\pi_{f,i,n}$. It is readily verified that the optimal level of output is given by

$$q_{i,n} = \left(\frac{A}{B}\right)^{\sigma} \left(\frac{\sigma-1}{\sigma}\right)^{\sigma} \prod_{j=1}^{M} w_j^{-\sigma\alpha_j} \varphi_{i,n}^{\sigma}.$$

According to the profit-sharing rule, the profit for both the government and firm i are respectively

$$\pi_{G,i,n} = \beta_i k \varphi_{i,n}^{\sigma-1}$$
$$\pi_{f,i,n} = \frac{1-\beta_i}{\beta_i} \pi_{G,i,n},$$

where $k \equiv \frac{A}{\sigma-1} \left(\frac{\sigma-1}{\sigma}\right)^{\sigma} \left(\frac{A}{B}\right)^{\sigma-1} \prod_{j=1}^{M} w_j^{-(\sigma-1)\alpha_j}$.

In the Permission Stage, the government chooses the firm that yields the highest $\pi_{G,n}$ given β and the realization of firm-location productivity $\varphi_{i,n}$. Given this decision rule, the probability density that a firm obtains the permission at the location before the shocks $z_{i,n}$ are observed is equivalent to the probability density that the firm yields the highest $\pi_{G,n}$ at this location. Recall that z is randomly drawn from a common Frechet distribution, the resulting distribution of π_G given a firm's innovation effort is also Frechet in each location, which we denote its c.d.f. and p.d.f. by $G_{i,n}(\pi_G)$ and $g_{i,n}(\pi_G)$. A change of variable yields

$$\begin{aligned} G_{i,n}(\pi_G) \equiv& \Pr\left(\pi_{G,i,n} \leq \pi_G\right) = \Pr\left(\beta_i k \varphi_{0,i}^{\sigma-1} z_{i,n}^{\sigma-1} \leq \pi_G\right) \\ =& e^{-k^{\frac{\theta}{\sigma-1}} \beta_i^{\frac{\theta}{\sigma-1}} \varphi_{0,i}^{\theta} \pi_G^{-\frac{\theta}{\sigma-1}}} \\ g_{i,n}(\pi_G) =& \frac{\theta}{\sigma-1} k^{\frac{\theta}{\sigma-1}} \beta_i^{\frac{\theta}{\sigma-1}} \varphi_{0,i}^{\theta} \pi_G^{-\frac{\theta}{\sigma-1}-1} e^{-k^{\frac{\theta}{\sigma-1}} \beta_i^{\frac{\theta}{\sigma-1}} \varphi_{0,i}^{\theta} \pi_G^{-\frac{\theta}{\sigma-1}}}. \end{aligned}$$

Since z is drawn i.i.d., the probability density that firm i obtains the permission is accordingly

$$\begin{aligned} h_{i,n}(\pi_G) =& g_{i,n}(\pi_G) \prod_{m \neq i} G_n(\pi_G) \\ =& \frac{\theta}{\sigma-1} k^{\frac{\theta}{\sigma-1}} \beta_i^{\frac{\theta}{\sigma-1}} \varphi_{0,i}^{\theta} \pi_G^{-\frac{\theta}{\sigma-1}-1} e^{-k^{\frac{\theta}{\sigma-1}} \pi_G^{-\frac{\theta}{\sigma-1}} \sum_m \beta_m^{\frac{\theta}{\sigma-1}} \varphi_{0,m}^{\theta}}. \end{aligned}$$

As a result, firm i's winning probability $r_{i,n}$ and expected operating profit at the location are given by

$$r_{i,n} \equiv \int_0^\infty h_{i,n}(\pi_G)\, d\pi_G = \frac{\beta_i^{\frac{\theta}{\sigma-1}} \varphi_{0,i}^{\theta}}{\sum_m \beta_m^{\frac{\theta}{\sigma-1}} \varphi_{0,m}^{\theta}} \tag{2}$$

$$E\left(\pi_{f,i,n}\right) = \frac{1-\beta_i}{\beta_i} \frac{\beta_i^{\frac{\theta}{\sigma-1}} \varphi_{0,i}^{\theta}}{\left(\sum_m \beta_m^{\frac{\theta}{\sigma-1}} \varphi_{0,m}^{\theta}\right)^{1-\frac{\sigma-1}{\theta}}} k \Gamma\left(1 - \frac{\sigma-1}{\theta}\right), \tag{3}$$

where we require $\theta > \sigma - 1$ for the gamma function $\Gamma\left(1 - \frac{\sigma-1}{\theta}\right)$ to be finite. The derivations are relegated to Appendix C.1.

Note that the cdf $G_{i,n}(\pi_G)$, the probability densities $g_{i,n}(\pi_G)$ and $h_{i,n}(\pi_G)$ and equations (2) and (3) are symmetric across all locations n. We therefore omit the location notation thereafter, and denote by $G_{i,n}(\pi_G) = G_i(\pi_G)$, $g_{i,n}(\pi_G) = g_i(\pi_G)$, $h_{i,n}(\pi_G) = h_i(\pi_G)$, $r_{i,n} = r_i$, and $E\left(\pi_{f,i,n}\right) = \overline{\pi}_{f,i}$.

In the first period each firm chooses its innovation effort $\varphi_{0,i}$ to maximize the present value of expected profit $V_{i,n}(\varphi_{0,i})$. Let $\delta \in (0,1)$ denotes the discount rate, and note that the expected profit in each period is the same, and that $\overline{\pi}_{f,i}$ is symmetric across locations. The expected value that firm i obtains from a given location is thus symmetric across locations and is given by

$$V_{i,n}(\varphi_{0,i}) \equiv V_i(\varphi_{0,i}) = \frac{\overline{\pi}_{f,i}}{1-\delta}.$$

As a result, firm i's expected value from the camphor monopoly system is given by

$$\int_0^1 V_i\left(\varphi_{0,i}\right) dn - c\left(\varphi_{0,i}\right) = \frac{\overline{\pi}_{f,i}}{1-\delta} - c\left(\varphi_{0,i}\right).$$

The interior solution is such that the first- and second-order conditions hold

$$\begin{aligned} \frac{d\overline{\pi}_{f,i}}{d\varphi_{0,i}} &= (1-\delta)\,\zeta\,\varphi_{0,i}^{\zeta-1} \\ \frac{d^2\overline{\pi}_{f,i}}{d\varphi_{0,i}^2} &< (1-\delta)\,\zeta\,(\zeta-1)\,\varphi_{0,i}^{\zeta-2}. \end{aligned}$$

The following proposition provides the condition for the unique existence of the interior solution, and inspects the role of firm-official connection on innovation efforts.

Proposition 1. *The interior solution of $\varphi_{0,i}$ exists and is unique if $(\theta-\delta)/(1-\delta) < \zeta$. A lower bargaining power to the government against firm i, β_i, incentivises the firm for higher innovation efforts if $\beta_i > 1 - \frac{\sigma-1}{\theta}$.*

Proof. See Appendix C.2. □

Proposition 1 shows that firm-official connection can encourage innovation efforts by that the government shifts the monopoly profit to the firm. Because the government's objective is to maximize its profit from the monopoly system, it prefers firms with either high innovation efforts or with weaker bargaining power against the government (weaker connection) as shown in (2). From the view of the firm, a weaker bargaining power reduces its share to the (expected) monopoly profit, which in turn discourages innovation effort since the monopoly profit is proportional to its innovation efforts. In other words, firms with better connection to the government are also incentivised to innovate.

The discussion above suggests that government's decision on picking winner is highly correlated with how good the connection between the firm and the government is. This finding helps to explain why winning firms under industrial promotion programs tend to be well-connected with the policy makers. However, picking winners can be costly to the government as it is required to shift more profits in order to incentivise firms for innovation. Because of this tradeoff, it is possible that the government does not always pick the most innovative firms. That is, the firms with highest $\varphi_{0,i}$'s might not be having the highest winning probability, and might not be the firms contributing the most to the government's (present value) expected profit.

The government's present value of expected income from location n is given by

$$\begin{aligned} E\left(V_{G,n}\right) &= \sum_i \frac{1}{1-\delta}\int_0^\infty \pi_G \frac{\theta}{\sigma-1} k^{\frac{\theta}{\sigma-1}} \beta_i^{\frac{\theta}{\sigma-1}} \varphi_{0,i}^{\theta} \pi_G^{-\frac{\theta}{\sigma-1}-1} e^{-k^{\frac{\theta}{\sigma-1}} \pi_G^{-\frac{\theta}{\sigma-1}} \sum_m \beta_m^{\frac{\theta}{\sigma-1}} \varphi_{0,m}^{\theta}} d\pi_G \\ &= \left(\sum_i \beta_i^{\frac{\theta}{\sigma-1}} \varphi_{0,i}^{\theta}\right)^{\frac{\sigma-1}{\theta}} \frac{k}{1-\delta}\Gamma\left(1-\frac{\sigma-1}{\theta}\right), \end{aligned}$$

which is symmetric across all locations. The government's total income from the camphor monopoly system is therefore given by

$$E(V_G) = \int_0^1 E\left(V_{G,n}\right) dn = E\left(V_{G,n}\right).$$

In the industrial equilibrium we have

$$k = \frac{I}{\sigma} \frac{1}{\sum_i \frac{\beta_i^{\frac{\theta}{\sigma-1}-1} \varphi_{0,i}^{\theta}}{\left(\sum_m \beta_m^{\frac{\theta}{\sigma-1}} \varphi_{0,m}^{\theta}\right)^{1-\frac{\sigma-1}{\theta}}} \Gamma\left(1-\frac{\sigma-1}{\theta}\right)}$$

$$\Rightarrow E(V_G) = \frac{1}{\sigma} \frac{I}{1-\delta} \frac{\sum_m \beta_m^{\frac{\theta}{\sigma-1}} \varphi_{0,m}^{\theta}}{\sum_m \beta_m^{\frac{\theta}{\sigma-1}-1} \varphi_{0,m}^{\theta}}. \tag{4}$$

The proof is relegated to Appendix C.3. A firm's expected profit net of innovation cost is similarly obtained as

$$\begin{aligned} V_i(\varphi_{0,i}) - c(\varphi_{0,i}) &= \frac{1}{\sigma} \frac{I}{1-\delta} \frac{1-\beta_i}{\beta_i} \frac{\beta_i^{\frac{\theta}{\sigma-1}} \varphi_{0,i}^{\theta}}{\sum_m \beta_m^{\frac{\theta}{\sigma-1}-1} \varphi_{0,m}^{\theta}} - \varphi_{0,i}^{\zeta} \\ &= \frac{1}{\sigma} \frac{I}{1-\delta} \frac{1-\beta_i}{\beta_i} \frac{\sum_m \beta_m^{\frac{\theta}{\sigma-1}} \varphi_{0,m}^{\theta}}{\sum_m \beta_m^{\frac{\theta}{\sigma-1}-1} \varphi_{0,m}^{\theta}} r_i - \varphi_{0,i}^{\zeta}. \end{aligned}$$

6 Quantitative Analysis

In this section we evaluate how firm-official connectivities impacts the performance of firms and the government's financial object under the camphor monopoly system. This is done by first calibrate both the firm-level bargaining powers and winning probabilities using the data we have constructed. Then we simulate the model, and compare the model-implied firm-level TFP and winning probabilities with their empirical counterparts. Recall that the model resembles the ideal version of the monopoly system wherein the government concerns about its financial income only. The differences in model-implied and empirical allocations thus reflects the government's deviation from its financial objective. Lastly, we gauge the *costs* of such a deviation using the government's profit rate from camphor monopoly.

6.1 Quantification Strategy

The key equations of camphor monopoly in our model includes the first-order conditions of firms' innovation efforts $\varphi_{0,i}$ and the winning probabilities r_i

$$\frac{1-\delta}{I}\frac{\sigma}{\theta}\zeta\varphi_{0,i}^{\zeta} = (1-\beta_i)\left[1-\left(1-\frac{\sigma-1}{\theta}\right)\frac{\beta_i^{\frac{\theta}{\sigma-1}}\varphi_{0,i}^{\theta}}{\sum_m \beta_m^{\frac{\theta}{\sigma-1}}\varphi_{0,m}^{\theta}}\right]\frac{\beta_i^{\frac{\theta}{\sigma-1}-1}\varphi_{0,i}^{\theta}}{\sum_m \beta_m^{\frac{\theta}{\sigma-1}-1}\varphi_{0,m}^{\theta}}$$

$$r_i = \frac{\beta_i^{\frac{\theta}{\sigma-1}}\varphi_{0,i}^{\theta}}{\sum_m \beta_m^{\frac{\theta}{\sigma-1}}\varphi_{0,m}^{\theta}}.$$

Given the model parameters, this system defines both the equilibrium firm productivities and winning probabilities.

Let $i = 1$ be a benchmark firm, we can further simplify this system in a hat-algebra fashion as

$$\widehat{\varphi}_{0,i}^{\zeta} = \frac{1-\left(1-\frac{\sigma-1}{\theta}\right)r_i}{1-\left(1-\frac{\sigma-1}{\theta}\right)r_1}\widehat{(1-\beta_i)}\widehat{\beta}_i^{\frac{\theta}{\sigma-1}-1}\widehat{\varphi}_{0,i}^{\theta}$$

$$r_i = \frac{\beta_1^{\frac{\theta}{\sigma-1}}\frac{\beta_i^{\frac{\theta}{\sigma-1}}}{\beta_1^{\frac{\theta}{\sigma-1}}}\varphi_{0,1}^{\theta}\frac{\varphi_{0,i}^{\theta}}{\varphi_{0,1}^{\theta}}}{\sum_m \beta_1^{\frac{\theta}{\sigma-1}}\frac{\beta_m^{\frac{\theta}{\sigma-1}}}{\beta_1^{\frac{\theta}{\sigma-1}}}\varphi_{0,1}^{\theta}\frac{\varphi_{0,m}^{\theta}}{\varphi_{0,1}^{\theta}}} = \frac{\widehat{\beta}_i^{\frac{\theta}{\sigma-1}}\widehat{\varphi}_{0,i}^{\theta}}{\sum_m \widehat{\beta}_m^{\frac{\theta}{\sigma-1}}\widehat{\varphi}_{0,m}^{\theta}}$$

$$r_1 = \frac{1}{\sum_m \widehat{\beta}_m^{\frac{\theta}{\sigma-1}}\widehat{\varphi}_{0,m}^{\theta}},$$

where $\widehat{x_i} \equiv x_i/x_1$ denotes for the firm-level variable relative to the benchmark firm. With this formulation, we can solve for the relative firm-level innovation $\widehat{\varphi}_{0,i}$ hence winning probabilities r_i given the relative bargaining powers $\widehat{\beta}_i$ and $\widehat{1-\beta_i}$ and model parameters (θ, σ, ζ). The level of market expenditure I is not needed. Note that while the discount rate δ does not enter the equations directly, Proposition 1 shows that the level of δ affects the permissible set of ζ for the unique existence of equilibrium. The parameters to be calibrated are therefore $(\beta_i, \theta, \sigma, \zeta, \delta)$.

Calibrating β_i

Recall that β_i is the profit sharing ratio of the government against firm i, and is related to the firm-official connectivity. We calibrate β_i as the ratio between the firm-level revenue **predicted by connectivity** and the inferred firm-level sales on the final goods market. For the connectivity-predicted revenue, we first predict firm-location-year level growth rate of compensation prices with the firm's change in connectivity to the Head-of-Ministry-ranked officials

$$\dot{p}_{i,t,l}^{comp,predict} = \gamma_{G02}\dot{d}_{i,t}^{G02},$$

where γ_{G02} is the (significant) coefficient that we estimated earlier. We use the most robust setting, where γ_{G02} is estimated when all three connectivity variables as well as full set of controls variables are considered, and the estimated coefficient is -0.688. Then for each firm-location we predict the time series of its compensation price $p_{i,t,l}^{comp,predict}$ using the revenue in its first available year. The connectivity-predicted revenue is then computed by multiplying the predicted compensation price with the actual output as $p_{i,t,l}^{comp,predict} q_{i,l,t}$. The inferred sales for each firm-location on the final goods market is computed by multiplying the observed output with the price on the final goods market as $p_t q_{i,l,t}$.

We assume that all firms in our data are potential entrants into the market, and we focus on the long-term performances of these entrants. We therefore calibrate firm-level bargaining power by pooling all years together, as

$$1-\beta_i = \frac{\sum_l \sum_t p_{i,t,l}^{comp,predict} q_{i,l,t}}{\sum_l \sum_t p_t q_{i,l,t}},$$

where the numerator is the firm-level connectivity-predicted revenue and the denominator is the inferred final market sales at firm-level. We set the ratio to 0.9 in the rare cases where the calibrated ratio exceeds 1. The bargaining power of the government β_i is accordingly obtained.

Calibrating $(\sigma, \zeta, \theta, \delta)$

Note that monopolistic pricing and CES preference together implies that σ relates to price markup in the final goods market as

$$\sigma = \frac{p/c}{p/c-1},$$

where c is the constant marginal cost of production. With the Cobb-Douglas production technology the marginal cost of production at firm-location-year level is given by

$$c_{i,l,t} = B\left(\prod_{j=1}^{M} w_{j,t}^{\alpha_j}\right)\varphi_{i,l,t}^{-1},$$

where $B\left(\prod_{j=1}^{M} w_{j,t}^{\alpha_j}\right)$ is the price index of input factors and can be think of as PPI. We can therefore calibrate the markup rate as the average PPI-deflated market price of camphor weighted by firm productivity as

$$E\left(\frac{p}{c}\right) = E\left(\frac{p_t}{B\left(\prod_{j=1}^{M} w_{j,t}^{\alpha_j}\right)}\varphi_{i,l,t}\right).$$

With this approach, σ is calibrated to approximately 1.41, implying a markup rate of 3.44.

The tail index θ is set to 1.2 to be consistent with power law in firm size. The discount rate δ is set to 0.95 as in various studies. Our parameterization thus requires $\zeta > 5$ to hold for the unique existence of equilibrium. We therefore set ζ to 5.1.

Computing Empirical Winning Probabilities and TFPs

We compute empirical revenue, winning probabilities and productivities at firm-level in order to compare with their model-implied counterparts. Since we focus on long-run performances of firms, we compute empirical revenue at firm-level as the sum of relevant firm-location-year revenue, and empirical firm-level productivity as the average of estimated firm-location-year level TFP using output as weight. The resulting firm-level TFP can be think of as a long-term average productivity of firm. Recall from the model that the expected productivities of firms $E(\varphi_i)$ are proportional to innovation efforts $\varphi_{0,i}$ up to a constant $\Gamma\left(1-\frac{1}{\theta}\right)$. The relative expected productivity of firm is thus equivalent to relative innovation level $\widehat{\varphi}_{0,i} = \widehat{E(\varphi_i)}$, which its empirical counterpart is exactly the relative firm-level TFP.

For winning probability, note that our symmetric setting with a unit continuum of location implies that r_i is equivalent to the fraction of production sites granted to a firm. We therefore compute its long-run empirical counterpart by counting the number of production sites as

$$r_i^{emp} = \frac{\sum_t \sum_l \#site_{i,l,t}}{\sum_i \sum_t \sum_l \#site_{i,l,t}}.$$

6.2 Simulation

Our simulation focuses on firms during 1910-18, during which period we are able to compute the time series of predicted revenue with a relatively stable pool of long-term surviving firms. The benchmark scenario is to consider all firms as potential entrants and compete for production sites throughout Taiwan. We refer to this scenario as the *pooled simulation* and is done by the firm-level variables that we have calibrated. As this scenario overlooks the potential heterogeneities across different prefectures, we also perform *regional simulations* using firm-location-level variables calibrated in the same fashion. Due to adjustments in prefectural jurisdictions in both central and eastern Taiwan, our regional simulation require us to combine relevant prefectures into larger regions. In the case that we need to merge firm-location observations due to these jurisdiction adjustments, we aggregate by summation for output, revenue and number of production sites, and by taking average using output as weights for productivity. In both simulations we pick the firm with the *highest* empirical TFP in the given market as our benchmark firm.

The left column of Figure 5 illustrates connectivity-predicted revenue against the empirical revenue with a 45-degree line. The predicted revenue is highly similar to its empirical counterpart at both firm- and firm-location levels: they are even nearly identical for some firms. As the predicted revenue by construction is positively related to connectivity with the government, this finding suggests that the empirically observed revenue for the most part is determined by connection, such that firms that are more familiar to the government officials tend to be better compensated thus earning higher revenue. The right column of Figure 5 further shows that firm bargaining power is positively associated with predicted revenue, indicating that firms with better connectivities indeed acquire a greater share to profits generated under the monopoly system. Moreover, firms composed of more Taiwanese shareholders tend to come with lower bargaining power against the government.

Figure 6 further inspects how firm bargaining power relate to empirical productivity and winning probability. The figure suggests that the bargaining power of firms tend to be negatively correlated with their empirical TFPs. As firms with more Japanese shareholders tend to be better connected with the authority, this finding is consistent with our earlier estimation that Japanese firms are less productive than Taiwanese firms. As for winning probability, the figure suggests a clustered pattern, and bargaining power tend to be positively correlated with winning probability. The last row of Figure

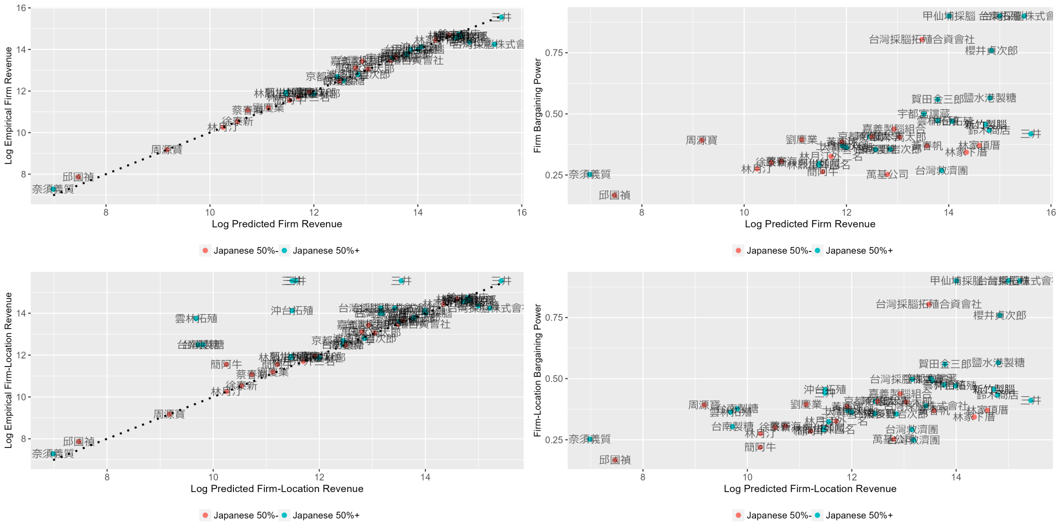

Figure 5: Connectivity-Predicted Revenue and Firm Bargaining Power

6 shows that firms with higher productivities tend to have lower winning probabilities. Note that firms with more Taiwanese shareholders tend to see lower winning probabilities and higher productivity levels. These patterns suggest that favoritism towards Japanese firms tend to affect the configuration of camphor monopoly.

The result of pooled simulation is provided in Figure 7, where the upper row illustrates model prediction and the lower row compares these results with their empirical counterparts. The upper-right panel shows that the government prefers firms with lower bargaining power against it, as the winning probability is increasing in the profit share of the government for the most part. This is reasonable as in our model the government cares only about its profit, hence the best firm to choose is the firm that leaves most of the profit to the government. The upper-left panel shows that firm productivity is hump-shaped in government's bargaining power. To see the intuition, first note that a firm that takes almost all of the profit is nearly impossible to be selected by the government hence its expected profit is low. As a result, this firm has least incentives in exerting innovation efforts. As the government's bargaining power increases slightly, firms become more likely to be selected but still at a low probability. To draw attention of the government, the firm is then incentivised to perform more innovation to enlarge the size of profit, so as to increase its likelihood of being picked by the government. When the government's bargaining power is high, the intuition behind Proposition 1 applies. In short, the mechanism behind is the tradeoff between the profit size and profit shares in an environment of scale economy. Leaving a profit too high or too low to the firm hurts the incentive for productivity improvements as the firm sees the expected profit to be too low when compared with the cost of innovation.

The lower row of Figure 7 compares model-implied winning probabilities and productivities with their empirical counterparts. The lower-right panel shows that the simulated winning probabilities are somewhat similar to the empirical levels. However, it exhibits a clustered pattern, that the model-predicted winning probabilities are much higher than the empirical ones for firms with high TFP

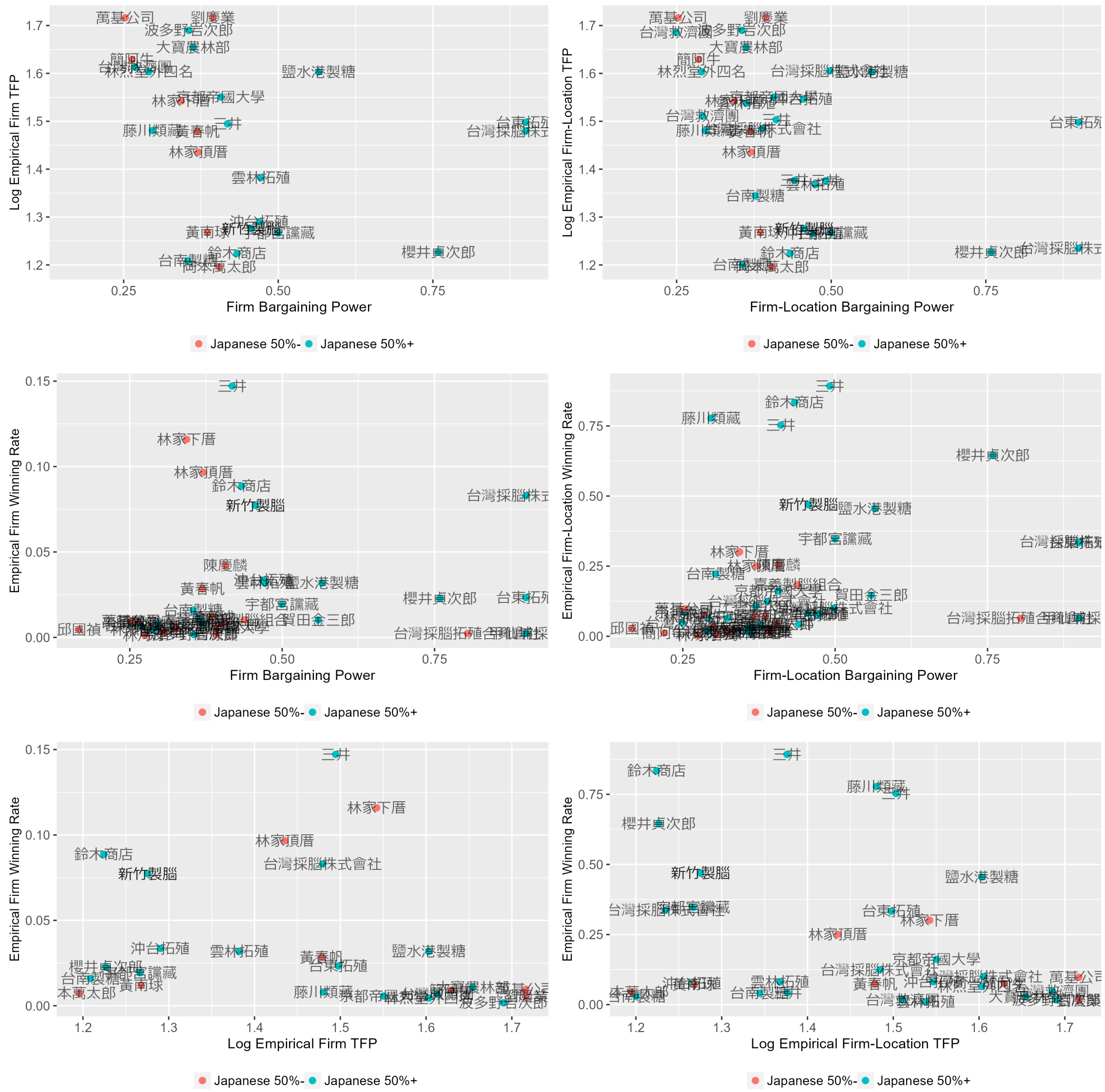

Figure 6: Firm Bargaining Power, Winning Probability and TFP

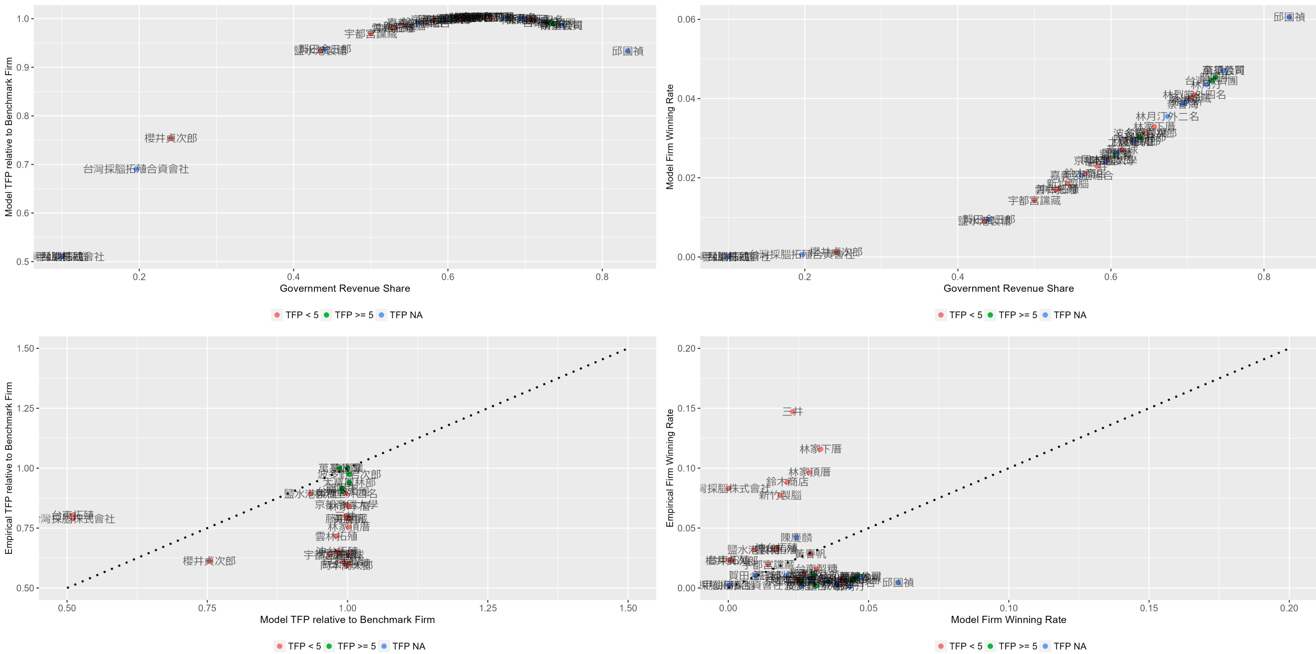

Figure 7: Pooled Simulation

levels[20], and firms that we do not have enough of data to compute their TFPs. This cluster are mainly Taiwanese firms of smaller sizes. In contrast, the model-implied winning probabilities for firms with lower TFP levels tend to be much lower than reality. Specifically, empirical winning probabilities are highly concentrated among larger Japanese firms and Zaibatsu such as Mitsui and Suzuki. For example, Mitsui alone obtains for about 15% of production sites in reality while model predicts only approximately 3%. Using the firm with the highest empirical TFP as benchmark, the lower-left Panel of Figure 7 shows that the empirical relative TFPs are much lower than their empirical counterparts. Moreover, firms falling far behind are mainly composed of larger Japanese firms and Zaibatsu.

The pooled simulation suggests that financial objective might not be the only concern to Monopoly Bureau when implementing camphor monopoly system. To some extent the government seem to be picking firms that are more likely to generate higher government income. However, the system seem to favor Zaibatsu as they are far more likely to obtain permissions than other firms while performing poorly in terms of productivities.

The pooled simulation overlooks the heterogeneity across different prefectures. In more remote regions such as eastern and southern Taiwan, the Monopoly Bureau tend to set up higher compensation prices for firms operating in these regions to secure their incentives of operations. This channel can potentially entail higher TFPR for firms low in TFP. Moreover, Zaibatsu may be more resilient to bad market conditions, allowing them to survive in regions where other firms are unwilling to enter. This channel may explain why the winning probability and productivity for Zaibatsu tend to be negatively correlated and the overshoot prediction by our model. To inspect such possibilities, we perform *regional simulation* by treating all firms operating in the same region as potential entrants and simulate for their winning probabilities and productivities. The results are illustrated in Figures 8 and 9.

[20]The firms correspond to the top 25% of firms in TFP distribution.

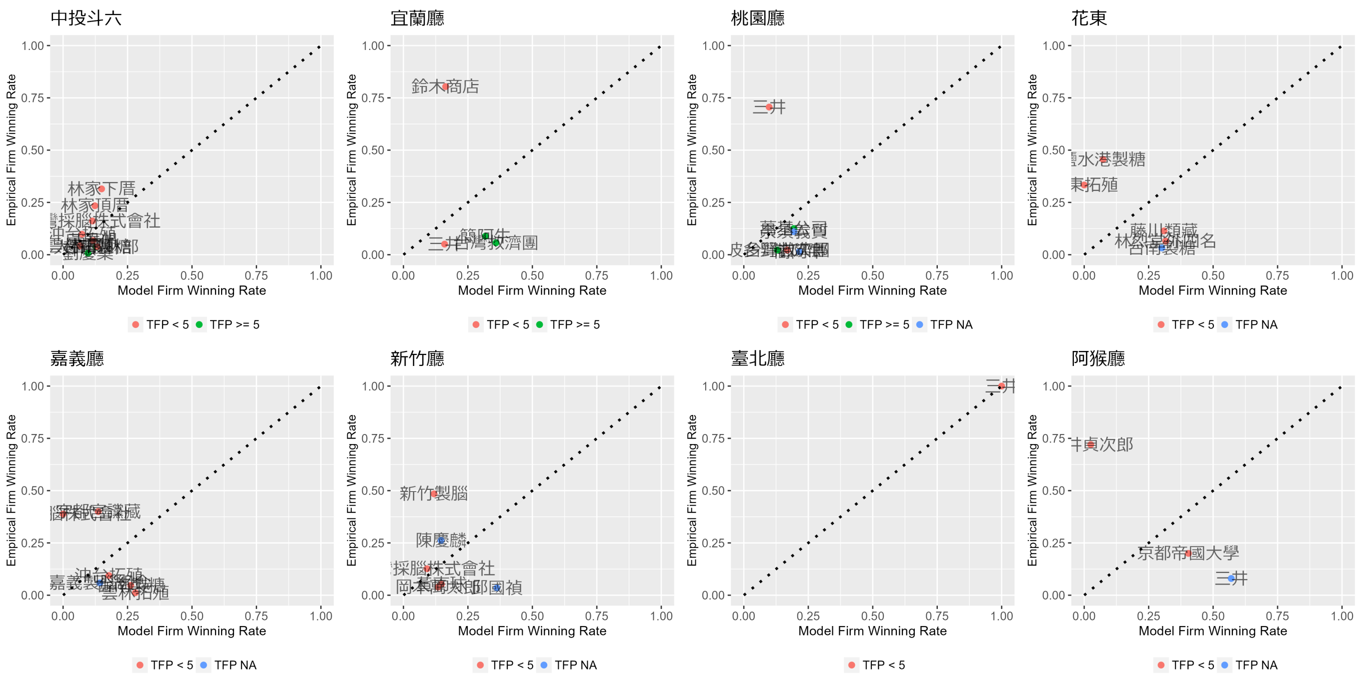

Figure 8: Regional Simulation: Winning Probabilities

The regional simulation show that Zaibatsu and larger Japanese firms tend to be less productive but disproportionately getting more production sites than model prediction. These firms include Mitsui and Suzuki Zaibatsu, Sakuraigumi (桜井組), Taiwan Camphor Extraction (台湾採脳株式会社), Hsinchu Camphor Manufacturing (新竹製脳), Yien-Shui-Gan Sugar (塩水港製糖) and Taitung Colonial Development (台東拓殖), and most of them engage in other industrial activities such as sugar production and local development at the same time. In contrast, the model prediction and empirical observations are more consistent for smaller firms. Such a pattern holds in regions wherein the larger Japanese firms present, regardless of whether the regions are historically less developed or not. In other words, our simulations suggest that the Monopoly Bureau may exhibit favoritism towards larger firms aside from the objective of generating government revenue.

We evaluate the efficiency of camphor monopoly in generating government income. First note that (4) can be restated in terms of hat algebra as

$$\frac{E\left(V_G\right)}{I/\left(1-\delta\right)} = \frac{1}{\sigma}\frac{\sum_m \beta_m^{\frac{\theta}{\sigma-1}}\varphi_{0,m}^{\theta}}{\sum_m \beta_m^{\frac{\theta}{\sigma-1}-1}\varphi_{0,m}^{\theta}} = \frac{\beta_1}{\sigma}\frac{\sum_m \widehat{\beta}_m^{\frac{\theta}{\sigma-1}}\widehat{\varphi}_{0,m}^{\theta}}{\sum_m \widehat{\beta}_m^{\frac{\theta}{\sigma-1}-1}\widehat{\varphi}_{0,m}^{\theta}}.$$

Note that $I/\left(1-\delta\right)$ is the present value of market expenditure to camphor products. In the context of camphor monopoly, this market expenditure thus equals the total sales revenue by the Monopoly Bureau. We can therefore interpret the ratio $E\left(V_G\right)/\frac{I}{1-\delta}$ as the Monopoly Bureau's profit rate. The pooled simulation implies that this profit rate is approximately 46% under which government revenue is the only concern of the authority.

For the empirical counterpart, we inspect the income statement of the Monopoly Bureau documented in *YMB* in each year, and extract all entries of income and expenditure where camphor is

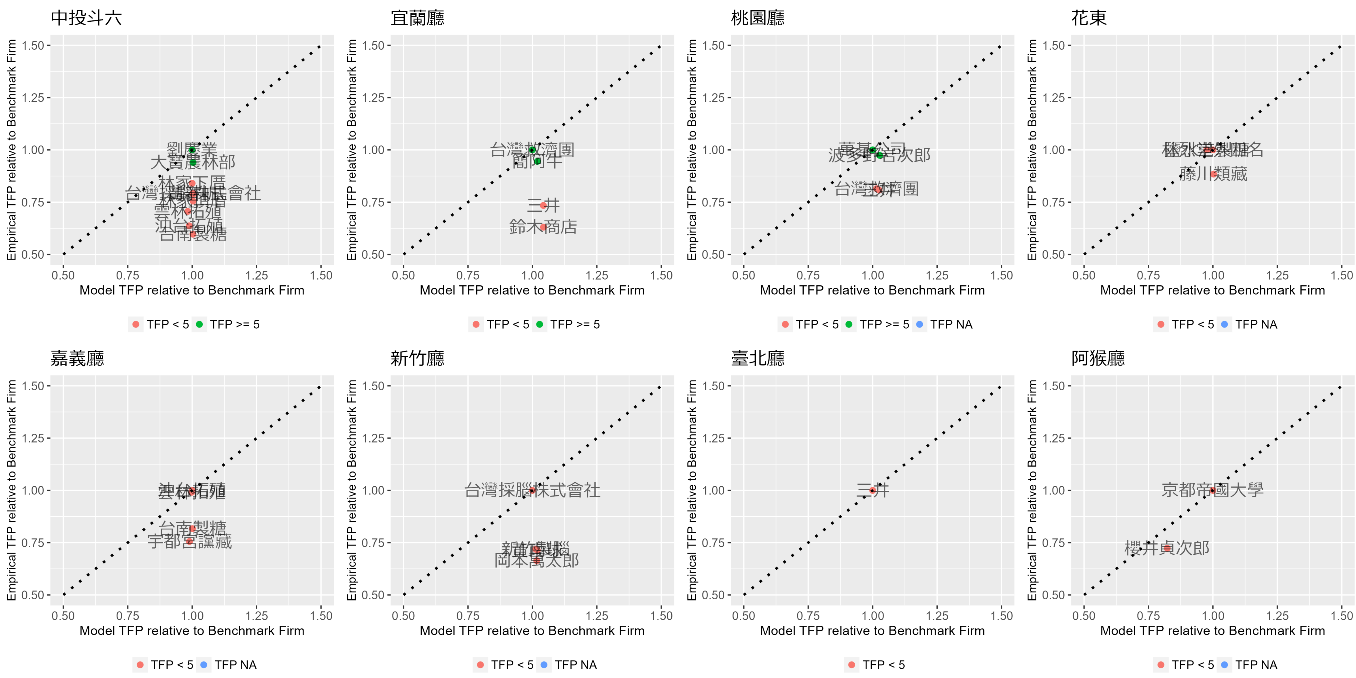

Figure 9: Regional Simulation: Relative Productivities

explicitly stated. The empirical profit rate is then computed as

$$\frac{\sum_t (revenue_t - cost_t)}{\sum_t revenue_t},$$

and is approximately 30% for 1907-18. Our simulation thus suggests that, the Monopoly Bureau enjoys a gain by 53% in its profit rate if it were to cease favoring larger firms and Zaibatsu and focus only on generating profits by firm performances. Conversely, the result implies that such a favoritism leads to a loss in efficiency of generating government profit by $|53-30|/53 \approx 35\%$.

7 Conclusion

We empirically inspects how firm-official connectivities impact the treatments that firms receive from the authority in the context of industrial policies by combining the micro-level data of the Camphor Monopoly System and the businessmen-official social network constructed from historical news archive. We first propose a new estimation approach to identify firm-level TFPs, and inspect whether the monopoly system leads to productivity growth as claimed by the official. Then we estimate the effect of connectivities on the compensation price and quota received by the firms using a shock design. Finally we perform a counterfactual simulation that compares the empirical allocation with the simulated allocation generated from a model wherein the monopoly system is ideally implemented to generate government profit. We find that connected firms tend to receive better policy treatments, and firms with more Japanese shareholders tend to be less productive but better compensated. Simulation further suggests that the larger Japanese firms and Zaibatsu are less productive but obtaining disproportionately more production sites than the more productive but smaller firms. In a nutshell, our results suggest that the Camphor Monopoly System was implemented with favoritism towards larger Japanese firms and Zaibatsu.

Our favoritism explanation is potentially challenged by the vertical and intersectoral linkages of the larger firms. Most of these firms also engage in sectors that potentially complements crude camphor production, such as traffic service, sugar production and local development. Mitsui and Suzuki zaibatsu are further assigned as delegates by the Monopoly Bureau in retailing and refining of camphor respectively. Considering the roles of these firms in the value chain of camphor industry and the whole economy, it could still be efficient for the authority to grant better treatments to them than the other firms despite that they might not be as efficient in the narrowly defined crude camphor sector. Detailed input-output data in early 20th century is needed for a comprehensive analysis on the whole camphor and chemical industries in order to comprehend the roles of these large conglomerates. This is beyond the scope of the paper due to the lack of available data, but is a potential direction to reconstruct the global economy in early 20th century.

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A Framework on TFP Estimation

A.1 Econometric Issues of Estimating Production Function

We assume that for each establishment i for firm j in region n at time t the relationship between output and inputs is determined by an underlying establishment production function f and a Hicks neutral productivity shocks v_{ijnt}. $\{Y_{ijnt}, L_{ijnt}, K_{ijnt}, W_{ijnt}, M_{ijnt}\}$, respectively, is the quantity of output, labor, capital, camphor woods, and fuel woods.[21]

To simplify the notations, we just denote them as $(Y_{it}, L_{it}, K_{it}, M_{it})$ and their log-value will be denoted in lowercase by $(y_{it}, l_{it}, k_{it}, w_{it}, m_{it})$ respectively. In particular, We assume that establishment production function is

$$
\begin{aligned}
Y_{it} &= f\left(L_{it}, K_{it}, W_{it}, M_{it}\right) && (5)\\
&= L_{it}^{\alpha_L} K_{it}^{\alpha_K} W_{it}^{\alpha_W} M_{it}^{\alpha_M} e^{v_{it}} && (6)\\
\iff y_{it} &= \alpha_l l_{it} + \alpha_k k_{it} + \alpha_w w_{it} + \alpha_m m_{it} + v_{it} && (7)
\end{aligned}
$$

Following the control function literature, we also decompose v_{it} as $v_{it} = \alpha_0 + \omega_{it} + \varepsilon_{it}$ where α_0 is a constant term and ω_{it} is the persistent productivity shock observed by establishments in period t but unobserved by econometricians, while ε_{it} is ex-post shock realized after establishments made production decisions.[22]

The difference of persistent shocks and ex-post shocks lies in whether it is included in firms' information set at time t. We assumes that firms' information set at t, denoted as $\mathbb{I}_{it}$, includes current and past productivity shocks $\{\omega_{i\tau}\}_{\tau=0}^{t}$ but does not include future productivity shocks. The ex-post shocks for time t, ε_{it} are not included in $\mathbb{I}_{it}$ and thus satisfy $E\left[\varepsilon_{it} | \mathbb{I}_{it}\right] = 0$.

[21] Each establishment can produce two products: crystal and oil. We assume that production function for camphor crystals and oil are the same and can be aggregated to a establishment-level production function. $Y_{ijrt} = \sum_{s=1}^{2} Y_{ijrst}$ is the sum of both products.

[22] In some papers, the notation ω_{it} also subsumes α_0. In practice, α_0 is the constant term estimated in the empirical model, and we may interpret it as mean productivity across firms and periods.

A.2 Endogeneity: Transmission Bias

Before describing our empirical strategy to estimate total productivity shocks,v_{it}, it is worthwhile to discuss the econometric issue of estimating productivity via regressing output on inputs without addressing anticipated shock ω_{it}, for example, via OLS. The identification problem of OLS is essentially concerned with a kind of simultaneity bias: firms with higher productivity tend to demand more inputs for production, which is called transmission bias by Marschak and Andrews (1944). In a nonparametric setting, GNR provides a general formula of transmission bias for empirical problems of regressing output y_{it} on $(l_{it}, k_{it}, w_{it}, m_{it})$:

$$E\left[y_{it}|l_{it}, k_{it}, w_{it}, m_{it}\right] = f\left(l_{it}, k_{it}, w_{it}, m_{it}\right) + E\left[\omega_{it}|l_{it}, k_{it}, w_{it}, m_{it}\right],$$

and, in consequence, the elasticity of the regression with respect to $x_{it} \in \{l_{it}, k_{it}, w_{it}, m_{it}\}$ is

$$\frac{\partial}{\partial x_{it}} E\left[y_{it}|l_{it}, k_{it}, w_{it}, m_{it}\right] = \frac{\partial}{\partial x_{it}} f\left(l_{it}, k_{it}, w_{it}, m_{it}\right) + \frac{\partial}{\partial x_{it}} E\left[\omega_{it}|l_{it}, k_{it}, w_{it}, m_{it}\right]$$

fails to identify true output elasticity $\frac{\partial}{\partial x_{it}} f\left(l_{it}, k_{it}, w_{it}, m_{it}\right)$. This further leads to a biased estimate of total productivity.

A.3 Control Function Approach

Traditional methods to address transmission bias includes instrumental variables approach and panel fixed effects approach. Yet, such two methods are often unavailable to empirical researchers.[23] As the mainstream approach, the control function approach (or proxy variable framework), addresses the transmission bias by imposing behavioral assumptions on economic agents and environment. Compared to traditional methods, the control function approach is "structural" because it exploits structural link between production function and firms' optimal input decisions. Specifically, many empirical works in this literature exploit the timing of choosing inputs to identify the econometric model.

Our approach considers a firm operating through discrete time and make decisions to maximize the discounted present value of profits. It assumes that the persistent productivity shocks evolve endogenously and follows a first-order Markov process with sub-periods. It also assumes the timing of firm operation and demand variable inputs. It also assume the timing of the officials' quota allocation, which will be made clear in Section 3.1.4. Finally, it imposes the restriction of the relationship between the quota function and productivity. Now we state our assumptions formally:

[23]Instrumental variable approach requires appropriate instruments that are correlated with input choices but do not enter into production function and are uncorrelated with total productivity shock, v_{it}. Assuming that no firm has influence on factor market, input price may serve as a valid instrument. Most of data, however, do not contain firm-specific input price. It is also very difficult to defend for exclusion restriction of a instrument in estimating production function. Panel fixed effect approach is also problematic because it requires balanced panel and may drop many observations. If firms' decisions of exit depend on their perception of future, then coefficients estimated from a balanced panel will suffer from a selection bias. Moreover, identification assumption of the panel fixed effects approach is that the persistent part of productivity, ω_{it} is constant over time. This strong assumption is unreasonable when we are interested in how changing economic environment like regulation and industrial policies impacts on firms productivity. We refer to Ackerberg et al. (2007) for readers who want to understand more traditional methods.

Assumption 1. *First order Markov evolution of productivity: persistent productivity shocks evolve according to the distribution*

$$p\left(\omega_{it-b}|\mathbb{I}_{it-1}\right) = p\left(\omega_{it-b}|\omega_{it-1}\right) \tag{8}$$

and

$$p\left(\omega_{it}|\mathbb{I}_{it-b}\right) = p\left(\omega_{it}|\omega_{it-b}\right). \tag{9}$$

The distribution is known to firms and stochastically increasing in ω_{it}.

Assumption 2. *Timing of Input Choices of CJ: Firms' capital accumulation is determined by investment function*

$$k_{it} = \kappa\left(k_{it-1}, \mathbb{I}_{it-1}\right). \tag{10}$$

where k_{it} is determined by investment decisions made in $t-1$. The variable inputs $x^v_{it} \in \{l_{it}, w_{it}, m_{it}\}$ are non-dynamic and chosen at $t-b$, that is,

$$x^v_{it} = \mathscr{G}^{x^v}_t\left(\omega_{it-b}, k_{it-b}\right) \tag{11}$$

Assumption 3. *Scalar Unobservable: Firms' quota decisions are governed by*

$$q_{it} = \ell_t\left(\omega_{it}, k_{it}\right).$$

Assumption 4. *Strict Monotonicity: $\ell_t\left(k_{it}, \omega_{it}\right)$ is strictly increasing in ω_{it}.*

By assumptions 3 and 4, $q_{it} = \ell_t\left(\omega_{it}, k_{it}\right)$ is strictly increasing in ω_{it} for all pairs of $\left(k_{it}, q_{it}\right)$, then we can construct an inverse function of the quota function to control for ω_{it}

$$\omega_{it} = \ell_t^{-1}\left(q_{it}, k_{it}\right) \tag{12}$$

Substituting (12) into the production function we have

$$\begin{aligned} y_{it} &= \alpha_0 + \alpha_l l_{it} + \alpha_k k_{it} + \alpha_w w_{it} + \alpha_m m_{it} + \omega_{it} + \varepsilon_{it} \\ &= \alpha_0 + \alpha_l l_{it} + \alpha_k k_{it} + \alpha_w w_{it} + \alpha_m m_{it} + \ell_t^{-1}\left(q_{it}, k_{it}\right) + \varepsilon_{it} \\ &= \alpha_l l_{it} + \alpha_w w_{it} + \alpha_m m_{it} + \phi_t\left(q_{it}, k_{it}\right) + \varepsilon_{it} \end{aligned} \tag{13}$$

where

$$\phi_t\left(q_{it}, k_{it}\right) = \alpha_0 + \alpha_k k_{it} + \omega_{it}. \tag{14}$$

Then our estimation procedure relies on two sets of moment conditions:

$$E\left[\varepsilon_{it}|\mathbb{I}_{it}\right] = E\left[y_{it} - \alpha_l l_{it} - \alpha_w w_{it} - \alpha_m m_{it} - \phi_t\left(q_{it}, k_{it}\right)|\mathbb{I}_{it}\right] = 0 \tag{15}$$

$$E\left[\xi_{it} + \varepsilon_{it}|\mathbb{I}_{t-1}\right] = 0 \tag{16}$$

We implement a two-stage procedure to estimate factor elasticity. The coefficients of variable inputs are estimated in the first stage, and the coefficient of capital is estimated in the second stage. The standard errors are bootstrapped.

A.4 Discussion of Identification Assumptions

We begin by introducing the timing assumption caused by the institutional arrangements of the Japanese camphor monopoly. The colonial officials needed to determine who can produce before firms started to producing outputs, because it would take weeks or even months for camphor producers to coordinate labors to sweep into some remote, wild mountains, meet forests, cut trees, haul woods to a high ground , and prepare stoves for refining crystals and oil. It implies that the officials needed to make initial permission of operating business before productivity shock during production, ω_{it} was fully revealed.

Our data suggest that the colonial government in a few cases adjust quotas twice to set down the quotas. Historical evidence also demonstrate that in the mid of this process firms' production were often affected by some sub-period shocks like typhoons or aboriginal attacks. We utilize this difference of timing between permitting operating business and deciding final quotas for each establishment to control persistent productivity, ω_{it}. We assume that the government make permission for running business at time $t-b, b \in (0,1)$, a period that can be though as the beginning of a year. The government later decided quotas at time t after observing ω_{it}. We also assume that firms started to "demand variable inputs" as they were permitted for running business at time $t-b$ by observing only ω_{it-b} because they they needed to coordinate labors into mountains and preparing intermediate inputs ahead of producing crude camphor.

Our empirical strategy differs from OP's method in two aspects. First, we have a different timing assumption of choosing inputs, which is close to ACF's modified DGP for OP's estimator. We assume that the permission of firm operation was made at time $t-b$, and firm started to recruit camphor workers at $t-b$, but once these manufacturers entered deep mountains, because of the costs of transportation and recruitment, they could not adjust the number of camphor workers and other variable inputs. It would take a sub-period from $t-b$ to t to fully realize the total factor productivity shocks, but the colonial officials could immediately adjust the final quotas as they saw the full shocks.

Second, we use the quota function, instead of the investment function of OP, to control for ω_{it}. Our behavioral assumption is that the quota function is also monotonic with ω_{it} conditional on other state variables and thus we can invert productivity from final quotas with assumptions similar with OP.

Using the quota function to proxy total productivity can avoid other problems of the investment function in OP's original estimator. To illustrate, LP proposes using intermediate input to proxy productivity, instead of investment function, because many data exhibit zero investments for firms. OP's method cannot account for firms making no investments. In our data all firms with permissions would acquire positive quotas, so the quota function does not suffer the similar problem. Additionally, ACF points out that investment function approach suffers from another problem: if some unobservables directly affect investment function, like adjustment cost of capital, the inversion of investment function becomes problematic. The quota function avoids the problem as well. Whereas it may take adjustment cost for accumulating capital, the officials can quickly adjust quotas immediately after observing full productivity shocks, ω_{it}.[24]

B Constructing Connectivity

B.1 Hanzen *Taiwan Daily News* Newspaper Archive

The *Taiwan Daily News* was a semi-state-owned daily newspaper published during 1898–1944. It was merged from *Taiwan Daily (臺灣日報)* and *Taiwan News (臺灣新報)* in 1898, and soon become the government gazette of the Government-General 3 weeks after its establishment. The news was published in Japanese, with two dedicated pages where selected news are translated into Chinese. A dedicated Chinese edition was published during 1905–1911, but then was reverted back to two pages of Chinese news in the main newspaper as before 1905.

Taiwan Daily News published a wide range of news, including activities of officials, entrepreneurs and VIPs, business and economy activities, government announcements, announcements from enterprises, interviews, and entertainment. For news about business and enterprises, one can frequently see news reporting the annual meetings of enterprises in detail, which not only provides information on participants and changes in the managerial board, but also a list of major shareholders. News involving in cooperation or disputes between enterprises are also frequently seen. For news about officials, entrepreneurs, and VIPs, one can easily find news about the activities that the reported individuals are involved, including participating in private dinner parties, promotions, and other semi-public activities.

The Hanzen *Taiwan Daily News* Newspaper Archive is a digitalized archive that covers *Taiwan Daily News*, both Chinese and Japanese editions, throughout 1898–1944. It also covers *Taiwan News* for years between 1896–1897. The news archive uses names of individual as meta data, which allows users to search for all news that the interested individual is involved in by his name. This allows us to search through all of the interested individuals and construct a network between the individuals by news appearances.

Because of the official background of *Taiwan Daily News*, the news is thought of as slanted towards the Japanese colonial government. One expect that a majority of news covered are about Japanese officials and entrepreneurs, and Taiwanese individuals favored by the Japanese government. Since our objective is to inspect how well the interested individuals are connected to the government, the slanting feature of the news archive is thus suitable as an individual appears on the news only if he / she is better connected. Our constructed network thus captures the variation of connectivity among the more connected individuals. Individuals with few or no newspaper appearances can thus be think

[24]ACF also indicates a less obvious problem of OP's assumption of scalar unobservable: if some serially-correlated unobservables affect firms' decisions of variable inputs, such as firm-specific wage shocks, the inversion of the investment function will still be problematic because of dynamic shocks for non-dynamic variable inputs. We address this problem by relaxing labor input to be dynamic and estimating our data with ACF's structural value-added production.Although we do not report the results of ACF's estimator, the productivity estimated by our method is quite close to the one estimated by ACF's estimator.

of as poorly or unconnected.

B.2 Official Rankings

We supply the government official to the connection network using two data archives: the *Official Staff in Taiwan Government-General* (henceforth *Official Staff*) digitalized by Institute of Taiwan History, Academia Sinica, and *Japanese Who's Who (人事興信録)* digitalized by Nagoya University.

The *Official Staff* database provides fully digitalized *Yearbook of Government Officials* published by the Taiwan Government-General during 1896–1944. In each yearbook, the Taiwan Government-General is decomposed into three major units: the Central Taiwan Government-General (府内), Agencies under Taiwan Government-General (所屬) and Local Governments (地方). The Central unit includes the Secretary Office and Bureaus / Departments that are directly under the Government-General. The Agencies unit include agencies under the Government-General. It includes, for examples, the Monopoly Bureau, Railway Department, the Taiwanese Customs, schools, jails and public hospitals. The Local Government is self-explanatory, which includes all units and subsidiaries of each county / prefecture governments.

For each unit, a full list of officials and employees are provided as fine as to street-level bureaucrats, e.g., police officers, teachers, and doctors. Each list includes the name of the official / employee, positions and titles, and the year that the individual is in seat. This dataset thus allows us to trace the turnover of a given position, as well as construct the time series of tenure for each specific individual. The bureaucracy structure of the Government-General had undergone several reforms from a more flatter structure to a more vertical one during 1896–1918. As a result, some positions and titles are no longer equivalent before and after the reforms. We read the yearbooks and manually assign the titles and positions to construct a more comparable official rankings at central-level. Our construction is as follows:

- Rank 1 (*G*01): Governor-General (總督), Director of Internal Affair (民政部/局長) or equivalent, Director of Monopoly Bureau (專賣局長, 1902–1918), and Directors of Camphor Monopoly Bureau, Salt Monopoly Bureau, and Directors of their Sections and Branches (1900–1901).

- Rank 2 (*G*02): Secretaries of Government-General (總督府官房秘書), Directors of Sections under the Department of Internal Affairs (1896–1901), Directors of Agencies under the Bureau of Internal Affairs (1902–1918), Directors of Sections or Branches under the Monopoly Bureau or equivalent (1902–1918).

- Rank 3 (*G*03): Managers of Sections under the Bureau of Internal Affairs and its agencies (1902–1918).

B.3 Constructing Network and Firm-level Connectivities

The construction of the network involves in the following steps.

Step 1: Retrieving the names of permitted entrepreneurs / enterprises from *Yearbook of Taiwan Government-General Monopoly Bureau*.

We first retrieve the list of names using from the section of the list of permittees in the *YMB*. The list includes names of the permitted individual or enterprise, title of the permitted individual, and the number of cooperators. The Yearbook does not provide the names of cooperators and shareholders, but some of them are mentioned in the introduction section in some years. We also retrieve these names to form the first-round name list of entrepreneurs / enterprises involved in the monopoly system.

Step 2: Supplementing the names of cooperators and shareholders using *Taiwan Daily News*.

As mentioned, *Taiwan Daily News* reports details about activities in enterprises and smaller businesses, including business strategies, interaction with the government, details in annual meetings, list of managerial members and shareholders, and changes in the list mentioned. We use the names obtained in Step 1 as keywords to search in the news archive for all possible years before the end of 1918, and retrieve all news that the individuals involved in. Then we manually read these news. For news that involves in the camphor permission, we check if the news discloses the names of cooperators and shareholders and supplement to the list of individuals involved if yes. This step provides us a comprehensive list of entrepreneurs and shareholders with the permission of crude camphor production as possible.

Step 3: News search for interactions among entrepreneurs and officials

We search the news archive using the list of names obtained in Step 1 and the names of other major shareholders obtained in Step 2. Our search returns about 2700 unique news reports. Then the author and 2 RAs manually go through each news, and keep only news wherein the multiple individuals or entities are explicitly reported to be involved in the same event in a given year, or developed obvious long-term relationships. For example, news reporting that an individual attempting to kickstart a business is excluded, but news reporting that an government official approves the individual to kickstart the business is kept. In this manner, we obtain about 700 news reports that go as early as to 1897, and document business and social activities, involving in camphor monopoly or not, for the individuals in our name list from Step 2.

Step 4: Constructing the network

For each news obtained in Step 3, we document the names of individuals appeared in the same news, and consider them as pair-wise connected. Each news entry thus forms a "subnetwork", where individuals are vertices and the sides between two vertices are the bilateral connections between the two individuals. Note that the subnetwork here are solely based on news event and does **not** include relationships within each camphor monopoly firms. We supplement this relationship using the list of known partners / shareholders obtained in Step 2 for each corresponding years according to the list of permitted businesses in *YMB*. We also construct subnetworks for known persistent partnerships, e.g., individuals belonging to the same family or working in the same enterprise before Japan's colonization to Taiwan, and use as the *base layers* of the network.

We assume that connections do not deteriorate once established. Then starting from 1897, upon removing repeated relationships and deceased individuals, we join all the subnetworks of the current year and years before on top of the base layer network to form a large network in the year. The network comes in the form of graph composed of vertices and edges. Each vertex represent an individual appeared in the current year and all years before due to news exposure, participating in camphor monopoly, or persistent relationships. Each edge between two vertices represents a pair of bilaterally directly connected individuals. Note that the same pair of individuals can occur multiple times in the same year if they take part in the same event multiple times.

Step 5: Computing individual-level connectivities

We define an individual's connectivity with another given individual by network distance, which is the *length of shortest path* between the two individuals *weighted* by the tail probabilities of network appearances between pairs of individuals along the path, and then is normalized to between $[0,1]$ with the formula $d \equiv x/(1+x)$. The tail probabilities are computed by first tabulating the numbers of occurrences for each **pair** of individuals in the network to obtain a frequency table. Then we sort the table in descending order, compute the fraction for each number of occurrences and cumulatively summing up from the right. Following the definition of (weighted) network distance as will be detailed below, we obtain the connectivity between an individual and an official of a given rank. We take average to the individual's distance to all officials of the same rank as the individual's connectivity to this rank of official.

The rationale behind our definition to connectivities are as follows. The network distance is by definition the numbers of edges / pairs of individuals required to reach the targeted individual in the unweighted case. The unweighted distance is thus quantitative as it concerns only about the head count of intermediate individuals. To further account for the quality of the path, weights can be assigned to each of the edges to characterise the *costs / unfamiliarity* between the intermediate individuals along the path. A higher weight on an edge thus lengthens the distance of the path.

The most intuitive way to construct the weights is to refer to the number of occurrences of an edge in the network. A higher number indicates that the individuals frequently cowork in camphor monopoly, or involve in the same event disclosed by the newspaper. Given the official background of the newspaper, more frequent newspaper exposure can further indicate favoritism by the government. In either way the connectivity between the individuals are strong, so that the *cost* to go through this edge is lower. We use tail probability of occurrences as weight not only because a higher network occurrence necessarily has a lower tail probability. But also, tail probability reflects how costly to go through an edge *relative* to the whole network hence is unit free and comparable between networks in different years. Tail probability also provides a simple interpretation. For example, a 5% tail probability for a number of occurrences reads as that the cost for the relevant individuals to meet is lower than 95% of the population.

Figure 10 provides an example for computing social distance between A and C in a network composed of 5 edges. The distance between A and C is actually defined by the indirect path ABC instead of by the direct path AC after accounting for frequency of common news exposure. For $\overline{AB}$, a weight $2/5$ is given since only two out of five edges (AB and BC) are disclosed by the news for no less than twice. Following the same reasoning the weight to BC is $1/5$ and is 1 for all other paths. As a result, the length of the indirect path is $\overline{ABC} = 3/5$ while that for the direct path is $\overline{AC} = 1$. The distance is therefore given by the indirect path as $3/5$.

Step 6: Constructing firm-level connectivities

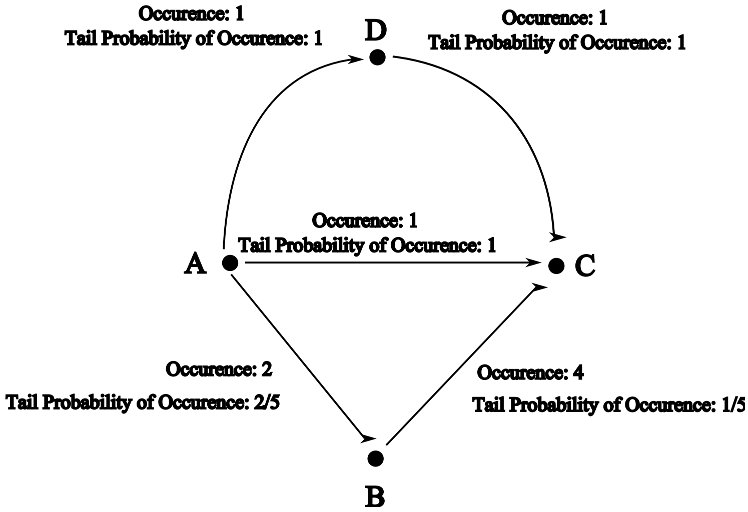

Figure 10: Example for Computing Social Distance

We classify individuals into four exogenous identity groups by their ethnicity-nobility combinations. Let e denote the identity group and g denote the official rank. We first compute the distance from each individual k to officials of rank g as a simple average of his distances to each relevant official j:

$$d_k^g \equiv \frac{\sum_{j \in g} d_{kj}}{\# j \in g},$$

where d is the normalized distance. The identity-official distance is then defined as the simple average of d_k^g for all individual k belonging to the same identity group e in the network:

$$d_e^g = \frac{\sum_{k \in e} d_k^g}{\# k \in e}.$$

We then aggregate up this distance to firm-level using the fraction of identity group e in firm i's shareholders $\omega_{i,e}$. For firm-level shocks in connectivity, we consider a shock design that mimics shift-share construction as

$$\dot{d}_{i,t}^g \equiv \sum_e \omega_{i,e,t} \frac{d_{e,t+1}^g - d_{e,t}^g}{d_{e,t}^g}.$$

The definition of official groups g follows from our classification to official ranks as in Section B.2. For identity groups, we consider the following categories:

- Japanese Nobilities: Japanese with family ranks belonging to *Kazoku* 華族, *Shizoku* 士族, and Royal Family; holding nobility titles such as dukes and earls, or being elected into *Kizokuin* (貴族院, equivalent to senate) or *Shyugiin* (衆議院, equivalent to house).

- Ordinary Japanese: Japanese not belonging to the previous group.

- Local Taiwanese Assistants (LTA): Taiwanese employed by Government-General as advisers (参事) or local executives (街庄區長) **before 1904**.

- Ordinary Taiwanese: Taiwanese not belonging to the previous group.

We can easily assign individuals as Japanese and Taiwanese by simply reading their names. To determine if a Japanese belonging to the Japanese Nobility class, we refer to both the 1903 and 1915 editions of *Japanese Who's Who* for information on family rank, and nobility titles. For observations before 1914 we supplement these information based on the 1903 edition, and for years after 1915 we refer to the 1915 edition. There were only three businessmen being elected into senate / house during the period of study, we supplement this information manually. For the Local Taiwanese Assistants, we simply extract the list of advisers and local executives of Taiwanese ethnicity before 1904 from *Official Staff*, and supplement to our data.

C Derivation of Camphor Monopoly Model

C.1 Derivation of (2) and (3)

Let

$$x \equiv k^{\frac{\theta}{\sigma-1}} \pi_G^{-\frac{\theta}{\sigma-1}} \sum_m \beta_m^{\frac{\theta}{\sigma-1}} \varphi_{0,m}^{\theta} \in (\infty, 0),$$

we obtain

$$\begin{aligned} dx =& -\frac{\theta}{\sigma-1} k^{\frac{\theta}{\sigma-1}} \pi_G^{-\frac{\theta}{\sigma-1}-1} \sum_m \beta_m^{\frac{\theta}{\sigma-1}} \varphi_{0,m}^{\theta} d\pi_G \\ \pi_G =& k x^{-\frac{\sigma-1}{\theta}} \left(\sum_m \beta_m^{\frac{\theta}{\sigma-1}} \varphi_{0,m}^{\theta} \right)^{\frac{\sigma-1}{\theta}}. \end{aligned}$$

Therefore,

$$\begin{aligned} \int_0^{\infty} h_i(\pi_G)\, d\pi_G =& \int_0^{\infty} \frac{\theta}{\sigma-1} k^{\frac{\theta}{\sigma-1}} \beta_i^{\frac{\theta}{\sigma-1}} \varphi_{0,i}^{\theta} \pi_G^{-\frac{\theta}{\sigma-1}-1} e^{-k^{\frac{\theta}{\sigma-1}} \pi_G^{-\frac{\theta}{\sigma-1}} \sum_m \beta_m^{\frac{\theta}{\sigma-1}} \varphi_{0,m}^{\theta}} d\pi_G \\ =& \int_0^{\infty} \frac{\beta_i^{\frac{\theta}{\sigma-1}} \varphi_{0,i}^{\theta}}{\sum_m \beta_m^{\frac{\theta}{\sigma-1}} \varphi_{0,m}^{\theta}} e^{-x} dx \\ =& \frac{\beta_i^{\frac{\theta}{\sigma-1}} \varphi_{0,i}^{\theta}}{\sum_m \beta_m^{\frac{\theta}{\sigma-1}} \varphi_{0,m}^{\theta}} \\ E\left(\pi_{f,i,n}\right) =& \frac{1-\beta_i}{\beta_i} \int_0^{\infty} \pi_G \frac{\theta}{\sigma-1} k^{\frac{\theta}{\sigma-1}} \beta_i^{\frac{\theta}{\sigma-1}} \varphi_{0,i}^{\theta} \pi_G^{-\frac{\theta}{\sigma-1}-1} e^{-k^{\frac{\theta}{\sigma-1}} \pi_G^{-\frac{\theta}{\sigma-1}} \sum_m \beta_m^{\frac{\theta}{\sigma-1}} \varphi_{0,m}^{\theta}} d\pi_G \\ =& \frac{1-\beta_i}{\beta_i} \int_0^{\infty} \frac{\beta_i^{\frac{\theta}{\sigma-1}} \varphi_{0,i}^{\theta}}{\sum_m \beta_m^{\frac{\theta}{\sigma-1}} \varphi_{0,m}^{\theta}} k x^{-\frac{\sigma-1}{\theta}} \left(\sum_m \beta_m^{\frac{\theta}{\sigma-1}} \varphi_{0,m}^{\theta} \right)^{\frac{\sigma-1}{\theta}} e^{-x} dx \\ =& \frac{1-\beta_i}{\beta_i} \frac{\beta_i^{\frac{\theta}{\sigma-1}} \varphi_{0,i}^{\theta}}{\left(\sum_m \beta_m^{\frac{\theta}{\sigma-1}} \varphi_{0,m}^{\theta} \right)^{1-\frac{\sigma-1}{\theta}}} k \int_0^{\infty} x^{1-\frac{\sigma-1}{\theta}-1} e^{-x} dx \end{aligned}$$

$$=\frac{1-\beta_i}{\beta_i}\frac{\beta_i^{\frac{\theta}{\sigma-1}}\varphi_{0,i}^{\theta}}{\left(\sum_m \beta_m^{\frac{\theta}{\sigma-1}}\varphi_{0,m}^{\theta}\right)^{1-\frac{\sigma-1}{\theta}}}k\Gamma\left(1-\frac{\sigma-1}{\theta}\right).$$

Note that we require $\theta>\sigma-1$ for $\Gamma\left(1-\frac{\sigma-1}{\theta}\right)$ hence the expected profit to be finite.

C.2 Proof of Proposition 1

Unique Existence of Equilibrium

We first study the first- and second-derivatives of $V_i(\varphi_{0,i})$ and provide the condition for the interior solution to be optimal if it exists. Let $\psi_i\equiv\beta_i^{\frac{\theta}{\sigma-1}}\varphi_{0,i}^{\theta}$, we have

$$\begin{aligned}
\frac{d\overline{\pi}_{f,i}}{d\varphi_{0,i}}=&\frac{d}{d\varphi_{0,i}}\frac{1-\beta_i}{\beta_i}\frac{\psi_i}{(\sum_m\psi_m)^{1-\frac{\sigma-1}{\theta}}}k\Gamma\left(1-\frac{\sigma-1}{\theta}\right)\\
=&k\Gamma\left(1-\frac{\sigma-1}{\theta}\right)\frac{1-\beta_i}{\beta_i}\frac{(\sum_m\psi_m)^{1-\frac{\sigma-1}{\theta}}-\left(1-\frac{\sigma-1}{\theta}\right)\psi_i(\sum_m\psi_m)^{1-\frac{\sigma-1}{\theta}}(\sum_m\psi_m)^{-1}}{(\sum_m\psi_m)^{1-\frac{\sigma-1}{\theta}}(\sum_m\psi_m)^{1-\frac{\sigma-1}{\theta}}}\frac{d\psi_i}{d\varphi_{0,i}}\\
=&k\Gamma\left(1-\frac{\sigma-1}{\theta}\right)\frac{1-\beta_i}{\beta_i}\frac{1-\left(1-\frac{\sigma-1}{\theta}\right)r_i}{(\sum_m\psi_m)^{1-\frac{\sigma-1}{\theta}}}\frac{d\psi_i}{d\varphi_{0,i}}\\
=&k\Gamma\left(1-\frac{\sigma-1}{\theta}\right)\frac{1-\beta_i}{\beta_i}\frac{1-\left(1-\frac{\sigma-1}{\theta}\right)r_i}{(\sum_m\psi_m)^{1-\frac{\sigma-1}{\theta}}}\theta\psi_i\varphi_{0,i}^{-1}.
\end{aligned}$$

The equation above is positive because $r_i\in(0,1)$ and $\theta>\sigma-1$. The interior solution is thus given by

$$k\Gamma\left(1-\frac{\sigma-1}{\theta}\right)\frac{1-\beta_i}{\beta_i}\frac{1-\left(1-\frac{\sigma-1}{\theta}\right)r_i}{(\sum_m\psi_m)^{1-\frac{\sigma-1}{\theta}}}\theta\psi_i\varphi_{0,i}^{-1}=(1-\delta)c'(\varphi_{0,i}).$$

For the second-order condition, note that

$$\begin{aligned}
\frac{d^2\overline{\pi}_{f,i}}{d\varphi_{0,i}^2}-(1-\delta)c''(\varphi_{0,i})=&\frac{1-\beta_i}{\beta_i}k\Gamma\left(1-\frac{\sigma-1}{\theta}\right)\frac{1-\left(1-\frac{\sigma-1}{\theta}\right)r_i}{(\sum_m\psi_m)^{1-\frac{\sigma-1}{\theta}}}\theta(\theta-1)\psi_i\varphi_{0,i}^{-2}\\
&-\frac{1-\beta_i}{\beta_i}k\Gamma\left(1-\frac{\sigma-1}{\theta}\right)\left(1-\frac{\sigma-1}{\theta}\right)\frac{2-\left(2-\frac{\sigma-1}{\theta}\right)r_i}{(\sum_m\psi_m)^{1-\frac{\sigma-1}{\theta}}}r_i\theta^2\psi_i\varphi_{0,i}^{-2}-(1-\delta)c''(\varphi_{0,i})\\
=&\frac{1-\beta_i}{\beta_i}\frac{\theta\psi_i\varphi_{0,i}^{-2}}{(\sum_m\psi_m)^{1-\frac{\sigma-1}{\theta}}}k\Gamma\left(1-\frac{\sigma-1}{\theta}\right)\left[1-\left(1-\frac{\sigma-1}{\theta}\right)r_i\right](\theta-1)\\
&-\frac{1-\beta_i}{\beta_i}\frac{\theta\psi_i\varphi_{0,i}^{-2}}{(\sum_m\psi_m)^{1-\frac{\sigma-1}{\theta}}}k\Gamma\left(1-\frac{\sigma-1}{\theta}\right)\left(1-\frac{\sigma-1}{\theta}\right)\left[2-\left(2-\frac{\sigma-1}{\theta}\right)r_i\right]r_i\theta-(1-\delta)c''(\varphi_{0,i}).
\end{aligned}$$

Combining with the first-order condition yields

$$\begin{aligned}
\frac{d^2\overline{\pi}_{f,i}}{d\varphi_{0,i}^2}-(1-\delta)c''(\varphi_{0,i})=&\frac{c'(\varphi_{0,i})\varphi_{0,i}^{-1}}{1-\left(1-\frac{\sigma-1}{\theta}\right)r_i}\left\{\left[1-\left(1-\frac{\sigma-1}{\theta}\right)r_i\right](\theta-1)-\left(1-\frac{\sigma-1}{\theta}\right)\left[2-\left(2-\frac{\sigma-1}{\theta}\right)r_i\right]r_i\theta\right\}\\
&-(1-\delta)c''(\varphi_{0,i})\\
=&c'(\varphi_{0,i})\varphi_{0,i}^{-1}\left[(\theta-1)-(\theta-\sigma+1)\frac{2-\left(2-\frac{\sigma-1}{\theta}\right)r_i}{1-\left(1-\frac{\sigma-1}{\theta}\right)r_i}r_i\right]-(1-\delta)c''(\varphi_{0,i})
\end{aligned}$$

$$
\begin{aligned}
&= c'(\varphi_{0,i})\,\varphi_{0,i}^{-1}\left[(\theta-1)-(\theta-\sigma+1)\left(1+\frac{1-r_i}{1-\left(1-\frac{\sigma-1}{\theta}\right)r_i}\right)r_i\right]-(1-\delta)\,c''(\varphi_{0,i})\\
&\equiv c'(\varphi_{0,i})\,\varphi_{0,i}^{-1}\left[(\theta-1)-(\theta-\sigma+1)K(r_i)\right]-(1-\delta)\,c''(\varphi_{0,i})\\
K(r_i) &\equiv \left(1+\frac{1-r_i}{1-\left(1-\frac{\sigma-1}{\theta}\right)r_i}\right)r_i.
\end{aligned}
$$

Observe that

$$
\begin{aligned}
\frac{dK}{dr_i} =& 1+\frac{\left[1-\left(1-\frac{\sigma-1}{\theta}\right)r_i\right](1-2r_i)+\left(1-\frac{\sigma-1}{\theta}\right)\left(r_i-r_i^2\right)}{\left[1-\left(1-\frac{\sigma-1}{\theta}\right)r_i\right]^2}\\
=& \frac{\left[1-\left(1-\frac{\sigma-1}{\theta}\right)r_i\right]^2+\left[1-\left(1-\frac{\sigma-1}{\theta}\right)r_i\right](1-2r_i)+\left(1-\frac{\sigma-1}{\theta}\right)\left(r_i-r_i^2\right)}{\left[1-\left(1-\frac{\sigma-1}{\theta}\right)r_i\right]^2}\\
\propto& 1-2\left(1-\frac{\sigma-1}{\theta}\right)r_i+\left(1-\frac{\sigma-1}{\theta}\right)^2 r_i^2+(1-2r_i)\\
&-\left(1-\frac{\sigma-1}{\theta}\right)r_i+2\left(1-\frac{\sigma-1}{\theta}\right)r_i^2\\
&+\left(1-\frac{\sigma-1}{\theta}\right)r_i-\left(1-\frac{\sigma-1}{\theta}\right)r_i^2\\
=& \left[\left(1-\frac{\sigma-1}{\theta}\right)^2+\left(1-\frac{\sigma-1}{\theta}\right)\right]r_i^2-2\left(2-\frac{\sigma-1}{\theta}\right)r_i+2.
\end{aligned}
$$

Let

$$
L(r_i)\equiv\left[\left(1-\frac{\sigma-1}{\theta}\right)^2+\left(1-\frac{\sigma-1}{\theta}\right)\right]r_i^2-2\left(2-\frac{\sigma-1}{\theta}\right)r_i
$$

and note that

$$
\frac{dL}{dr_i}=2\underbrace{\left[\left(1-\frac{\sigma-1}{\theta}\right)^2+\left(1-\frac{\sigma-1}{\theta}\right)\right]}_{+}r_i-2\underbrace{\left(2-\frac{\sigma-1}{\theta}\right)}_{+},
$$

and If $dL/dr_i<0$ if and only if

$$
r_i<\frac{1+1-\frac{\sigma-1}{\theta}}{\left(1-\frac{\sigma-1}{\theta}\right)^2+\left(1-\frac{\sigma-1}{\theta}\right)}\equiv\bar{r}_i.
$$

The requirement that $\theta>\sigma-1$ implies that $\bar{r}_i>1$, hence $dL/dr_i<0$ holds for all $r_i\in[0,1]$. The monotonicity of $L(r_i)$ implies that $K(r_i)\in[K(1),K(0)]$, where

$$
\begin{aligned}
K(0) =& 2\\
K(1) \propto& \left(1-\frac{\sigma-1}{\theta}\right)^2-\left(2-\frac{\sigma-1}{\theta}\right)+2\\
=& 1-\frac{\sigma-1}{\theta}\left(1-\frac{\sigma-1}{\theta}\right)>0\ \because\ \frac{\theta}{\sigma-1}>1.
\end{aligned}
$$

We therefore conclude that $K > 0$ holds for all r_i, and that the second-order condition is most difficult to hold when $r_i = 0$. The parametric condition such that the second-order condition holds in this case is therefore sufficient for the second-order condition to hold globally. When $r_i = 0$, the second-order condition holds if and only if

$$\theta - 1 < \varphi_{0,i} (1-\delta) \frac{c''(\varphi_{0,i})}{c'(\varphi_{0,i})}.$$

Since $c(\varphi_{0,i}) = \varphi_{0,i}^{\zeta}$, the above inequality holds strictly when $\theta < 1 + (1-\delta)(\zeta - 1)$, or equivalently, $(\theta - \delta)/(1-\delta) < \zeta$. This condition ensures that $V_i(\varphi_{0,i})$ is **strictly** concave in $\varphi_{0,i}$, hence the interior solution is optimal.

We show that the interior solution exists and is unique. First note that the first-order condition can be expressed as

$$\begin{aligned}
\frac{\zeta}{\theta} \frac{\beta_i}{1-\beta_i} \frac{1-\delta}{k\Gamma\left(1 - \frac{\sigma-1}{\theta}\right)} =& \frac{1 - \left(1 - \frac{\sigma-1}{\theta}\right) r_i}{\left(\sum_m \psi_m\right)^{1-\frac{\sigma-1}{\theta}}} \psi_i \varphi_{0,i}^{-1} \varphi_{0,i}^{1-\zeta} \\
=& \frac{1 - \left(1 - \frac{\sigma-1}{\theta}\right) \frac{\beta_i^{\frac{\theta}{\sigma-1}} \varphi_{0,i}^{\theta}}{\beta_i^{\frac{\theta}{\sigma-1}} \varphi_{0,i}^{\theta} + \sum_{m\neq i} \beta_m^{\frac{\theta}{\sigma-1}} \varphi_{0,m}^{\theta}}}{\left(\beta_i^{\frac{\theta}{\sigma-1}} \varphi_{0,i}^{\theta} + \sum_{m\neq i} \beta_m^{\frac{\theta}{\sigma-1}} \varphi_{0,m}^{\theta}\right)^{1-\frac{\sigma-1}{\theta}}} \beta_i^{\frac{\theta}{\sigma-1}} \varphi_{0,i}^{\theta-\zeta} \\
\equiv& RHS.
\end{aligned}$$

Note that the condition $\theta < 1 + (1-\delta)(\zeta - 1)$ implies that

$$\begin{aligned}
\theta <& 1 + (1-\delta)(\zeta - 1) \\
=& \zeta - \delta(\zeta - 1) \\
<& \zeta
\end{aligned}$$

since $\zeta > 1$. It is readily checked that

$$\begin{aligned}
\lim_{\varphi_{0,i}\to\infty} RHS =& \frac{\sigma-1}{\theta} \beta_i^{\frac{\theta}{\sigma-1}} \lim_{\varphi_{0,i}\to\infty} \frac{1}{\varphi_{0,i}^{\zeta-\theta} \left(\beta_i^{\frac{\theta}{\sigma-1}} \varphi_{0,i}^{\theta} + \sum_{m\neq i} \beta_m^{\frac{\theta}{\sigma-1}} \varphi_{0,m}^{\theta}\right)^{1-\frac{\sigma-1}{\theta}}} \\
=& 0 \\
\lim_{\varphi_{0,i}\to 0} RHS =& \frac{\beta_i^{\frac{\theta}{\sigma-1}}}{\left(\sum_{m\neq i} \beta_m^{\frac{\theta}{\sigma-1}} \varphi_{0,m}^{\theta}\right)^{1-\frac{\sigma-1}{\theta}}} \lim_{\varphi_{0,i}\to 0} \frac{1}{\varphi_{0,i}^{\zeta-\theta}} \\
=& \infty
\end{aligned}$$

under the assumption that $(\theta - \delta)/(1-\delta) < \zeta$ and $\theta > \sigma - 1$. This ensures the existence of the interior solution of $\varphi_{0,i}$ because the left-hand-side of the first-order condition is a constant.

For the uniqueness of the interior solution, note that $V_i(\varphi_{0,i})$ is continuous and twice-differentiable in $\varphi_{0,i}$. Our analysis to the second-order condition shows that the expected profit is concave at the interior solution. Suppose that there are two interior solutions $\varphi_{0,i}^A$ and $\varphi_{0,i}^B$, we know that $V_i(\varphi_{0,i})$ reaches local maxima at both $\varphi_{0,i}^A$ and $\varphi_{0,i}^B$ and is strictly concave at these interior points. Assume that $\varphi_{0,i}^A < \varphi_{0,i}^B$ without loss of generality, the continuity of $V_i(\varphi_{0,i})$ implies that there exists $V_i(\varphi_{0,i}) < \min\left\{V_i\left(\varphi_{0,i}^A\right), V_i\left(\varphi_{0,i}^B\right)\right\}$ holds for all $\varphi_{0,i} \in \left(\varphi_{0,i}^A, \varphi_{0,i}^B\right)$, and that there exists a $\varphi_{0,i}^C \in \left(\varphi_{0,i}^A, \varphi_{0,i}^B\right)$ such that $V_i\left(\varphi_{0,i}^C\right) < V_i(\varphi_{0,i})$ for all $\varphi_{0,i} \in \left(\varphi_{0,i}^A, \varphi_{0,i}^B\right)$. The differentiability of $V_i(\varphi_{0,i})$ implies that $V_i'\left(\varphi_{0,i}^C\right) = 0$ and $V_i''\left(\varphi_{0,i}^C\right) \geq 0$ holds, but this contradicts with the fact that $V_i(\varphi_{0,i})$ being concave at all interior solutions. As a result, the interior solution must be unique.

Bargaining Power and Innovation Effort

Now we check the incentive to innovate by changes in connection β_i. Remember that a lower β_i means that the connection is better. Here,

$$
\begin{aligned}
\frac{d}{d\beta_i}\frac{d\overline{\pi}_{f,i}}{d\varphi_{0,i}} =& \frac{d}{d\beta_i} k\Gamma\left(1-\frac{\sigma-1}{\theta}\right)\frac{1-\beta_i}{\beta_i}\frac{1-\left(1-\frac{\sigma-1}{\theta}\right)r_i}{\left(\sum_m \psi_m\right)^{1-\frac{\sigma-1}{\theta}}}\theta\psi_i\varphi_{0,i}^{-1} \\
\propto & \frac{1-\beta_i}{\beta_i}\frac{1-\left(1-\frac{\sigma-1}{\theta}\right)r_i}{\left(\sum_m \psi_m\right)^{1-\frac{\sigma-1}{\theta}}}\theta\frac{\theta}{\sigma-1}\psi_i\beta_i^{-1}\varphi_{0,i}^{-1} \\
& - \frac{1-\beta_i}{\beta_i}\left(1-\frac{\sigma-1}{\theta}\right)\frac{\left(\sum_m \psi_m\right)^{1-\frac{\sigma-1}{\theta}}\frac{dr_i}{d\beta_i} + \left[1-\left(1-\frac{\sigma-1}{\theta}\right)r_i\right]\left(\sum_m \psi_m\right)^{1-\frac{\sigma-1}{\theta}-1}\frac{d\psi_i}{d\beta_i}}{\left(\sum_m \psi_m\right)^{1-\frac{\sigma-1}{\theta}}\left(\sum_m \psi_m\right)^{1-\frac{\sigma-1}{\theta}}}\theta\psi_i\varphi_{0,i}^{-1} \\
& - \frac{1}{\beta_i\beta_i}\frac{1-\left(1-\frac{\sigma-1}{\theta}\right)r_i}{\left(\sum_m \psi_m\right)^{1-\frac{\sigma-1}{\theta}}}\theta\psi_i\varphi_{0,i}^{-1} \\
=& \frac{1-\beta_i}{\beta_i\beta_i}\frac{1-\left(1-\frac{\sigma-1}{\theta}\right)r_i}{\left(\sum_m \psi_m\right)^{1-\frac{\sigma-1}{\theta}}}\theta\frac{\theta}{\sigma-1}\psi_i\varphi_{0,i}^{-1} \\
& - \frac{1-\beta_i}{\beta_i\beta_i}\left(1-\frac{\sigma-1}{\theta}\right)\frac{\theta}{\sigma-1}r_i\frac{(1-r_i)+\left[1-\left(1-\frac{\sigma-1}{\theta}\right)r_i\right]}{\left(\sum_m \psi_m\right)^{1-\frac{\sigma-1}{\theta}}}\theta\psi_i\varphi_{0,i}^{-1} \\
& - \frac{1}{\beta_i\beta_i}\frac{1-\left(1-\frac{\sigma-1}{\theta}\right)r_i}{\left(\sum_m \psi_m\right)^{1-\frac{\sigma-1}{\theta}}}\theta\psi_i\varphi_{0,i}^{-1} \\
\propto & \frac{\theta}{\sigma-1}(1-\beta_i)\left[1-\left(1-\frac{\sigma-1}{\theta}\right)r_i\right] \\
& - \left(1-\frac{\sigma-1}{\theta}\right)\frac{\theta}{\sigma-1}(1-\beta_i)r_i\left\{(1-r_i)+\left[1-\left(1-\frac{\sigma-1}{\theta}\right)r_i\right]\right\} \\
& - \left[1-\left(1-\frac{\sigma-1}{\theta}\right)r_i\right] \\
=& \frac{\theta}{\sigma-1}(1-\beta_i)(1-r_i) - \left(1-\frac{\sigma-1}{\theta}\right)\frac{\theta}{\sigma-1}(1-\beta_i)r_i(1-r_i) \\
& - \left(1-\frac{\sigma-1}{\theta}\right)\frac{\theta}{\sigma-1}(1-\beta_i)r_i(1-r_i) \\
& + \frac{\theta}{\sigma-1}(1-\beta_i)r_i\frac{\sigma-1}{\theta} - \left(1-\frac{\sigma-1}{\theta}\right)\frac{\theta}{\sigma-1}(1-\beta_i)r_ir_i\frac{\sigma-1}{\theta}
\end{aligned}
$$

$$
\begin{aligned}
&-\left[1-\left(1-\frac{\sigma-1}{\theta}\right)r_i\right] \\
=&\frac{\theta}{\sigma-1}(1-\beta_i)(1-r_i)\left[1-\left(1-\frac{\sigma-1}{\theta}\right)r_i\right]-\frac{\theta}{\sigma-1}(1-\beta_i)(1-r_i)\left(1-\frac{\sigma-1}{\theta}\right)r_i \\
&-[1-(1-\beta_i)r_i]\left[1-\left(1-\frac{\sigma-1}{\theta}\right)r_i\right] \\
=&\left[\frac{\theta}{\sigma-1}(1-\beta_i)(1-r_i)-1+(1-\beta_i)r_i\right]\left[1-\left(1-\frac{\sigma-1}{\theta}\right)r_i\right] \\
&-(1-\beta_i)(1-r_i)\left(\frac{\theta}{\sigma-1}-1\right)r_i \\
=&\left[\frac{\theta}{\sigma-1}(1-\beta_i)-1+(1-\beta_i)r_i\left(1-\frac{\theta}{\sigma-1}\right)\right]\underbrace{\left[1-\left(1-\frac{\sigma-1}{\theta}\right)r_i\right]}_{+} \\
&-\underbrace{(1-\beta_i)(1-r_i)\left(\frac{\theta}{\sigma-1}-1\right)r_i}_{+}.
\end{aligned}
$$

The equation above is negative if

$$\frac{\theta}{\sigma-1}(1-\beta_i)-1+(1-\beta_i)r_i\left(1-\frac{\theta}{\sigma-1}\right)<0,$$

which is equivalent to requiring that

$$r_i>\frac{\frac{\theta}{\sigma-1}(1-\beta_i)-1}{(1-\beta_i)\left(\frac{\theta}{\sigma-1}-1\right)}\equiv\bar{r}_i.$$

Because r_i is the winning probability, the inequality above holds trivially if

$$
\begin{aligned}
\frac{\theta}{\sigma-1}(1-\beta_i)-1<&0 \\
\Rightarrow 1-\frac{\sigma-1}{\theta}<&\beta_i,
\end{aligned}
$$

where $1-\frac{\sigma-1}{\theta}\in(0,1)$ by the requirement that $\theta>\sigma-1$. We can therefore conclude that

$$\frac{d}{d\beta_i}\frac{dV_i(\varphi_{0,i})}{d\varphi_{0,i}}=\frac{1}{1-\delta}\frac{d}{d\beta_i}\frac{d\overline{\pi}_{f,i}}{d\varphi_{0,i}}<0$$

holds globally if $\beta_i>1-\frac{\sigma-1}{\theta}$ holds.

C.3 Derivation of (4)

Recall that the demand function and the optimal output level

$$q_i=\left(\frac{A}{B}\right)^{\sigma}\left(\frac{\sigma-1}{\sigma}\right)^{\sigma}\prod_{j=1}^{M}w_j^{-\sigma\alpha_j}\varphi_i^{\sigma},$$

we have the price as

$$p_i = B\left(\frac{\sigma-1}{\sigma}\right)^{-1}\prod_{j=1}^{M} w_j^{\alpha_j}\varphi_i^{-1}.$$

Recall that $\pi_{G,i} = \beta_i k \varphi_i^{\sigma-1}$, we obtain

$$p_i^{1-\sigma} = B^{1-\sigma}\left(\frac{\sigma-1}{\sigma}\right)^{\sigma-1}\prod_{j=1}^{M} w_j^{(1-\sigma)\alpha_j}\frac{\pi_{G,i}}{\beta_i k}.$$

Then from the definition of price index and the procedure in Appendix C.1, we have

$$\begin{aligned}
P^{1-\sigma} = E\left(p^{1-\sigma}\right) =& \sum_i \frac{B^{1-\sigma}}{\beta_i k}\left(\frac{\sigma-1}{\sigma}\right)^{\sigma-1}\prod_{j=1}^{M} w_j^{(1-\sigma)\alpha_j}\int_0^\infty \pi_G h_i\left(\pi_G\right)d\pi_G \\
=& \sum_i \frac{B^{1-\sigma}}{\beta_i k}\left(\frac{\sigma-1}{\sigma}\right)^{\sigma-1}\prod_{j=1}^{M} w_j^{(1-\sigma)\alpha_j}\frac{\beta_i^{\frac{\theta}{\sigma-1}}\varphi_{0,i}^{\theta}}{\left(\sum_m \beta_m^{\frac{\theta}{\sigma-1}}\varphi_{0,m}^{\theta}\right)^{1-\frac{\sigma-1}{\theta}}} k\Gamma\left(1-\frac{\sigma-1}{\theta}\right) \\
=& B^{1-\sigma}\left(\frac{\sigma-1}{\sigma}\right)^{\sigma-1}\prod_{j=1}^{M} w_j^{(1-\sigma)\alpha_j}\frac{\sum_i \beta_i^{\frac{\theta}{\sigma-1}-1}\varphi_{0,i}^{\theta}}{\left(\sum_m \beta_m^{\frac{\theta}{\sigma-1}}\varphi_{0,m}^{\theta}\right)^{1-\frac{\sigma-1}{\theta}}}\Gamma\left(1-\frac{\sigma-1}{\theta}\right).
\end{aligned}$$

Recall that $A \equiv I^{\frac{1}{\sigma}}P^{\frac{\sigma-1}{\sigma}}$ and $k \equiv \frac{A}{\sigma-1}\left(\frac{\sigma-1}{\sigma}\right)^{\sigma}\left(\frac{A}{B}\right)^{\sigma-1}\prod_{j=1}^{M} w_j^{-(\sigma-1)\alpha_j}$, we have

$$\begin{aligned}
k \equiv& \frac{A}{\sigma-1}\left(\frac{\sigma-1}{\sigma}\right)^{\sigma}\left(\frac{A}{B}\right)^{\sigma-1}\prod_{j=1}^{M} w_j^{-(\sigma-1)\alpha_j} \\
=& A^{\sigma}\frac{1}{\sigma-1}\left(\frac{\sigma-1}{\sigma}\right)^{\sigma}B^{1-\sigma}\prod_{j=1}^{M} w_j^{-(\sigma-1)\alpha_j} \\
=& IP^{\sigma-1}\frac{1}{\sigma-1}\left(\frac{\sigma-1}{\sigma}\right)^{\sigma}B^{1-\sigma}\prod_{j=1}^{M} w_j^{-(\sigma-1)\alpha_j} \\
=& \frac{I}{\sigma\frac{\sum_i \beta_i^{\frac{\theta}{\sigma-1}-1}\varphi_{0,i}^{\theta}}{\left(\sum_m \beta_m^{\frac{\theta}{\sigma-1}}\varphi_{0,m}^{\theta}\right)^{1-\frac{\sigma-1}{\theta}}}\Gamma\left(1-\frac{\sigma-1}{\theta}\right)}.
\end{aligned}$$

Therefore,

$$\begin{aligned}
E\left(V_G\right) =& \left(\sum_i \beta_i^{\frac{\theta}{\sigma-1}}\varphi_{0,i}^{\theta}\right)^{\frac{\sigma-1}{\theta}}\frac{k}{1-\delta}\Gamma\left(1-\frac{\sigma-1}{\theta}\right) \\
=& \frac{1}{1-\delta}\frac{I}{\sigma}\frac{\sum_m \beta_m^{\frac{\theta}{\sigma-1}}\varphi_{0,m}^{\theta}}{\sum_m \beta_m^{\frac{\theta}{\sigma-1}-1}\varphi_{0,m}^{\theta}}.
\end{aligned}$$