The Market Potential and Optimality of Industrial Policy: Revisiting Korean Industrial Policy in the 1970s

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Abstract

We assess optimal industrial policy factoring in external economies of scale under changing global market conditions. Since policy effects naturally materialize with a time lag, policy assessment should compare the short-run distortion of the intervention to its long-run gain. In this context, we expand the small open economy model of Bartelme et al. (2021) into a two-period dynamic setting to figure out how important the dynamics of global market conditions are in determining optimal policy. Optimal industrial policy in our model depends not only on the scale elasticity, but also on a multiplier which is larger when more resources are re-allocated to the industry in the long-run based on export market penetration. This optimal policy implies that an industry with a growing future market should receive stronger support than earlier papers suggest. We quantitatively evaluate the industrial policy of South Korea in the 1970s. With the estimate of the scale elasticity of 29 manufacturing industries, our quantitative analysis presents two main results. First, even though the scale elasticity of targeted industries does not dominate that of non-targeted industries, industrial policy increased the welfare of South Korea. Second, the suggested optimal subsidy rate for the targeted industries is even higher than the actual rate.

Keywords: optimal industrial policy, global market conditions, external economies of scale

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1 Introduction

We have witnessed a recent "rebirth" of industrial policy that involves developed economies such as the United States and European Union striving to strengthen their domestic industries, especially on ones that center around key manufacturing technologies. Considering that industrial policy had not gained much popularity among the developed nations, it warrants a question of what is so special about recent days for such economies to decide on market intervention.

In this paper, we argue that the optimal industrial policy proactively reflects the global environment, which we characterize as the global demand of goods in each industry. Theoretically, we derive the expression for optimal industrial policy that reflects both (i) external economy of scale, which is a conventional motive for intervention, and (ii) relative importance, which is summarized by the allocation of inputs across time. This relative importance, which is a novel factor that we introduce in determining optimal industrial policy, reflects final consumption share, and the importance of an industry in terms of how the output of an industry is linked to other industries' production. Shifts in global environment now works as a complement to the industrial policy in facilitating the transition of the economy towards the targeted industries, which increases welfare in our framework.

We contribute to the literature by providing a novel framework which could reverse the policy suggestion solely based on external economies of scale. There is several evidence that external economies of scale is both present and heterogeneous across sectors, which naturally leads to an optimal Pigovian subsidy that is proportional to the scale elasticity. However, without acknowledging the technological change, geographical relations and its ensuing global demand shifts, our result implies that such policy could be misleading.

Formally, we extend the static small open economy model of Bartelme et al. (2021) into a two-period dynamic model to reflect the dynamics of global market conditions and show how it is reflected in the optimal industrial policy. In the model, the government conducts industrial policy in the first period (short-run) and the policy effect, which is the realization of external economies of scale, materializes in the second period (long-run). Because of the time lag in policy effects, policy should aim to incorporate long-run (future) conditions, and compare the short-run distortion of the intervention to its long-run gain. The cost and benefit structure in our model leads to a different optimal policy suggestion from the previous literature. Scale elasticity is no longer a sufficient statistics for optimal industrial policy. Instead, the optimal subsidy rate is a combination of scale elasticity and relative importance that summarizes the change in input share across time. This expression of optimal industrial policy suggests a novel policy implication: policy-induced productivity growth is not sufficient to determine policy, but external demand growth could be as important.

We also quantitatively evaluate the industrial policy of South Korea that was implemented between 1973 and 1979 to promote heavy and chemical industries (HCI drive). We find this intervention particularly relevant to our framework since the export demand of the targeted industries in South Korea grew significantly during the 1970s and 1980s due to the emergence of product sharing and precipitous increase in trade flows. For calibration, we first estimate the scale elasticity of 29 manufacturing industries in South Korea based on Irwin and Klenow (1994) using regional level data between 1967 and 1989 from the Korean Mining and Manufacturing Survey. The estimate of the scale elasticity of 29 manufacturing industries ranges from 0.04 to 0.68 and its average is 0.26. We also compute the production and consumption structure using the South Korea Input-Output table and the World Input-Output Database.

Our quantitative analysis yields two main results. First, although the scale elasticity of targeted industries was similar to that of non-targeted industries, the HCI drive increased the welfare of South Korea. Second, the suggested optimal subsidy rate for the targeted industries is even higher than the actual rate, resulting from the higher growth rate of export demand for the targeted industries.

The rest of this paper is structured as follows. Section 2 reviews relevant literature and Section 3 presents the model setup and provides an example to demonstrate our mechanism of the model. Section 4 analyzes South Korea's Heavy and Chemical Industry Drive based on our model framework and quantitatively evaluate its welfare implication. Section 5 concludes.

2 Literature review

External economy of scale

The conventional motive for industrial policy is the existence of external economies of scale. Because firms do not fully appropriate the knowledge they create from increased production, it is desirable for the government intervention (Krugman (1987a)). Formal treatment of external economies of scale has been provided by Ethier (1982), Chipman (1970), Krugman (1980), and Markusen (1990), Grossman and Rossi-Hansberg (2010), and most recently Bartelme et al. (2021) derives optimal policies under external economy of scale[1].

In a dynamic setting, learning-by-doing is another way of characterizing external economies of scale. Krugman (1987b), Redding (1999), and Melitz (2005) present models of dynamic comparative advantage where temporary protection from trade may prove optimal. These models are based on the assumption that an industry's cumulative production generates knowledge spillovers. Since firms do no internalize such spillovers, subsidies to accelerate production can boost overall growth and welfare.

Our contribution to the literature is to extend the static (long-run) model of Bartelme et al. (2021) into two-period dynamic model. In this framework, our derivation of optimal industrial policy reflects not only the features inherent to the production side of the

[1]External economy of scale is not the only rationale for industrial policy. See Itskhoki and Moll (2019) for optimal industrial policy with financial constraints on the entrepreneurs. Liu (2019) shows how input-output linkages can amplify frictions from the upstream sectors.

industry focused on in the previous literature (e.g. external economy of scale, learning-by-doing), but more crucially on the factors mostly *exogenous* to the production aspect of the industry (e.g. global market conditions). In this way, we relate our framework to the recent re-emergence of industrial policy that is centered around the key industries.

Estimation of scale elasticity

Empirically, Caballero and Lyons (1990) and Caballero and Lyons (1992) estimated the external economy of scale separately from the internal economy of scale, and found a significant industry-level external economy for US and European countries. Lindström (2000) applied the same Caballero-Lyons model with firm-level data (instead of industry-level data), and found similar results. Bartelme et al. (2021) exploited the novel exogenous variation in demand across countries and found that external economies of scale vary across sectors.

Similarly, some authors have estimated a learning-by-doing elasticity in a variety of industries: Irwin and Klenow (1994) for semi-conductors, Thornton and Thompson (2001) for shipbuilding, and Lieberman (1987) for chemicals[2]. In our paper, we use industry-region level data for manufacturing plants in Korea from 1967-1989 and apply Irwin and Klenow (1994) methodology to estimate the scale elasticity for 29 different industries[3]. Our estimates of scale elasticity is more specific to our country of interest (South Korea), and hence possibly more appropriate to conduct welfare analysis with regards to the industrial policy than the previous literature[4].

[2] See Thompson (2010) for further reference

[3] Using a region-level data instead of plant-level enables us to use the data as early as 1967, and is also consistent with the argument that the Korean industrial policy was mostly targeted to support firms at the regional level.

[4] For example, scale elasticity estimates can be different across countries depending on their stage of development, industry life cycle, other country-specific characteristics.

Market potential

Our framework relates to the market potential literature, in which the proximity of a region (country) to a large market can factor into its own aggregate outcome. The terminology was first introduced by Harris (1954), who formalized it as the summation of market access (demand) weighted by the distance to each market, and market potential concept was further developed in the new economic geography literature notably in Krugman (1991), Fujita et al. (1999). In the context of our paper, we examine market potential as a primitive that can differ by each sector, and show that rapid change in sector-level market potential could have strong implications in the optimal industrial policy. Specifically, we will present an illustrative example where global market condition outweighs external economy of scale in determining the optimal industrial policy.

Industrial policy of South Korea

In the empirical part of this paper, we will focus on the industrial policy of South Korea in the 1970s, which targeted mainly heavy and chemical industry (HCI drive). Lane (2022) documents how South Korea was able to obtain its dynamic comparative advantage from the policy. Choi and Levchenko (2021) uses unique data on firm-level subsidies to estimate large long-term effect from the industrial policy. Kim et al. (2021) documents several aspect of the policy that indicate inefficient allocation stemming from the intervention. For example, they show increased dispersion in revenue productivity (TFPR, Hsieh and Klenow (2009)).

Contrary to previous papers evaluating industrial policy in South Korea, we investigate the role of evolving global market environments on the optimal subsidy rate. To the best of our knowledge, this aspect has been overlooked in the literature. Since the time of the intervention was around the onset of a new wave of globalization, the targeted industries experienced a significant increase in global demand. Our quantitative analysis points to further welfare gains that might have been realized from an even more activist policy had external demand growth been taken more fully into account. We believe the case of South Korea is not confined to a particular country or time, as the environment bears close resemblance to the present agenda of industrial policy revolving around the *key* industries such as semiconductor or green energy industry.

3 Model

The model closely follows the small open economy model of Bartelme et al. (2021), but we introduce the assumption that firms have market power (imperfect competition) and there is no free entry[5]. Importantly, the model incorporates two periods ($t = 1, 2$), and the external economy of scale is realized with a time lag. It is assumed that each time period corresponds to approximately 10 years. Any variable with a tilde, $\tilde{x}$, denotes x in the second period (t=2).

3.1 Preference

The representative household in destination country j has the following utility function:

$$c_j = \left(\sum_{k=1}^{J} c_{j,k}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}, \tag{1}$$

where c_j is a CES aggregate of sector-level composite bundle, $c_{j,k}$, and σ denotes the elasticity of substitution between sectors. A sector-level composite bundle in industry k is defined as follows:

$$c_{j,k} = \left(\sum_{h=1} c_{jj,k}(h)^{\frac{\gamma_k-1}{\gamma_k}} + \sum_{i \neq j} \sum_{f} c_{ij,k}(f)^{\frac{\gamma_k-1}{\gamma_k}} \right)^{\frac{\gamma_k}{\gamma_k-1}}. \tag{2}$$

[5] This is similar with the framework in Choi and Levchenko (2021), however, we are interested in deriving optimal policy.

where h represents a home variety, f represents a foreign variety from country i, and γ_k denotes the elasticity of substitution across varieties in sector k.

The price index for the sector-level composite bundle in industry k is:

$$P_{j,k} = \left(\sum_h p_{jj,k}(h)^{1-\gamma_k} + \sum_{i \neq j} \sum_f p_{ij,k}(f)^{1-\gamma_k} \right)^{\frac{1}{1-\gamma_k}}, \tag{3}$$

and the aggregate consumer price index is:

$$P_j = \left(\sum_k P_{j,k}^{1-\sigma} \right)^{\frac{1}{1-\sigma}}. \tag{4}$$

3.2 Production and market structure

The production function for the variety h in industry k in origin country i has the following Cobb-Douglas form:

$$y_{ij,k}(h) = A_{ij,k}(h) E(Q_{i,k,-1}) l_{ij,k}(h) \tag{5}$$

where $A_{ij,k}(h)$ represents the origin-destination specific productivity and $l_{ij,k}(h)$ denotes the labor used to produce the variety h in industry k in an origin country i for a destination country j. Additionally, $E(\cdot)$ represents the external scale economy, which depends on the cumulative production until last period, $Q_{j,k,-1}$. For simplicity, we assume that the external economy of scale is fixed in period 1, but changes in period 2 depending on the aggregate production in period 1. This productivity gain is realized outside of the firm boundary, and as a result, it may lead to inefficiency in resource allocation.

Every domestic and foreign firm in industry k faces monopolistic competition and therefore sets a price with a constant markup over marginal cost:

$$p_{ij,k}(h) = \frac{1}{1+t_{ij,k}} \frac{\gamma_k}{\gamma_k - 1} mc_{ij,k}(h), \tag{6}$$

where

$$mc_{ij,k}(h) = \frac{(1 - s_{i,k}) w_i}{A_{ij,k}(h) E(Q_{i,k,-1})}. \tag{7}$$

Trade cost is incorporated in $A_{ij,k}(h)$.[6] $t_{ij,k}$ denotes the production subsidy rate for products in industry k in an origin country i originating from country i and destined for country j, while $s_{i,k}$ represents the wage subsidy rate for industry k in country i. Detailed explanations of these policy tools will be provided in the next section.

3.3 Policy Instruments

We introduce two policy instruments: (i) wage subsidy, $s_{i,k}$, which aims to address misallocation resulting from cross-industry heterogeneity in external economies of scale, and (ii) production subsidy, $t_{ii,k}$, which aims to correct market power exhibited by domestic firms in the domestic market. Since our main objective is to choose $s_{i,k}$ to address resource misallocation resulting from external economies of scale, we assume that the government in the origin country i sets $t_{ii,k} = \frac{1}{\gamma_k - 1}$ and $t_{ij,k} = 0$ for $i \neq j$ to solely correct the distortion in domestic markets caused by market power. Government spending (T_i) would be financed by the household through a lump-sum manner:

$$T_i = \sum_j \sum_k s_{i,k} w_i l_{ij,k} + \sum_k \frac{t_{ii,k}}{1 + t_{ii,k}} p_{ii,k} c_{ii,k}. \tag{8}$$

[6]Specifically, $A_{ij,k}(h) = \tau_{ij,k} A_{i,k}(h)$, where $\tau_{ij,k}$ represents the origin-destination specific iceberg trade cost.

It is worth noting that the tax amount required for the production subsidies (the second term) is equal to the firms' profit from the domestic market in equilibrium, and thus they are canceled out in the consumer's budget constraint.

From this point onwards, we will use the terms "industrial policy," "industry subsidy," and "wage subsidy" interchangeably, as they are identical within the model framework.

3.4 General Equilibrium

In general equilibrium in each period, firms maximize profit, consumers maximize utility, and market clearing conditions hold. For simplicity in this section, we will omit the notation for variety h and f, as well as the time subscript t.

Profit maximization

For any firm, any industry k, any origin country i, and any destination country j, profit maximization requires

$$(l_{ij,k}, y_{ij,k}) \in \text{argmax}_{\{l,y\}} \quad \{q_{ij,k}(y)y - \nu_{i,k}l \,|\, y = A_{ij,k}E_k(Q_{i,k,-1})l\}, \tag{9}$$

where $q_{ij,k}$ represents the price received by the firm in industry k in country i when it sells its good in country j, and $\nu_{i,k}$ denotes the wage faced by the firm in industry k in country i. We will denote the value function of this problem as $\pi_{ij,k}$.

Utility maximization

For any destination country j, utility maximization requires

$$c_j \in \text{argmax}_{\{c\}} \quad \{u_j(c) \,|\, \sum_i \sum_k p_{ij,k}c_{ij,k} = w_jL_j + \sum_i \sum_k \pi_{ji,k} - T_j\}, \tag{10}$$

Where $p_{ij,k}$ represents the price that consumers in the destination country j pay to purchase a good in industry k produced in country i. For the sake of notation, we will denote $I_j = w_j L_j + \sum_i \sum_k \pi_{ji,k} - T_j$.

Market clearing

For any industry k, any origin country i, and any destination country j, goods and labor market clearing requires

$$y_{ij,k} = c_{ij,k} \tag{11}$$

$$\sum_j \sum_k l_{ij,k} = L_i \tag{12}$$

Government budget balance

The total tax expenditure in any origin country i is equal to the amount spent on wage and production subsidies:

$$T_i = \sum_j \sum_k s_{i,k} w_i l_{ij,k} + \sum_k t_{ii,k} p_{ii,k} c_{ii,k} \tag{13}$$

Prices and taxes

For any industry k, any origin country i, and any destination country j, the prices faced by consumers in the destination country j and the firm in the origin country i ($p_{ji,k}$ and $q_{ji,k}$), as well as the wages faced by consumers and firms in the origin country i (w_i and $v_{i,k}$), are as follows:

$$q_{ii,k} = (1 + t_{ii,k}) p_{ii,k} \tag{14}$$

$$q_{ij,k} = p_{ij,k} \text{ for } i \neq j \tag{15}$$

$$v_{i,k} = (1 - s_{i,k}) w_i \tag{16}$$

Definition

Given production subsidies in all origin countries, $\{s_{i,k}, t_{ii,k}\}_{i,k}$, a general equilibrium in the model is defined by the set of prices and wages, $\{p_{ij,k}, q_{ij,k}, w_{i,k}, v_{i,k}\}_{i,j,k}$, along with an allocation, $\{l_{ij,k}, y_{ij,k}, c_{ij,k}\}_{i,j,k}$, and lump-sum tax, $\{T_i\}_i$, such that equations (9)-(16) are satisfied in each period $(t = 1, t = 2)$.

3.5 Optimal industrial policy

Government's problem is to maximize welfare of consumers in j:

$$\ln \mathbb{W} = \ln c_j(\mathbf{s}_j, \mathbf{t}_{jj}) + \beta \ln \tilde{c}_j(\tilde{\mathbf{t}}_{jj}) \qquad \text{s.t.} \quad \tilde{t}_{jj,k} = t_{jj,k} = \frac{1}{\gamma_k - 1}, \quad \forall k$$

Specifically,

$$c_j = \frac{I_j}{P_j} = \frac{w_j L_j + \sum_i \sum_k \pi_{ji,k} - T_j}{P_j}$$

and this is true for the period 2 consumption as well.

We will proceed by evaluating the first order conditions for $\ln c_j$ and $\beta \ln \tilde{c}_j$ in turn.

3.5.1 Period 1

Note that

$$\begin{aligned} I_j = w_j L_j &+ \sum_k \Big[p_{jj,k} c_{jj,k} - (1 - s_{j,k}) w_j l_{jj,k} \Big] \\ &+ \sum_{i \neq j} \sum_k \Big[p_{ji,k} c_{ji,k} - (1 - s_{j,k}) w_j l_{ji,k}) \Big] \\ &- \sum_k s_{j,k} w_j L_{j,k} - \sum_k t_{jj,k} p_{jj,k} c_{jj,k}, \end{aligned}$$

where the each summation in the right hand side refers to (i) profit of firms from domestic sales, (ii) foreign sales and (iii) cost for labor subsidy and (iv) cost for product subsidy.

Firms set price as:

$$p_{jj,k} = \frac{\gamma_k - 1}{\gamma_k} \frac{1}{1 + t_{jj,k}} \frac{(1 - s_{j,k}) w_j}{A_{jj,k}}$$

for domestic sales and

$$p_{ji,k} = \frac{\gamma_k - 1}{\gamma_k} \frac{(1 - s_{j,k}) w_j}{A_{ji,k}}$$

for foreign sales. Since we impose domestic product subsidy $t_{jj,k} = \frac{1}{1-\gamma_k}$, profit from home sales is exactly offset by the cost for product subsidy. Further derivation results in:

$$\frac{d\ln c_j}{d s_{j,k_0}} = \frac{1}{I_j} \left[- \sum_k s_{j,k} w_j L_{j,k} \frac{d\ln L_{j,k}}{d s_{j,k_0}} \right]. \tag{17}$$

This shows that subsidy on any industry k_0 is a pure loss in terms of the present, since policy effect is not materialized immediately.

3.5.2 Period 2

With a similar derivation, we can obtain welfare gain in period 2. Note that the productivity gain from economy of scale is materialized based on the resource allocated in period 1:

$$\frac{d\ln \tilde{c}_j}{d s_{j,k_0}} = \beta \sum_k \zeta_k \frac{\tilde{w}_j \tilde{L}_{j,k}}{\tilde{I}_j} \frac{d\ln L_{j,k}}{d s_{j,k_0}}. \tag{18}$$

Welfare thus is :

$$\frac{d\mathbb{W}}{d s_{j,k_0}} = \left[\sum_k \left(\beta \zeta_k \frac{\tilde{w}_j \tilde{L}_{j,k}}{\tilde{I}_j} - s_{j,k} \frac{w_j L_{j,k}}{I_j} \right) \frac{d\ln L_{j,k}}{d s_{j,k_0}} \right]. \tag{19}$$

Hence, we showed the following proposition:

Proposition 1: Given $t_{jj,k} = \frac{1}{\gamma_k - 1}$ at $t = 1, 2$, optimal wage subsidy $\{s_{j,k}\}_k$ is

$$s^*_{j,k} = \beta\zeta_k \underbrace{\left(\frac{\tilde{w}^*_j \tilde{L}^*_{j,k}/\tilde{I}^*_j}{w^*_j L^*_{j,k}/I^*_j}\right)}_{\mathbb{A}_k} \quad \forall k,$$

where β is the discount factor for the social planner, $\tilde{x}$ is a future variable of x, and ζ_k is the scale elasticity of sector k, and I_j is the aggregate income of country j, and all variables with asterisk($*$) is a notation for variables at the optimal subsidy level.

This expression indicates that the optimal industrial policy should reflect not only the external economy of scale that firms fail to internalize, but crucially on the multiplier that reflects future resource allocation ($\mathbb{A}_k$).

The optimal policy expression differs from the standard argument for industrial policy under external economy of scale, i.e., Bartelme et al. (2021). In a static setting, optimal industrial policy is slightly lower than the scale elasticity ($s^{*BCDR}_{j,k} = \zeta_k/(\zeta_k + 1)$) since policy has a contemporaneous general equilibrium effect on wage. However, since policy effect on wage is separated in this dynamic setting, optimal policy shows more direct reflection of external economy of scale[7].

Our main argument for industrial policy is reflected in the second term, $\mathbb{A}_k$, which is the ratio of resource allocated to an industry for each period. Since $\mathbb{A}_k$ is a general equilibrium term, it incorporates the degree of change in the industrial structure. For example, when an economy targets an industry could grow dramatically within an economy in the future compared to the current period, it is reflected in a higher $\mathbb{A}_k$. The growth in an industry may be caused by the external economy of scale, however, it crucially depends on, and interacts with the evolving global market conditions that governments must account for. The government should aim to support industries which will have future importance, usually indicated by its large projected market size. To our

[7]The optimal policy expression also differs from Bartelme et al. (2021) in that export tax is unnecessary. This is because of our assumption on market structure, and the *product* subsidy that eliminates distortion from firm's market power on domestic consumption.

knowledge, this factor has been overlooked in the literature, even though it often has been pointed out in the policy circle.

The following proposition enables us to set a reference industry by fixing its subsidy rate at zero. Hence we consider subsidies relative to the reference industry.

Proposition 2: For any α, alternative policy $s' = \{\frac{\alpha+s_{j,k}}{1+\alpha}\}_k$ generates the same allocation $\{l_{ji,k}, c_{ji,k}, y_{ji,k}\}_i$ as with $\{s_{j,k}\}_k$.

Proof See the Appendix F.1.

3.6 Introducing Input-Output linkages

In this section, we extend our baseline model to include input-output linkages. Introducing input-output linkages is essential because it allows for an amplification of external economies of scale through the linkages.

In the model with input-output linkages, firms use a sector-specific composite input, denoted as $z_{ji,k}(h)$, for production.

$$y_{ji,k}(h) = A_{ji,k}(h)E(Q_{i,k,-1})z_{ji,k}(h) \tag{20}$$

where $z_{ji,k}(h)$ comprises labor, capital and sector-specific intermediate input.

$$z_{ji,k}(h) = f_k\left(l_{ji,k}(h), l_{ji,k}(h), m_{ji,k}(h)\right) \tag{21}$$

Sector-specific intermediate input, $m_{ji,k}(h)$, is aggregated in CES as follows:

$$m_{ji,k}(h) = \left\{\sum_l \eta_l^{\frac{1}{\delta_k}} m_{j,l}(h)^{\frac{\delta_k-1}{\delta_k}}\right\}^{\frac{\delta_k}{\delta_k-1}}, \quad \text{where } \sum_l \eta_l = 1 \tag{22}$$

where $m_{j,l}(h)$ represents the goods in sector l from country j used to produce intermediate goods in sector k in country j. η_l is the parameter that reflects the input usage intensity from industry l good in producing k intermediate inputs[8]. The external economies of scale of sector k is realized based on the aggregate sector-specific composite inputs in the industry ($Z_{j,k} = \sum_h z_{ji,k}(h)$). General equilibrium is defined in detail in Appendix A.

Similarly to the baseline model, the following proposition demonstrates the optimal subsidy rate for each industry.

Proposition 3: In a general environment with input-output linkages, optimal industrial policy $\{s^*_{j,k}\}_k$ is such that:

$$s^*_{j,k} = \beta\zeta_k\left(\frac{\tilde{w}^*_{j,k}\tilde{z}^*_{j,k}/\tilde{I}^*_j}{w^*_{j,k}z^*_{j,k}/I^*_j}\right) \quad \forall k,$$

where $w^*_{j,k}$ is the price of composite input $z_{j,k}$.

Proof See the Appendix F.2.

This proposition makes it clear that the optimal industrial policy reflects the relative importance of an industry summarized by *domar weight* of each industry. This general framework provides one mechanism that may amplify the welfare gains, as demonstrated in Bartelme et al. (2021). Furthermore, since composite input is not constrained as the endowment, Proposition 2 does not hold in this framework.

3.7 Illustrative example

We provide an illustrative example that shows how the central mechanisms of our model work. In this example, there are two countries (home, foreign) and two industries. Home is assumed to be small and thus does not affect resource allocation in the foreign country. This is represented by labor and capital endowment in the home country being only 1% of the labor and capital endowment in the foreign country.

The utility function is assumed to be a Cobb-Douglas function (i.e. $\sigma = 1$) for simplicity

[8]Note that when $\delta_k \to 1$, then η_l is the cost share of l industry good in producing input in sector k.

as follows:

$$c_j = c_{j,1}^{\alpha_1} c_{j,2}^{\alpha_2}, \text{ where } \alpha_1 + \alpha_2 = 1 \tag{23}$$

$c_{j,k}$ is constructed as in equation (2). The production function uses labor, capital, and intermediate goods and is assumed to be a nested CES:

$$y_{ji,k}(h) = A_{ji,k}(h) Q_{i,k,-1}^{\zeta_k} z_{ji,k}(h), \text{ where } Q_{i,k,-1} = 1 \text{ if } t = 1 \tag{24}$$

$$z_{ji,k}(h) = l_{ji,k}(h)^{a_k} k_{ji,k}(h)^{b_k} m_{ji,k}(h)^{1-a_k-b_k} \tag{25}$$

$m_{ji,k}(h)$ is constructed as in equation (22).

Additionally, We assume that both in the home and foreign markets, the consumption and input demand for goods produced by industry 1 is expected to increase significantly compared to industry 2 in period 2. We can imagine that industry 1 is related to the electric vehicle and its essential inputs. Due to environmental regulations, consumers will primarily purchase electric vehicles in the near future. As a result, the consumption share for the industry will significantly increase compared to the industry associated with fossil fuel cars. Naturally, there will be a corresponding rise in demand for inputs specific to electric vehicles, such as batteries and electric traction motor.

This assumption is reflected in the increase in the final consumption share of industry 1 good, α, from 0.4 to 0.6, and an increase in the (input) demand shifters for industry 1 in the input-output linkages, η_1 and η_2, from 0.4 to 0.6. We set other parameters, especially the scale elasticity for the two industries to be the same for both countries, allowing us to focus on how changes in the demand structure in period 2 can affect optimal policy. Table 1 lists the parameter values, assumptions on productivity, and demand structure in each industry for both the home and abroad.

[9] If the home country does not implement any wage subsidy, the productivity of sector 1 and 2 in the home country increases by 1.4 and 1.5, respectively, in period 2 due to the external economies of scale. By assuming that the foreign country's productivity in each sector increases at the same rate as the home

Table 1: Parameters and Assumptions

	Description	Industry 1		Industry 2	
ζ_k	Scale elasticity	0.15		0.15	
τ_k	Trade cost	0.25		0.25	
γ_k	Within-sector elasticity of substitution	2.5		2.5	
a_k	Labor share in production	0.15		0.15	
b_k	Capital share in production	0.15		0.15	
δ_k	Across-sector elasticity of substitution in intermediate goods	1.5		1.5	
β	Discount factor	1			
	Home economy size				
L_j	Labor	10			
K_j	Capital	10			
	Foreign economy size				
L_i	Labor	1,000			
K_i	Capital	1,000			
		$t = 1$	$t = 2$	$t = 1$	$t = 2$
$A_{j,k}$	Home productivity	1	$(Z_{1,1})^{\zeta_1}$	1	$(Z_{2,1})^{\zeta_2}$
$A_{i,k}$	Foreign productivity [9]	1	1.4	1	1.5
α_k	Consumption share	0.4	0.6	0.6	0.4
η_k	Demand shifter in IO linkages	0.4	0.6	0.6	0.4

Notes: We use the median value of the estimates of scale elasticity in Bartelme et al. (2021) as the scale elasticity for both industries in this example. We obtain the parameter values for trade cost and within-sector elasticity of substitution from Obstfeld and Rogoff (2000) and Broda and Weinstein (2006), respectively.

Under these conditions, the optimal subsidy rates are $s_1 = 0.154$ and $s_2 = 0.080$, with the multipliers $\mathbb{A}_1$ and $\mathbb{A}_2$ being 1.02 and 0.54, respectively. Figure 1 shows the optimal subsidy rates derived based on our model and Bartelme et al. (2021). While Bartelme et al. (2021) propose $s_1 = 0.130$ and $s_2 = 0.130$ as the optimal subsidy rates, our model suggests a higher subsidy for industry 1 and a lower subsidy for industry 2 than theirs. Although the scale elasticity is the same for both industries, more resources need to be reallocated to industry 1 through a higher subsidy rate in order for the home country to exploit the economies of scale in that industry, whose importance in global demand significantly increases in period 2. When examining the optimal subsidy rate in relative

country, we ensure that the comparative advantage of the home and foreign country remains the same in period 2 without any intervention of the home country.

terms[10] ($\frac{s1^*}{s2^*}$), which is 1.91 in our model while it is 1 in Bartelme et al. (2021), our result shows differences in the policy recommendations[11].

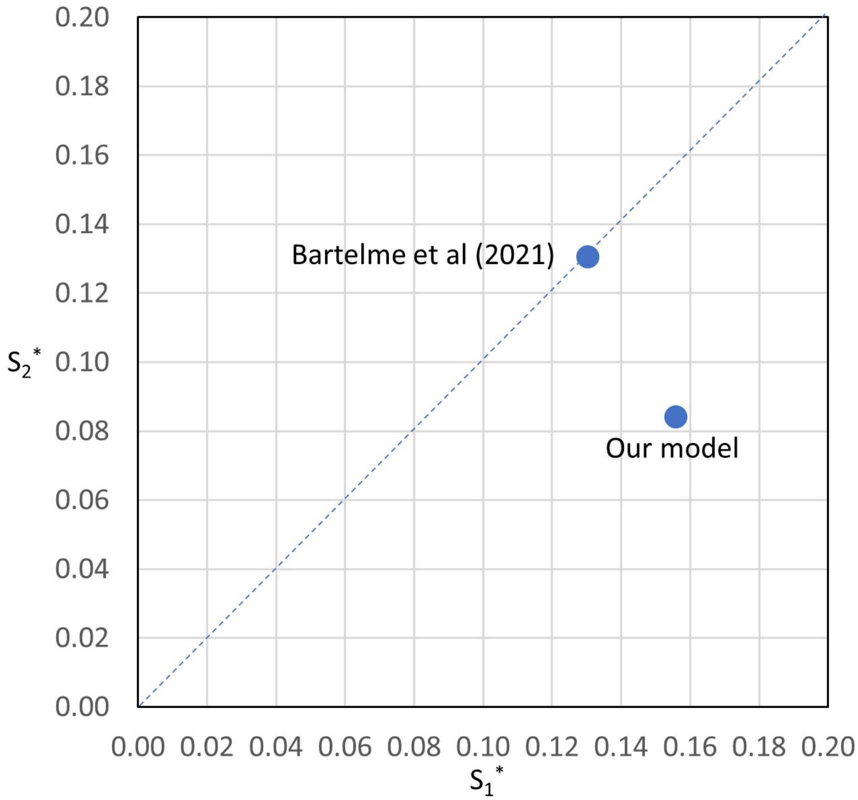


Figure 1: Optimal subsidy rate based on our model and Bartelme et al. (2021)

Notes: The position of the marker corresponds to the optimal industry policy for the two industries when the scale elasticity are fixed to 0.15 for both industries. The optimal industrial policy is derived following Proposition 1.

Decomposition of welfare gains In this example, home welfare increases by 2.78% under the optimal policy. This welfare increase can be attributed to two factors: (1) external economies of scale and (2) changes in the (global) demand structure. Thus we

[10]The point on the 45-degree line represents optimal subsidy rate based on Bartelme et al. (2021), while the point below the 45-degree line represents optimal subsidy rate based on our model. It demonstrates different policy suggestions. The slope of a line from the origin to the point ($\frac{s_2^*}{s_1^*}$) indicates the intensity of the optimal policy support to sector 2 relative to sector 1. Thus, if the slope is smaller than 1, as in the case of our model, optimal subsidy implies more support for sector 1.

[11]In fact, no policy is optimal without considering the global demand.

calculate the extent to which changes in the (global) demand structure contribute to the welfare gain under the optimal policy. We calculate the welfare gains from external economies of scale by computing the welfare gains under the scenario where the demand structure stays the same. The remaining welfare gains from the policy can be attributed to the welfare gains from the global market. This can be summarized by the following equation(26):

$$\begin{aligned}\underbrace{\ln W(s_1^*, s_2^*) - \ln W(0,0)}_{+2.78\%} &= \underbrace{\ln W(s_1^*, s_2^*)|_{DS_1=DS_2} - \ln W(0,0)|_{DS_1=DS_2}}_{\text{External economies of scale, }+1.89\%} \\ &+ \underbrace{\left[(\ln W(s_1^*, s_2^*) - \ln W(0,0)) - \left(\ln W(s_1^*, s_2^*)|_{DS_1=DS_2} - \ln W(0,0)|_{DS_1=DS_2}\right)\right]}_{\text{Demand structure change, }+0.89\%}\end{aligned} \tag{26}$$

In this example, out of the overall increase in welfare under the optimal subsidy rate, 32.1% results from changes in the demand structure, while 67.9% arises from external economies of scale. Overall, this example suggests that scale elasticity is not a sufficient statistic for determining the optimal policy, and the government should consider how the importance of targeted industries in the global market may change in the future. When global market conditions are favorably evolving for a specific industry, it is recommended to adopt an even more proactive policy for that industry.

The following section will map the data from South Korea in the 1970s and 1980s into the model and numerically evaluate the impact of industrial policy on welfare.

4 Quantitative Analysis

Based on our model, we quantitatively assess welfare effects of the Heavy and Chemical Industry drive (HCI drive) by the Korean government during 1973-1979 to promote heavy and chemical industries[12]. We use exact hat-algebra from Dekle et al. (2008), and construct counterfactuals based on different industry-level subsidy rates.

[12]Table 2 provides a list of 29 manufacturing industries classified into treated and non-treated industries

We believe South Korea's HCI drive is particularly appropriate to evaluate within our framework. As in Figure 2, the intervention took place when global trade experienced significant growth, which mainly can be ascribed to the emergence of global production sharing and the third industrial revolution. The growth in export demand did not uniformly affect all industries equally, as the share of global trade was becoming more concentrated on the industries that South Korean government targeted[13]. Hence, our purpose is to numerically evaluate whether the policy that supported industries which gained much importance internationally has benefited the economy.

Our quantitative framework recognizes that HCI drive may not be the sole reason for acquiring dynamic comparative advantage (Lane (2022), Choi and Levchenko (2021)), which makes our welfare implication more conservative[14]. Since our estimation on scale elasticity captures the productivity growth from the industry-level cumulative production, we are allowing for firms to achieve productivity gain complementary to the policy. To the extent one believes policy affected firm (internal) growth, it should be reflected in the increase in scale elasticity and making the welfare implication larger than what we present.

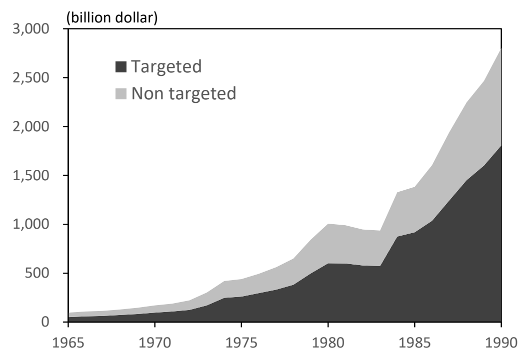
We use exact hat-algebra (Dekle et al. (2008)) to compute counterfactual equilibrium when there had been no subsidy. We relegate all equations used for computation in the appendix B. The relevant equation to evaluate welfare at the counterfactual is the following:

$$\widehat{\mathbb{W}} = \ln(\widehat{I_h}/\widehat{P_h}) + \beta \ln(\widehat{\tilde{I}_h}/\widehat{\tilde{P}_h}),$$

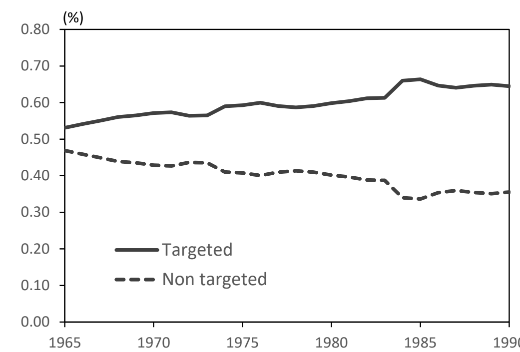
where $\hat{x}$ is the relative change (x'/x) in variable x.

[13]South Korea is small enough to lead this trend. Given our small open economy model, this exogenous change in global market condition make the South Korean industrial policy more relevant to our framework.

[14]Ascribing firm-level productivity gain to policy would result in a larger welfare estimate since the policy can now be more capable to change the dynamic comparative advantage. See Choi and Levchenko (2021) for instance.



(a) Global trade value



(b) Global trade share

Figure 2: World trade during 1970s and 1980s

Notes: Figure 2 (a) is the aggregate global trade volumes (exports) of the targeted and non-targeted industries using the data from Feenstra et al. (2005). Figure 2 (b) represents the share of the targeted and non-targeted industries in global trade. We classified the targeted industries based on the classification in Table 2.

4.1 Calibration

Scale Elasticity We first estimate scale elasticity of 29 manufacturing industries in South Korea. Since the scale elasticity has important implication in our model, we find it more appropriate to directly estimate the parameters using South Korean data, instead of borrowing point estimates from the literature.

The data we used mostly come from Annual Mining and Manufacturing Survey (MMS) published by Statistics Korea annually. In order to utilize the data as early as 1967, we aggregated every variable upto industry-regional level, since plant-level identifier are not provided until 1978.

We draw on Irwin and Klenow (1994)'s methodology for estimating the scale elasticity. Specifically, we extracted proxy variable for regional level marginal cost using the variation on production share among different regions[15]. Taking the first difference of the regional level marginal cost (mc^{r_j}) and allowing for heterogeneous productivity growth across

[15]See the Appendix C for details.

different industry-region and adding time fixed effect, we run the regression of the following form[16] :

$$d\ln mc^{r}_{j,k,t} = -\ln(1+g^{r}_{k}) - \zeta_k d\ln Q_{j,k,t-1} + \delta_t + \epsilon^{r}_{j,k,t} \tag{27}$$

where g^r_k is the growth rate of a regional productivity of industry k in region r and δ_t is a time fixed effect.

In Table 2, we report the estimation results of the scale elasticity for 29 manufacturing industries. The average scale elasticity is about 0.26, which is slightly higher than the result in Bartelme et al. (2021), where they report 0.17. This is reasonable considering that South Korea was at an early stage of industrialization in 1970s and 1980s, and learning-by-doing spillover was possibly larger than the developed economies. Our estimates shows considerable variation across industries, which vary between 0.04 and 0.68.

It is worth noting two points based on our estimates of scale elasticity. The average scale elasticity does not significantly differ between the targeted and the non-targeted. Taking these estimates face value, HCI drive definitely decreased welfare of South Korea in a static model, which does not consider the evolution of global market environments[17]. Second, scale elasticity for light industries such as textiles, apparel and leather industry, where South Korea was deemed to have comparative advantage in in the early 1970s, is higher than the other industries. This indicates that the criticism for HCI drive back in the early 1970s, arguing South Korea should foster light industries based on its current comparative advantage can be supported in terms of the external economies of scale in a static view.

[16]In the baseline estimating equation (62), we assume that error terms follow a difference stationary process. We also estimate under an assumption that error terms follow the AR(1) process for robustness check. The results are very similar with the baseline estimates.

[17]In the model of Bartelme et al. (2021), the optimal wage subsidy is determined by $\frac{\zeta_k}{1+\zeta_k}$. Thus, their framework suggests that no intervention is optimal.

Table 2: Estimates of Industry-Level Scale Elasticity (ζ_k)

Industry Name	ζ_k	t-value	HCI
Food (1)	$0.29^{\dagger}$	1.84	
Food (2)	0.17	1.15	
Beverages	$0.24^{\dagger}$	1.70	
Tobacco	$0.39^{\dagger}$	1.92	
Textile	0.34^{*}	2.16	
Apparel	0.36^{*}	2.26	
Leather and Fur	0.68^{**}	5.57	
Footwear	$0.26^{\dagger}$	1.75	
Wood and Cork	$0.20^{\dagger}$	1.74	
Furniture	$0.29^{\dagger}$	1.77	
Pulp and Paper	0.35^{*}	2.11	
Print	0.19	1.34	
Chemical	0.24^{**}	3.06	Y
Chemical n.e.c	0.14	0.83	
Refined Petroleum	0.10	0.47	Y
Coke and Briquettes	0.04	0.32	
Rubber	0.18	1.09	
Plastic	0.43^{**}	4.59	
Ceramics	0.28	1.45	
Glass	0.06	0.32	
Non-metallic Mineral Products	0.26	1.66	
Iron and Steel	0.18	1.18	Y
Non-ferrous Metals	0.38^{*}	2.04	Y
Fabricated Metal	0.23	1.42	Y
Machinery and Equipment n.e.c.	$0.41^{\dagger}$	1.93	Y
Electronic	0.39^{**}	3.17	Y
Transport Equipment	0.18	1.29	Y
Medical and Optical	$0.25^{\dagger}$	1.82	
Other Manufacturing	0.14	1.20	
Average of HCI	0.26		
Average of non-HCI	0.26		

Notes: **: 1% significance level, *: 5% significance level, †: 10% significance level

Remaining parameters and data inputs We set discount factor (β) at 1 for two reasons. First, policy makers put great importance on future period when conducting industrial policy. Second, since productivity increase from learning-by-doing can last for a long time, it is reasonable to add more weight to long-run gain as in Choi and Levchenko (2021). We set the elasticity of substitution between industries (σ) at 1.28 based on the estimate in Bartelme et al. (2021).

To calibrate the elasticities of substitution between varieties within an industry, γ_k, we use the median value of the trade elasticity ($\gamma_k - 1$) from the existing literature. Accordingly, we set $\gamma_{HCI} = 7.9$ and $\gamma_{non-HCI} = 6.0$[18].

We use South Korea's Input-Output table in 1975 and 1985 from the Bank of Korea to compute the industrial and trade structure of South Korea. We complement our data with the World Input-Output Database (WIOD) to calculate the share of South Korea's HCI and non-HCI in the global market share. Table 3 summarizes the inputs.

Table 3: Parameters and data inputs

	HCI		Non-HCI		Source
β	1				
σ	1.28				Bartelme et al. (2021)
ζ_k	0.26		0.26		Our estimation
γ_k	7.9		6.0		See Appendix 4
	$t = 1975$	$t = 1985$	$t = 1975$	$t = 1985$	
$x^l_{h,k}$	0.34	0.45	0.66	0.55	South Korea IO table
$x_{h,k}$	0.41	0.48	0.59	0.52	South Korea IO table
$x_{hh,k}$	0.60	0.70	0.89	0.89	South Korea IO table
$x_{fh,k}$	0.40	0.30	0.11	0.11	South Korea IO table
$x_{hf,k}$	0.0005	0.0023	0.0012	0.0030	WIOD

Notes: $x^l_{h,k}$ is the share of labor used in k good production in home country. $x_{h,k}$ is the consumption share of industry k good in home country. $x_{ij,k}$ is the consumption share of industry k good in country j imported from country i.

Lastly, we compute industry subsidy rate ($s_{h,HCI}$) which the Korean government would have provided to the targeted industries during HCI drive if the government supported those industries in the form of wage subsidy. We first calculate how much HCI were benefited relative to non-HCI by HCI drive using the effective marginal corporate tax rate for HCI and non-HCI during 1970-1983 provided in Yoo (1991)[19]. Then, we calculate s_0

[18] We list the source and values of γ_k estimates from recent studies in the Appendix D

[19] See Appendix E for a detailed information on the effective marginal corporate tax rate during 1970-1983 in Yoo (1991).

by dividing HCI's production costs by the benefited amount. Through this method, we set $s_{h,HCI} = 0.1$ and $s_{h,non-HCI} = 0$[20].

4.2 Result

Figure 3 shows how South Korea's welfare would have changed if the wage subsidy rate for HCI ($s_{h,HCI}$) were different than the actual (imputed) rate. We highlight two points from the result.

First, the result shows that the HCI drive increased welfare even though the scale elasticity for the HCI did not dominate the non-HCI. Numerically, the welfare increases by 0.9% from the policy. It can be interpreted that the consumption of the representative consumer in South Korea increases by 0.9% in every period on average[21] for 20 years which is the time period considered in this analysis.[22] The result is more striking when we consider the fact that welfare evaluation from other static frameworks suggests that HCI drive definitely decreases South Korea's welfare in the aspect solely based on the external economies of scale.

Second, our quantitative analysis suggests 0.12 as the optimal policy rate on HCI, implying that even stronger industrial policy was desirable. Considering that our estimation on scale elasticity is conservative in terms of the power and role of the policy on firm and regional-level productivity growth, our quantitative analysis reinforces the message from the two illustrative examples: at the time of evolving global market conditions, the government may need to take on a more active role to construct an industrial structure with dynamic and long-term view.

[20] Since we calculate the benefited amount of HCI in relative to non-HCI than absolute terms, we can set $s_{h,non-HCI} = 0$.

[21] Our quantitative analysis clearly shows the trade-off between short-run cost and long-run benefit from industrial policy. It presents that the consumption of the representative consumer in South Korea decreases by 0.4% in period 1 but increases by 1.2% in period 2.

[22] If it is assumed that the the productivity increase caused by external economies of scale lasts persistently, welfare increase becomes much larger.

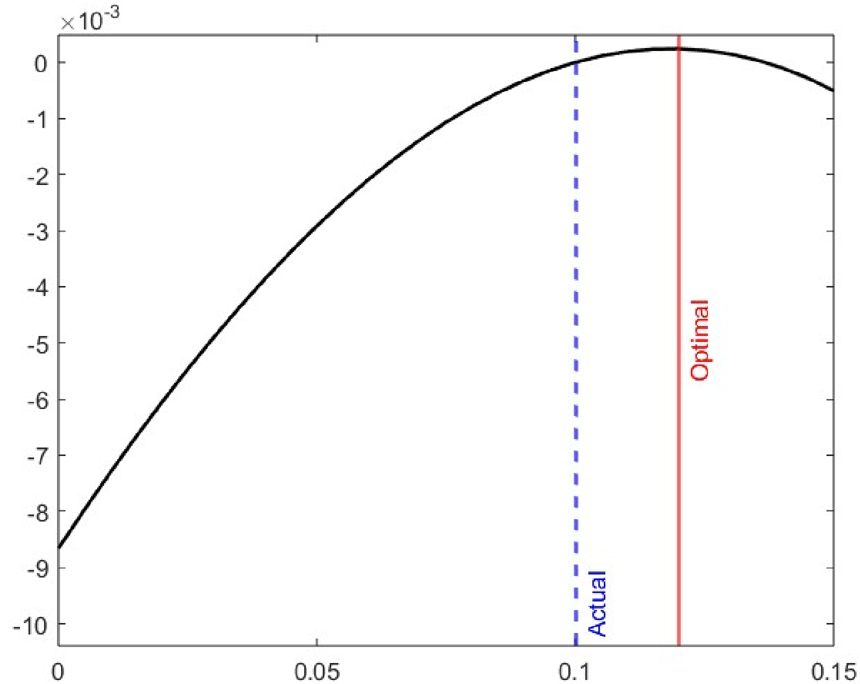


Figure 3: Welfare change by $s_{h,HCI}$

Notes: The horizontal axis is the subsidy rate s for the targeted industry, and the vertical axis is the percentage change in welfare compared to the actual (imputed) rate ($s_{h,HCI} = 0.1$). The dashed line indicates the actual subsidy rate of the South Korean government in the 1970s, and the solid line is the optimal industrial policy derived from the model (≈ 0.12).

4.3 Sensitivity Analysis

As described in the illustrative example, policymakers may have uncertainty regarding the point estimates of scale elasticity for making any policy suggestions. Similarly to the previous section, we might ask how sensitive is the policy suggestion to the key parameters, namely ζ. We iterated the counterfactual analysis by different set of scale elasticities, and found the region of parameters where the industrial policy on the HCI can be justified.

Figure 4 plots the range of scale elasticity for targeted and non-targeted industries, and the color of the marker indicates which policy is suggested to support. The size of the marker is proportional to the optimal subsidy rate. The solid line is the 45 degree

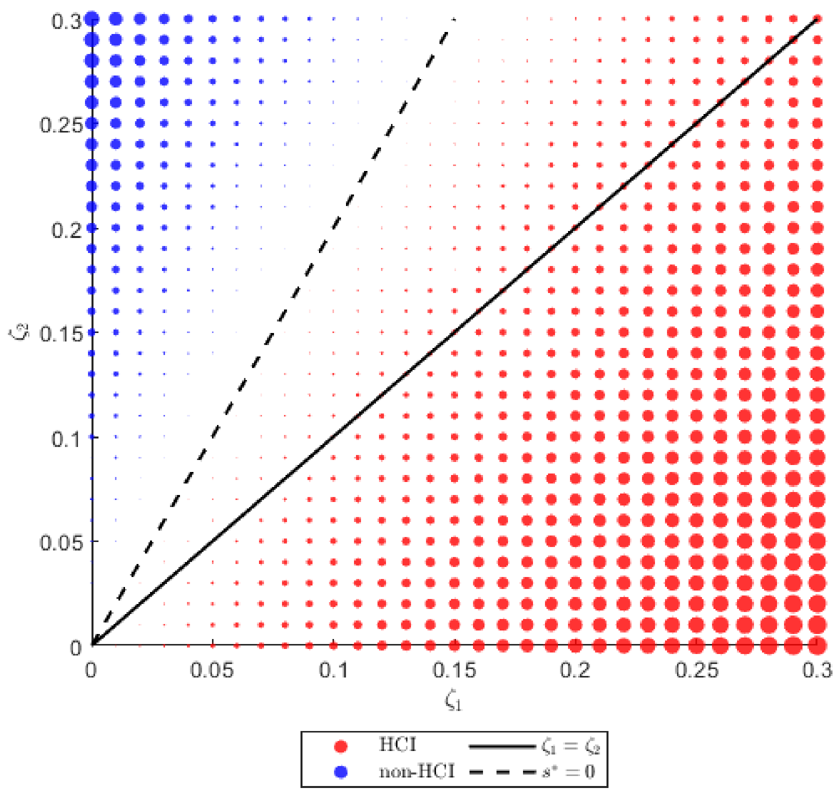


Figure 4: Sensitivity analysis

Notes: The color of each marker indicates which industry should be subsidized, given the scale elasticity pair (ζ_1, ζ_2). The size of the marker implies the magnitude of the subsidy at the optimum. The dashed line is the case where no-subsidy is optimal. The solid line is the no-subsidy case in the standard argument for Pigouvian subsidy.

line where scale elasticity is the same across two sectors, and the dashed line implies the (approximate) set of scale elasticity where no policy is suggested.

The region where solid line crosses implies that the government should still support the targeted industry, even though they have the same scale elasticity. According to the standard argument for industrial policy, however, industrial policy always worsens efficiency when there is no difference in ζ. Therefore, the global market conditions are crucial in determining whether the government should actively do industrial policy or not.

Furthermore, no policy is recommended only when the scale elasticity of the non-targeted industry was twice as high as the targeted industry (indicated by the dashed line). This means that the environment similar to the South Korea in the 1970s and 1980s could justify supportive policy towards the targeted industry even when policymaker faces wide confidence interval on scale elasticity. The region between the dashed line and the solid line therefore captures the set of ζ_1 and ζ_2 values that policymaker makes wrong industry selection when one determines optimal policy solely based on scale elasticity.

5 Conclusion

Many countries including advanced economies are recently revisiting industrial policy in response to dynamic development of technology and shifts in global environment. In this context, we extend the small open economy model of Bartelme et al. (2021) into a two-period dynamic model to derive optimal industrial policy under rapidly changing global market conditions.

The optimal policy presented in our model is novel in that the policy rate reflects not only scale elasticity but also a multiplier that indicates how much resource will be allocated to an industry in the future relative to the current period. Thus, when global market conditions change rapidly, the multiplier naturally plays an important role in optimal industrial policy. Our framework suggests an active role of the government to support industries that will gain much importance.

Our quantitative analysis on the industrial policy in South Korea suggests that the economy has gained from the industrial policy and could have benefited more from even more activist policy. This is in stark contrast to the standard argument for industrial policy, where it is necessary for the targeted industry to have higher scale elasticity than the non-targeted.

Our framework can be extended to incorporate a number of realistic aspects. Firstly, one can explicitly model firms' response to the industrial policy. If firms do make intertemporal decisions based on their anticipation of future environments (shifts in global demand and industrial policy), it might be interesting to see what form the policy should take, and what is then the optimal policy. Secondly, it might be interesting to reflect the global input-output linkages and economic geography into the model. As our illustrative example demonstrated, as long as we identify the global demand shifts in the future, industrial policy suggestion might crucially depend on the country's current and future position in the global value chain. Lastly, as we modeled unilateral optimal policy, it might be also important to evaluate the interaction of such policies across countries.

Appendix A General Equilibrium with Input-Output Linkages

In a general equilibrium in the extended model with Input-Output linkages, the equilibrium conditions change as follows.

Profit maximization

For any firm, any industry k, any origin country i, and any destination country j, profit maximization requires

$$(l_{ij,k}, k_{ij,k}, m_{i,kl}, z^{s}_{ij,k}) \in argmax_{\{l,k,m_l,y\}} \quad \{w_{i,k}z - w_i l - r_i k - \sum_{l} p_{i,l} m_l \,|\, z = f_k\,(l,k,m)\}, \tag{28}$$

$$(z^{d}_{ij,k}, y_{ij,k}) \in argmax_{\{z,y\}} \quad \{q_{ij,k}(y)y - v_{i,k}z \,|\, y = A_{ij,k}E_k(Q_{i,k,-1})z\}, \tag{29}$$

$$(m_{oi,k}, y_{i,k}) \in argmax_{\{m_o,y\}} \quad \{p_{i,k}y - \sum_{o} p_{oi,k}m_o \,|\, y = \left(\sum_{o} m_o^{\frac{\gamma_k-1}{\gamma_k}}\right)^{\frac{\gamma_k}{\gamma_k-1}}\} \tag{30}$$

In the above equations, $w_{i,k}$ represents the price received by firms in country i for producing the composite input of industry k, while $v_{i,k}$ represents the price faced by firms in industry k in country i when purchasing it. Additionally, w_i, r_i, and $p_{i,k}$ denote the wage, rental rate of capital, and the price of a sector-level composite bundle, respectively, in country i.

Utility maximization

The consumer's utility maximization remains the same as in the baseline model.

Market clearing

For any industry k, any origin country i, and any destination country j, goods and labor market clearing requires

$$\sum_j \sum_k l_{ij,k} = L_i \tag{31}$$

$$\sum_j \sum_k k_{ij,k} = K_i \tag{32}$$

$$z^d_{ij,k} = z^s_{ij,k} \tag{33}$$

$$y_{ij,k} = m_{ij,k} \tag{34}$$

$$y_{i,k} = c_{i,k} + \sum_l m_{i,lk} \tag{35}$$

Government budget balance

Total tax expenditure in any origin country i is equal to the amount spent on wage and production subsidies:

$$T_i = \sum_j \sum_k s_{i,k} w_{i,k} z_{ij,k} + \sum_k t_{ii,k} p_{ii,k} c_{ii,k} \tag{36}$$

Prices and taxes

For any industry k, any origin country i, and any destination country j, prices faced by consumer in the destination country j and firm in the origin country i ($p_{ji,k}$ and $q_{ji,k}$) and wages faced by consumer and firm in the origin country i (w_i and $v_{i,k}$) are:

$$q_{ii,k} = (1 + t_{ii,k}) p_{ii,k} \tag{37}$$

$$q_{ij,k} = p_{ij,k} \text{ for } i \neq j \tag{38}$$

$$v_{i,k} = (1 - s_{i,k}) w_{i,k} \tag{39}$$

Definition

Given production subsidies in all origin countries, $\{s_{i,k}, t_{ii,k}\}_{i,k}$, a general equilibrium in the model is characterized by the set of prices for goods, $\{p_{ij,k}, q_{ij,k}, p_{i,k}\}_{i,j,k}$, input prices, $\{w_i, r_i, w_{i,k}, v_{i,k}\}_{i,j,k}$, as well as an allocation, $\{l_{ij,k}, k_{ij,k}, m_{i,kl}, z_{ij,k}, y_{ij,k}, m_{ij,k}, y_{i,k}, c_{i,k}\}_{i,j,k}$, and lump-sum tax, $\{T_i\}_i$, such that equations (10) and (43)-(54) are satisfied in each period $(t=1, t=2)$.

Appendix B Exact-hat Algebra

Our counterfactual analysis is based on the following equations for two time periods. Our counterfactual environment is the when the subsidy rate for the targeted industry is zero instead of the imputed rate.

Period 1

$$\widehat{w}_h \widehat{L}_{h,k} = \frac{1-s_{h,k}}{1-s'_{h,k}} \widehat{x}_{hh,k} \widehat{x}_{h,k} \frac{\widehat{w}_h w_h L_h + \widehat{T}_h T_h + D_h}{I_h} x^l_{hh,k} + \frac{1-s_{h,k}}{1-s'_{h,k}} \widehat{x}_{hf,k} \widehat{x}_{f,k} x^l_{hf,k} \tag{40}$$

$$\widehat{x}_{ij,k} = \frac{\widehat{p}_{ij,k}^{1-\gamma_k}}{\sum_{i'} \widehat{p}_{i'j,k}^{1-\gamma_k} x_{i'j,k}} \tag{41}$$

$$\widehat{x}_{h,k} = \frac{\widehat{p}_{h,k}^{1-\sigma}}{\sum_{k'} \widehat{p}_{h,k'}^{1-\sigma} x_{h,k'}} \tag{42}$$

$$\widehat{p}_{hf,k} = \widehat{p}_{hh,k} = \frac{(1-s'_{h,k})\widehat{w}_h}{(1-s_{h,k})} \tag{43}$$

$$\widehat{p}_{h,k} = (\widehat{p}_{hh,k}^{1-\sigma} x_{hh,k} + \widehat{p}_{fh,k}^{1-\sigma} x_{fh,k})^{1/(1-\sigma)} \tag{44}$$

$$\widehat{T}_h = -\sum_k \frac{s'_{h,k}}{s_{h,k}} \frac{1-s_{h,k}}{1-s'_{h,k}} \widehat{x}_{hf,k} x^l_{hf,k} \frac{s_{h,k} w_h L_{h,k}}{\sum_{k'} s_{h,k'} w_h L_{h,k'}} - \sum_k \frac{s'_{h,k}}{s_{h,k}} \frac{1-s_{h,k}}{1-s'_{h,k}} \widehat{x}_{hh,k} \widehat{x}_{h,k} \frac{\widehat{w}_h w_h L_h + \widehat{T}_h T_h + D_h}{I_h} x^l_{hh,k} \frac{s_{h,k} w_h L_{h,k}}{\sum_{k'} s_{h,k'} w_h L_{h,k'}} \tag{45}$$

$$\widehat{\pi}_h \pi_h = \sum_k \widehat{x}_{hf,k} \pi_{hf,k} \tag{46}$$

$$\sum_{k'} \widehat{L}_{h,k'} x^l_{h,k'} = 1 \tag{47}$$

$\hat{x}$ is the relative change in variable x; i.e., x'/x. Subscript h is for home country, we suppress foreign countries into f. $\pi_{hf,k}$ is the profit of home firms in sector k get from selling to country i. $x_{ji,k}$ is the expenditure share of country i in k industry from j. $x^l_{ji,k}$ is the labor share of k industry in country j used to sell in country i[23].

For period 2:

Period 2

$$\widehat{w}_h \widehat{L}_{h,k} = \widehat{x}_{hh,k} \widehat{x}_{h,k} \frac{\widehat{w}_h w_h L_h + \widehat{T}_h T_h + D_h}{I_h} x^l_{hh,k} + \widehat{x}_{hf,k} x^l_{hf,k} \tag{48}$$

$$\widehat{x}_{ij,k} = \frac{\widehat{p}_{ij,k}^{1-\gamma_k}}{\sum_{i'} \widehat{p}_{i'j,k}^{1-\gamma_k} x_{i'j,k}} \tag{49}$$

$$\widehat{x}_{h,k} = \frac{\widehat{p}_{h,k}^{1-\sigma}}{\sum_{k'} \widehat{p}_{h,k'}^{1-\sigma} x_{h,k'}} \tag{50}$$

$$\widehat{p}_{hh,k} = \widehat{p}_{hf,k} = \frac{\widehat{w}_h}{\widehat{L^0}_{h,k}^{\zeta_k}} \tag{51}$$

$$\widehat{p}_{h,k} = (\widehat{p}_{hh,k}^{1-\sigma} x_{hh,k} + \widehat{p}_{fh,k}^{1-\sigma} x_{fh,k})^{1/(1-\sigma)} \tag{52}$$

$$\widehat{\pi}_h \pi_h = \sum_k \widehat{x}_{hf,k} \pi_{hf,k} \tag{53}$$

$$\sum_{k'} \widehat{L}_{h,k'} x^l_{h,k'} = 1 \tag{54}$$

We dropped the $\tilde{a}$ to avoid notational clutter. Hence, from solving these equations with hats, we can evaluate welfare at the counterfactual by the following equation:

$$\widehat{\mathbb{W}} = \ln(\widehat{I_h}/\widehat{P_h}) + \beta \ln(\widehat{\tilde{I}_h}/\widehat{\tilde{P}_h})$$

[23]If we accept perfect competition assumption, labor shares are simply sales shares.

Appendix C Estimation of Scale Elasticity

As in Irwin and Klenow (1994) and Caballero and Lyons (1990), we estimate the scale elasticity of 29 manufacturing industries in South Korea using information on the production function.

Establishing regional production function Since value-added data for manufacturing industries is available at the regional level from Statistics Korea's annual Mining and Manufacturing Survey, we first construct a regional production function. From a regional aggregate consumption index for products produced in industry k in region r of country i and consumed in country j at time t, $C^r_{ij,k,t} = \sum h \left[c_{ij,k,t}(h)^{\frac{\gamma_k - 1}{\gamma_k}} \right]^{\frac{\gamma_k}{\gamma_k - 1}}$, we derive the corresponding regional production function as follows:

$$Y^r_{ij,k,t} = A^r_{ij,k,t} E(Q_{i,k,t-1}) L^r_{ij,k,t} \tag{55}$$

where $A^r_{ij,k,t} \equiv \left[\sum_h A_{ij,k,t}(h)^{\gamma_k - 1} \right]^{\frac{1}{\gamma_k - 1}}$. Hereafter, we drop the time subscript t for simplicity of notation for a while.

Constructing regional marginal cost data From the solution of the representative consumer's utility maximization problem, we rewrite the value added of industry k in region r of production country i ($VA^r_{i,k}$) as follows.

$$VA^r_{i,k} \equiv \sum_j P^r_{ij,k} Y^r_{ij,k} = \sum_j \left(\frac{\gamma_k}{\gamma_k - 1} \right)^{1-\gamma_k} (1 + \tau_{ij,k})^{1-\gamma_k} {mc^r_{i,k}}^{1-\gamma_k} P^{\gamma_k}_{j,k} C_{j,k} \tag{56}$$

where $mc^r_{i,k} \equiv \frac{w_i}{A^r_{i,k} E(L_{i,k})}$ which captures the common cost factor regardless of destination.

By using equation (56), the share of value added of industry k in region r of production country i for the country j market out of total value added of industry k in production country country i for the country j market can be expressed as:

$$s_{ij,k}^{r} \equiv \frac{VA_{ij,k}^{r}}{\sum_r VA_{ij,k}^{r}} = \frac{{mc_{i,k}^{r}}^{1-\gamma_k}}{\sum_r {mc_{i,k}^{r}}^{1-\gamma_k}} \tag{57}$$

Then, the aggregate price index of industry k in production country i for the domestic market, which is the Producer Price Index (PPI) for industry k in country i, is expressed in terms of the regional marginal cost and the value added share.

$$P_{ii,k} = \left[\sum_r {P_{ii,k}^{r}}^{1-\gamma_k}\right]^{\frac{1}{1-\gamma_k}} = \frac{\gamma_k}{\gamma_k - 1}\left[\sum_r {mc_{i,k}^{r}}^{1-\gamma_k}\right]^{\frac{1}{1-\gamma_k}} = \frac{\gamma_k}{\gamma_k - 1}\left[\frac{{mc_{i,k}^{r}}^{1-\gamma_k}}{s_{ii,k}^{r}}\right]^{\frac{1}{1-\gamma_k}} \tag{58}$$

From equation (58), regional marginal cost can be derived by

$$mc_{i,k}^{r} = \frac{\gamma_k}{\gamma_k - 1} P_{ii,k} {s_{ii,k}^{r}}^{\frac{1}{1-\gamma_k}} \tag{59}$$

Based on equation (60), we construct regional marginal cost data using PPI and value added share data of manufacturing industries in South Korea.

Estimating equation From now on, we will use the time subscript t again but omit the production country subscript i for simplicity of notation. From the definition of regional marginal cost, $mc_{k,t}^{r} \equiv \frac{w_t}{A_{k,t}^{r} E(L_{k,t})}$, the following equation can be derived.

$$\ln mc_{k,t}^{r} = \ln w_t - \ln A_{k,t}^{r} - \zeta_k \ln Q_{k,t-1} \tag{60}$$

We add assumptions on $A_{k,t}^{r}$ as in Lakshmi (1995) as follows.

$$A_{k,t}^{r} = (1 + g_k^{r})^{t}\, u_{k,t}^{r} \tag{61}$$

where $u_{k,t}^{r}$ represents an industry and region-specific productivity shock, which can include shocks from industrial policy. Then, equation (60) can be rewritten as follows.

$$\ln mc^r_{k,t} = -\ln(1+g^r_k)t - \zeta_k \ln Q_{k,t-1} + \delta_t + u^r_{k,t} \tag{62}$$

where δ_t is a time fixed effect which includes the effect from input cost, w_t.

Since the Korean government targeted specific industries and regions during the HCI drive, we assume that an industry and region-specific shock persists from 1967 to 1989, and $u_{j,k,t}$ follows a difference stationary process.

$$u^r_{j,k,t} = u^r_{j,k,t-1} + \epsilon^r_{j,k,t} \tag{63}$$

Finally, our baseline estimation equation is derived as follow

$$d\ln mc^r_{j,k,t} = -\ln(1+g^r_k) - \zeta_k d\ln Q_{j,k,t-1} + \delta_t + \epsilon^r_{j,k,t} \tag{64}$$

Appendix D Estimates from the Existing Literature

Table 4: Estimates of the Elasticity of Substitution between Varieties in an Industry (γ_k)

Industry Name	HCI	CP	Shapiro	GYY	Median
Food, Beverages and Tobacco	N	3.6	6.3	4.6	4.6
Textiles	N	9.1	19.6	5.4	9.1
Wood Products	N	12.5	6.9	5.2	6.9
Paper Products	N	17.5	6.8	4.0	6.8
Coke/Petroleum Products	Y	65.9	10.0	4.8	10.0
Chemicals	Y	4.1	2.6	4.8	4.1
Rubber and Plastics	N	2.7	2.6	5.1	2.7
Mineral Products	N	3.4	13.9	6.1	6.1
Basic Metals	Y	4.3	13.9	9.9	9.9
Fabricated Metals	Y	8.0	13.9	6.1	8.0
Machinery and Equipment	Y	2.5	11.8	4.3	4.3
Computers and Electronics	Y	14.0	11.8	4.3	11.8
Electrical Machinery, NEC	Y	13.9	11.8	4.3	11.8
Motor Vehicles	Y	2.8	7.9	5.5	5.5
Other Transport Equipment	Y	1.4	7.9	5.5	5.5
Average of HCI		13.0	10.2	5.5	7.9
Average of non-HCI		8.1	9.4	5.1	6.0

Source: Caliendo and Parro (2015), Shapiro (2016), Giri et al. (2021)

Appendix E Effective Marginal Corporate Tax during HCI drive

Table 5: Effective Marginal Corporate Tax during HCI drive in Yoo (1991)

Year	HCI	Non-HCI
1970	39.2	39.4
1971	34.9	34.7
1972	27.7	29.8
1973	33.5	38.6
1974	29.9	37.7
1975	15.9	52.1
1976	18.0	51.0
1977	17.5	49.5
1978	16.9	48.4
1979	18.3	48.5
1980	18.3	48.8
1981	20.6	51.1
1982	47.1	48.2
1983	40.4	42.2

Source: Yoo (1991)

Appendix F Proof for Propositions

F.1 Proposition 2

Given $\{s_k^*\}_k$, suppose $\{s_k^{*'}\}_k$ such that

$$s_k^{*'} = \frac{\alpha + s_k^*}{1+\alpha}$$

and

$$w^{*'} = (1+\alpha)w^*$$

for some $\alpha \in \mathbb{R}$.

Then, any price under $\{s_k^{*'}\}$ will be identical to the price under the previous equilibrium:

$$p_{ji,k}^{*'} = \frac{\gamma_k}{\gamma_k - 1} \frac{w^{*'}(1 - s_k^{*'})}{A_{ji,k}} = \frac{\gamma_k}{\gamma_k - 1} \frac{w^*(1 - s_k^*)}{A_{ji,k}},$$

and market clearing also holds:

$$\begin{aligned}
(1+\alpha)w^* = w^{*'}L &= \sum_k p_{jj,k}^* c_{jj,k}^* + \sum_k \sum_{i \neq j} p_{ij,k} c_{ij,k}^* + \sum_k s_k^{*'} w^{*'} L_k^{*'} \\
&= \sum_k p_{jj,k}^* c_{jj,k}^* + \sum_k \sum_{i \neq j} p_{ij,k} c_{ij,k}^* + \sum_k \frac{\alpha + s_k^*}{1+\alpha} \times (1+\alpha)w^* \times L_k^{*'}.
\end{aligned}$$

Hence, alternative industrial policy result in identical resource allocation.

F.2 Proposition 3

In a general framework with input-output linkages, external economy of scale is materialized by the sector-aggregate of composite input, $z_{j,k} = f(l, k, m)$. l is labor, k is capital, and m is the goods from other sectors used as part of the inputs (inclusive of domestic and foreign variety). The cost of such composite input is $w_{j,k}$. Thus, firm in industry k in country j produces goods selling to i using the technology:

$$y_{ji,k} = A_{ji,k} E(z_{j,k}) z_{ji,k}.$$

Income is defined as the value of factor endowments and profits from firms. With product subsidy previously specified, profit accrued from domestic consumption is offset by the tax expenditure.

$$I_j = \sum_k w_{j,k} z_{j,k} - \sum_k p_{j,k} c^m_{j,k} + \sum_{i \neq j} \sum_k \frac{1}{\gamma_k} \left(\frac{\gamma_k}{\gamma_k - 1} \frac{(1 - s_{j,k}) w_{j,k}}{A_{ji,k}} \right)^{1-\gamma_k} p^{\gamma_k}_{i,k} (c_{i,k} + c^m_{i,k}) - \sum_k s_{j,k} w_{j,k} z_{j,k}, \tag{65}$$

To characterize optimal industrial policy in such environment:

$$\begin{aligned}
\frac{dI_j}{ds_{j,k_0}} = & \sum_k w_{j,k} \left(\frac{d\ln w_{j,k}}{ds_{j,k_0}} + \frac{d\ln z_{j,k}}{ds_{j,k_0}} \right) - \sum_k p_{j,k} c^m_{j,k} \left(\frac{d\ln p_{j,k}}{ds_{j,k_0}} + \frac{d\ln c^m_{j,k}}{ds_{j,k_0}} \right) \\
& + \sum_{i \neq j} w_{j,k_0} w_{ji,k_0} - \sum_{i \neq j} \sum_k (1 - s_{j,k}) w_{j,k} z_{ji,k} \frac{d\ln w_{j,k}}{ds_{j,k_0}} \\
& - \sum_k s_{j,k} w_{j,k} z_{j,k} \left(\frac{d\ln w_{j,k}}{ds_{j,k_0}} + \frac{d\ln z_{j,k}}{ds_{j,k_0}} \right) - w_{j,k_0} z_{j,k_0}
\end{aligned} \tag{66}$$

By further derivation:

$$\frac{dI_j}{ds_{j,k_0}} = \sum_k (1 - s_{j,k}) w_{j,k} z_{jj,k} \frac{d\ln w_{j,k}}{ds_{j,k_0}} - w_{j,k_0} z_{jj,k_0} + \sum_k w_{j,k} z_{j,k} \frac{d\ln z_{j,k}}{ds_{j,k_0}} - \sum_k p_{j,k} c^m_{j,k} \left(\frac{d\ln p_{j,k}}{ds_{j,k_0}} + \frac{d\ln c^m_{j,k}}{ds_{j,k_0}} \right) \tag{67}$$

$$- \sum_k s_{j,k} w_{j,k} z_{j,k} \frac{d\ln z_{j,k}}{ds_{j,k_0}}$$

Note that

$$\frac{d\ln z_{j,k}}{ds_{j,k_0}} = \underbrace{\frac{w_j L_{j,k}}{w_{j,k} z_{j,k}}}_{\frac{f_L L_{j,k}}{w_{j,k} z_{j,k}}} \frac{d\ln L_{j,k}}{ds_{j,k_0}} + \frac{r_j K_{j,k}}{w_{j,k} z_{j,k}} \frac{d\ln K_{j,k}}{ds_{j,k_0}} + \sum_l \frac{p_{j,l} c^m_{j,lk}}{w_{j,k} z_{j,k}} \frac{d\ln c^m_{j,lk}}{ds_{j,k_0}}$$

and $\sum_l c^m_{j,lk} = c^m_{j,k}$. Since

$$\sum_k \sum_l p_{j,l} c^m_{j,lk} \frac{d\ln c^m_{j,lk}}{ds_{j,k_0}} = \sum_k \sum_l p_{j,k} c^m_{j,kl} \frac{d\ln c^m_{j,kl}}{ds_{j,k_0}},$$

we have[24]

$$\frac{dI_j}{ds_{j,k_0}} = \sum_k (1 - s_{j,k}) w_{j,k} z_{jj,k} \frac{d\ln w_{j,k}}{ds_{j,k_0}} - w_{j,k_0} z_{jj,k_0} - \sum_k p_{j,k} c^m_{j,k} \frac{d\ln p_{j,k}}{ds_{j,k_0}} - \sum_k s_{j,k} w_{j,k} z_{j,k} \frac{d\ln z_{j,k}}{ds_{j,k_0}}. \tag{68}$$

Since $\ln c_j = \ln I_j - \ln P_j$,

$$-\ln P_j = \frac{p_{jj,k_0} c_{jj,k_0}}{I_j} \frac{1}{1 - s_{j,k_0}} - \sum_k \frac{p_{jj,k} c_{jj,k}}{I_j} \frac{d\ln w_{j,k}}{ds_{j,k_0}}, \tag{69}$$

and by $p_{jj,k} c_{jj,k} + p_{jj,k} c^m_{jj,k} = (1 - s_{j,k}) w_{j,k} z_{jj,k}$, we have:

$$\frac{d\ln I_j}{ds_{j,k_0}} - \frac{d\ln P_j}{ds_{j,k_0}} = \frac{1}{I_j} \left(- \sum_k s_{j,k} w_{j,k} z_{j,k} \frac{d\ln z_{j,k}}{ds_{j,k_0}} \right). \tag{70}$$

For period 2, we can derive similarly as:

$$\frac{d\ln \tilde{I}_j}{ds_{j,k_0}} - \frac{d\ln \tilde{P}_j}{ds_{j,k_0}} = \frac{1}{\tilde{I}_j} \left(\sum_k \zeta_k \tilde{w}_{j,k} \tilde{z}_{j,k} \frac{d\ln z_{j,k}}{ds_{j,k_0}} \right) \tag{71}$$

Hence, we derived the optimal industry policy under inputs through the following

[24] Since aggregated industry k good is both used as final good and input, proportionality assumption is implied.

condition for all k_0:

$$\frac{d\ln \mathbb{W}}{ds_{j,k_0}} = \sum_k \left(\beta\zeta_k \frac{\tilde{w}_{j,k}\tilde{z}_{j,k}}{\tilde{I}_j} - s_{j,k}\frac{w_{j,k}z_{j,k}}{I_j} \right) \frac{d\ln z_{j,k}}{ds_{j,k_0}}. \tag{72}$$

It follows that

$$s^*_{j,k} = \beta\zeta \frac{\tilde{w}_{j,k}\tilde{z}_{j,k}/\tilde{I}_j}{w_{j,k}z_{j,k}/I_j}.$$

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