Firms and Technology Adoption: The Role of Political Institutions and Market Size

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The study presents a political economy model and analyses how firms behave towards technology up-gradation given the different dynamics of political and market institutions. The model presented here depicts that political power is controlled by the elite, who formulate trade policy to consolidate power. While the middle-class access the production technology and the labour class provides labour inelastically. The model shows that the technology adoption decision of a firm essentially depends upon the political institutions and the market size of the country. Firms in a country with strong democratic institutions adopt new technology more rapidly. While in a weak democracy, firms successfully persuade the elite policymaker to impose higher trade restrictions and obtain higher protection from technologically advanced foreign firms. Moreover, the model also shows that firms operating in a large market adopt technology more rapidly since a large market has a high price elasticity of demand and supports a large number of larger firms. Furthermore, firms adopt technologies more swiftly when the productivity gains from the adoption are relatively large.

JEL Classification: F12, P16, O38, O33, D72 Keywords: Political Economy, Technological Diffusion, Trade Policy, Rent-seeking, Lobbying

1. INTRODUCTION

Many economists have underlined the importance of political institutions and policies for the adoption of new technologies.¹ At the same time, the decision to adopt new technology is the decision of an individual firm. Therefore, technology adoption in an economy critically depends upon the behaviour of firms towards the adoption.² However, there is still a lack of a theoretical framework to analyse, how political institutions impact the behavior of an individual firm toward technology adoption. If new technology makes firms more productive and enhances welfare, then why do firms in some societies resist adopting it? Furthermore, what role the market size can play in the technology adoption decision of a firm? These are the key points that this study seeks to address.

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¹See, among others, Acemoglu and Robinson (2019), Cervellati, et al. (2018), Acemoglu (2007), Acemoglu and Robinson (2006), Stoneman and Diederen (1994), Stoneman and David (1986), Miyagiwa and Ohno (1995), Parente and Prescott (1994) or Cheng (1987).

²For discussion see, Cirera, et al. (2022), Cirera, et al. (2021a), Cirera, et al. (2021b), Cirera, et al. (2020), Ludema and Takeno (2007), Liu, et al. (2001), Comin and Hobijn (2009), Weymouth (2012), or Atkeson and Burstein (2008).

Acemoglu (2007) shows that inefficient institutions generate inefficient policies, and the existence of inefficient institutions is due to the induced preferences of power groups. The development patterns we observed significantly depend upon whether the institutions within a society are extractive or inclusive (Acemoglu & Robinson, 2019). In a society where the elite controls political power, the policy formation always intends either to extract revenue, manipulate factor prices, or consolidate political power. One illustration of power consolidation is the oligarchic society, where power upholding is ensured by having entry barriers and full property rights enforcement. However, these entry barriers cause economic losses in the long run (Acemoglu, 2008). The adoption of new technology could potentially create political losers and contains a political threat to the elite. Thus, the incumbent political power-holding elite erects barriers against technology adoption (Acemoglu & Robinson, 2000). Parente and Prescott (1994) provide empirical evidence that the technology adoption barriers are the primary elements in explaining economic performances on the front of income disparity among countries. Technology adoption in economies with large adoption barriers is slow since firms must make enormous investments for the adoption. Since technology adoption in society rests upon the decision of firms, therefore, in a less competitive environment with huge entry barriers firms do not have any incentive to upgrade the technology (Cerira, et al. 2022). Resultantly, less developed countries are unable to achieve higher productivity, which is the engine of growth. On the other hand, low barriers always encourage technology adoption and diffusion (Amoroso & Martino, 2020). Besides, the technology adoption decision also rests upon the market size. For instance, technology adoption is very responsive to trade openness as trade increases the market size that a firm can serve, Atkeson and Burstein (2008). Therefore, the welfare gains from trade openness originate not only from productivity gains but also from rapid technology adoption by firms.

The purpose of this study is to develop a political economy model with heterogeneous firms at the helm of technology adoption decision-making. The twocountry two-factor model assumes that the population is divided into three groups: the elite political power-holding group, the middle-class entrepreneur group, and the labour group. The policy option available to the elite involves only trade policy and the elites devise trade policy to maximise their welfare. The middle class has the access to production technology that involves labour and capital as the factors of production. While the labour class supplies labour inelastically. The model assumes technological differences among countries and one country has superior technology compared to the other. The firms with inferior technology face a critical problem: whether to adopt the superior technology or not. The adoption is costly, and firms must incur a fixed cost of adoption in the form of R&D. On the other hand, the model also assumes that firms can resist the adoption and lobby for higher trade restrictions whereby the foreign importing firms are excluded from the competition in the domestic market.

The contributions of this work to the literature are threefold. First, it develops a political economy model with the production sector comprised of heterogeneous firms as in Melitz (2003).³ The baseline model considered here specifically elaborates on the trade

³Driven by the empirical evidence, Melitz (2003) developed a framework that incorporates firm-level heterogeneity. The model developed by Melitz has a structure closely related to Krugman (1980) except firms are heterogeneous with respect to their productivity level. This model becomes the standard framework in trade literature.

policy formation and how trade policy affects the entry and exit conditions of the firm. Second, the response of technologically backward firms toward trade openness has been explored. As the model assumes a limited set of available varieties, therefore, domestic firm resists trade openness not only on technological inferiority basis but also on an anticompetition basis. Last and most important, the model seeks to characterise the role of the political institution and the market size in the technology adoption decision of a firm.

The theoretical excursion shows that the technology adoption decision of a firm in an economy is contingent upon the market size. Firms in a large market adopt new technology more rapidly than firms in a small market. Moreover, the decision of firms to adopt new technology critically depends upon the political orientation of the country. Since policy-maker selects import tariffs and export taxes as trade policy tools. Therefore, in the case of a weak democracy, where policy-making is not exclusively dependent on political consensus, firms lobby and persuade the elite policymaker to impose a higher import tariff. By having higher protection from foreign technological advance importing firms, domestic firms shield themselves from the competition in a small market. Another important result that emerges from the model is that firms adopt technology when the productivity gain from the adoption is relatively larger and new technology is way much superior to the current technology. This is intuitive in the sense that since technology adoption is costly, firms will not adopt new technology unless the perceived benefits of adoption outweigh the cost of adoption.

1.1. Empirical Motivation

The model presented here is driven by the empiric of the relative performances of the Indian and Pakistani auto sectors. The auto sector in both countries has comparable initial conditions, but the current state of its progress and growth is far asunder.⁴ The auto sector of Pakistan represents 16 percent of total manufacturing and contributes merely 2.8 percent to the GDP and provides 200,000 direct employment opportunities (Bari, et al. 2016). While the auto sector embodies 5.27 percent of value-added in total manufacturing in Pakistan, (Qadir, 2016). According to the International Organisation of Motor Vehicle Manufacturers (OICA) data, Pakistan ranked 30th in the world ranking of motor vehicle producers and has the lowest level of motor vehicle production i.e., 1.7 per 1000 people. Furthermore, the market size in Pakistan is small (according to the United Nations, Pakistan ranks 25th in the market size measured by the households' final consumption expenditure) and consumer choice is limited due to high market concentration.

In contrast, the auto sector of India comprises 49 percent of national manufacturing and contributes 7.1 percent to GDP with a growth rate of 14.5 percent during 2019.⁵ India is the 4th largest motor vehicle producer and 7th largest commercial vehicle producer in the world.⁶ According to the Department for Promotion of Industry and Internal Trade Statistics (DPIIT) India, the auto sector in India has received \$21.38 billion in foreign direct investment between 2000-2019. Furthermore, during 2018-19 the Indian auto sector exports 46,29,054 units of automobiles. The table below contains a brief snapshot of the production of the auto sector in both countries.

⁵Source: IBEF report (2019) "Indian auto industry analysis".

⁴For a historical review see, Pasha & Ismail (2002) for Pakistan and Tiwari, et al. (2017) for India.

⁶See: https://www.oica.net/category/about-us/members/india/

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	Pak	kistan	India		
	Production	Domestic	Production	Domestic	
		Market Share		Market Share	
Cars	94,325	6.22%	3,400,440	13%	
Commercial Vehicles	51,713	3.41%	1,054,400	4%	
Motorcycles /Three Wheelers	1,370,417	90.36%	21,298,880	80%	

The Production of the Automotive Sector (2020)

Source: For Pakistan "Automotive Manufacturers Association for Pakistan". For India "Brand Equity Foundation for India."⁷

The Indian auto sector has relatively outperformed the Pakistani auto sector in every aspect. The study in hand envisions this outperformance of the Indian auto sector partially due to the existence of a strong democracy and the large market size. The political arena in India features continuous democracy since independence. The continuation of democracy ensures the continuation of development policies, which is crucial to realising the development objectives. While the political history of Pakistan is stained with frequent military coups (1958-1971, 1977-1988, 199-2008), almost half of her political history (36 years out of 74 independent years) was ruled by martial law. These frequent regime changes bring discontinuation of policies and cause dis-alignment with development goals that were once envisioned through political consensus. Furthermore, India also has a large market, which ranks 6th as per the United Nations data on household final consumption expenditures. Therefore, having a weak democracy with a small market size retains the auto sector of Pakistan underdeveloped.

Outwardly the current policies related to the auto sector in both countries are protectionist and India provides the highest effective rate of protection to the auto sector via tariffs among all regional countries, (Bari, et al. 2016). The current auto sector policy of the Indian government is outlined in Automotive Mission Plan 2016-26. The mission plan also ensures policy stability as well as policy predictability and sustainability. While in the case of Pakistan, the Auto Development Policy 2016-21 provides the basic policy guidelines for the auto sector.

By comparing the policy plans of both countries, we can attribute the dismal performance of the Pakistani auto sector to the stability and predictability of the policies. Unfortunately, both vital factors for the development of the auto industry include (i) the business environment, and (ii) reliable trade flow, which is fragmented in Pakistan.⁸ The policy plan does not outline any specific policy measure to address these issues. Moreover, policy unpredictability is further aggravated when effective policies vary from the announced policies. One reason for these variations is the Statutory Regulatory Orders (SROs), which are aimed to offer concessions and exemptions during the fiscal year. The drawback of these SROs is that they amend the effective policy rate and do not

⁷For details in the case of Pakistan see https://www.pama.org.pk/annual-sales-production/and in the case of India see: https://www.ibef.org/industry/india-automobiles

⁸For example, in the case of doing business India ranked 63rd and Pakistan ranked 108th out of 190 countries according to the World Bank's ease of doing business report 2020. Similarly, in the case of reliable trade flow, the logistic performance report 2018 of the World Bank ranked India 44th and Pakistan 122nd out of 166 countries.

require a consensus among legislators to be effective. The rampant use of SROs is evident by the fact that there are 103 active SROs related to imports and 29 related to exports in 2022, as per the Federal Board of Revenue of Pakistan.⁹ In short, policies in Pakistan are less reliable because the way policymaking is done is less democratic. This policy unreliability creates commitment problems, which is another source of economic inefficiency and is known as the hold-up problem in the literature (see, Acemoglu, 2007).

The rest of the paper is structured as follows. Section 2 presents the basic model and describes the behavior of firms in the economy. Section 3 characterises the close economy equilibrium and discusses capital accumulation in autarky. Section 4 discusses costly trade openness and trade policy formation. Section 5 describes the decision of the individual firm to adopt new technology or block new technology. Section 6 concludes.

2. THE MODEL

The world economy consists of two countries, home country h, and foreign country f. Following Acemoglu (2007), we also assumed that the population in the home country h is divided into three social classes: elite class denoted by e with total agents θ^e , middle-class with total agents θ^m , and labour class with total agents $\theta^l = 1$. The elite controls the political power and makes policy decisions, while the middle class is the entrepreneur and has access to production technology. However, the labour class provides labour inelastically in the economy, and total labour endowment $\overline{L}_h(t)$ is normalised to 1 at time t. Individuals in society are unable to change their class/group association over time and the set of elite and middle-class is denoted by S^e and S^m . Moreover, the foreign country is assumed to have superior technology compared to the home country. Therefore, foreign firms are more productive than domestic firms. The superscript i is used to denote individuals or groups and subscript $j \in (h, f)$ indicates the countries.

To begin with, we first assume that technology adoption by firms from the home country is not possible. This simplified version of the model will help us to characterise the equilibrium and to determine the number of firms operating in the country. Later we consider the case of technology adoption and explore the determining factors of technology adoption by firms in the home country.

2.1. Household Sector

The utility of an agent *i* in home country *h* at time t = 0 is given by:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t C_h^i(t) \qquad \dots \qquad (1)$$

where $C_h^i(t)$ is the consumption of agent *i* and \mathbb{E}_t is the expectations operator that is conditional on the available information at time *t*. The preferences are Dixit and Stiglitz type and based on the consumption of the finite number of differentiated varieties:

9For details see: https://www.fbr.gov.pk/ActiveSrosImport

The set of available varieties is represented by *V* and *v* represents an individual variety with the elasticity of substitution $\sigma > 1$. Following Yang and Heijdra (1993), we also assume that an individual firm's price-setting behaviour affects the aggregate price index of the economy. This effect emerges because the set of differentiated varieties *V* is assumed not extremely large, contrary to the assumption in Dixit and Stiglitz (1977). Another outcome of assuming a small set of varieties is that the elasticity of substitution between the differentiated varieties (σ) and the price elasticity of demand (ϵ) are not the same.¹⁰ The solution of utility maximisation of agent *i* gives the demand of an individual variety at time *t*, which is:

$$q_h(v,t) = Y_h^i(t) P_h(t)^{\sigma-1} p_h(v,t)^{-\sigma} \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad (3)$$

where $Y_h^i(t)$ denotes the income of an agent *i* at time *t* and $P_h^i(t)$ is the aggregate price index at time *t* that is given as:

2.2. Production Sector

The production function involves capital and labour as the factors of production. Each firm in the economy produces a unique variety of differentiated goods. The capital is provided by the middle class and labour comes inelastically from the labour class. The production technology at the time t that entrepreneurs can access is:

$$q_h^m(\varphi_h, t) = \varphi_h\left(\left(L_h^m(t)\right)^\delta \left(K_h^m(t)\right)^{1-\delta} - f_h\right) \,\forall m \in S^m \text{ at each } t. \qquad \dots \qquad (5)$$

where φ_h indicates the productivity of the firm, which realises after paying the entry cost f_h^{ent} . In the meanwhile, f_h denotes the fixed cost of production and depends upon the market location. The factor intensity of the fixed and entry costs is assumed to be the same. The share of labour and capital in the production function is given by δ and $(1 - \delta)$, respectively. The total capital $\overline{K}_h(t)$ at time t depends on the capital stock in period (t - 1) and investment along with depreciation rate ψ . The aggregate capital stock at time t in the economy is $\overline{K}_h(t) = (1 - \psi)\overline{K}_h(t - 1) + I_h(t - 1)$. The conditional demand for labour by an individual firm with the wage rate $w_h(t)$ and the rate of return $r_h(t)$ can be represented as:

$$L_h^m(t) = \left(\frac{q_h(\varphi_h, t)}{\varphi_h} + f_h\right) \left(\frac{\delta}{1-\delta}\right)^{1-\delta} \left(\frac{w_h(t)}{r_h(t)}\right)^{\delta-1} \qquad \dots \qquad \dots \qquad \dots \qquad (6)$$

Following Acemoglu (2009), I also assume that the individual heterogeneous firm can employ the maximum \overline{L}_h number of workers and $L_h^m(t) \in [0, \overline{L}_h]$. To ensure no unemployment, further assume that all entrepreneurs employ the same number of workers, so that:

$$L_h^m(t) = L_h^* = \min\left\{\bar{L}_h, \frac{1}{\theta^m}\right\}$$

By assuming $\theta^m \overline{L}_h > 1$, full employment is ensured, and $L_h^* = \frac{1}{\theta^m}$.

¹⁰Section 2.3 elaborates this point.

2.3. Firm's Behaviour

From the production function, we can derive the cost function of a firm with a productivity level φ_h at time t as:

$$Z_h(\varphi_h, t) = \left(\frac{q_h(\varphi_h, t)}{\varphi_h} + f_h\right) \mu r_h(t)^{1-\delta} w_h(t)^{\delta}, \text{ with } \mu = \left(\left(\frac{\delta}{1-\delta}\right)^{1-\delta} + \left(\frac{\delta}{1-\delta}\right)^{-\delta}\right) (7)$$

Given the demand for each variety in Equation (3), the optimal pricing rule for the firm is:

$$p_h(\varphi_h, t) = \left(\frac{\epsilon}{\epsilon - 1}\right) \frac{1}{\varphi_h} \zeta_h(t), \text{ with } \zeta_h(t) = \mu r_h(t)^{1 - \delta} w_h(t)^{\delta} \qquad \dots \qquad (8)$$

where $\left(\frac{\epsilon}{\epsilon-1}\right)$ is the markup of the firm and ϵ is the price elasticity of demand. In Dixit and Stiglitz's (1977) characterisation of monopolistic competition, this price elasticity of demand is equal to the elasticity of substitution between differentiated varieties $\epsilon = \sigma$, while here we have a limited number of varieties, and the price elasticity of demand is given as $\epsilon = \sigma - \frac{(\sigma-1)}{\frac{P_h(t)}{p_h(\varphi_h, t)}} = \sigma - \frac{(\sigma-1)}{v}$. This shows that as the number of differentiated

varieties increases the price elasticity of demand also increases because the consumer has more varieties to choose from. The optimal pricing rule also indicates that the price charged by a firm is inversely related to the productivity of the firm. A more productive firm charges a lower price and captures a larger share of the market as the markup is constant for all firms.

The revenue and profit earned by a firm from home country h at time t is given as:

$$R_h(\varphi_h, t) = Y_h^i(t) P_h(t)^{\sigma-1} \left(\left(\frac{\epsilon}{\epsilon - 1} \right) \frac{1}{\varphi_h} \zeta_h(t) \right)^{1 - \sigma} \qquad \dots \qquad \dots \qquad (9)$$

$$\pi_h(\varphi_h, t) = \frac{1}{\epsilon} Y_h^i(t) P_h(t)^{\sigma-1} \left(\left(\frac{\epsilon}{\epsilon-1} \right) \frac{1}{\varphi_h} \zeta_h(t) \right)^{1-\sigma} - \zeta_h(t) f_h \qquad \dots \qquad (10)$$

3. CLOSED ECONOMY EQUILIBRIUM

I start with the characterisation of a closed economy equilibrium to explain some simple features of the model. Then in the next section, I will consider the case of costly trade.

3.1. Entry and Exit

Firms realise their productivity after incurring the sunk entry $\cot \zeta_h(t) f_h^{ent}$. The productivity is drawn from cumulative distribution $G(\varphi_h)$ and cumulative productivity distribution is assumed to be a Pareto distribution $G(\varphi_h) = 1 - \left(\frac{\varphi_h}{\varphi_h}\right)^{\alpha}$ with $\underline{\varphi}_h$ as the lowest possible productivity that a firm can draw in home country h. The firm decides either to produce and serve the market or to exit the market once productivity is realised. In this regard, the minimum productivity level φ_h^* , which is required to produce and remain active in the market, can be determined by a zero-profit condition. The zero-profit condition states as:

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$$Y_h^i(t)P_h(t)^{\sigma-1}\left(\left(\frac{\epsilon}{\epsilon-1}\right)\frac{1}{\varphi_h^*}\zeta_h(t)\right)^{1-\sigma} = \epsilon\zeta_h(t)f_{hh} \qquad \dots \qquad \dots \qquad (11)$$

Hence, firms with realised productivity level $\varphi_h < \varphi_h^*$ quit the market and firms with realised productivity $\varphi_h^* \le \varphi_h$ participate in production and remain active in the market. Meanwhile, the decision of a firm to enter the market and bears the entry cost depends upon the expected revenue that a firm can accrue. The expected revenue of entering the home market with a successful entry is:

$$\bar{R}_h(t) = \int_{\varphi_h^*}^{\infty} R_h(\varphi_h, t) \frac{dG(\varphi)}{1 - G(\varphi_h^*)} = \epsilon \chi \zeta_h(t) f_h, \text{ where } \chi = \frac{\alpha}{\alpha - \sigma - 1} \quad \dots \quad (12)$$

In the same way, the expected profit would be $\bar{\pi}_h(t) = (\chi - 1)\zeta_h(t)f_h$. Next, the free entry condition dictates that the expected ex-ante profit $\bar{\pi}_h(t)$ that include entry cost must be equal to zero in the equilibrium, that is:

$$(\chi - 1)f_h \varphi_h^{*-\alpha} = f_h^{ent} \underline{\varphi}_h^{-\alpha} \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad (13)$$

In the above condition, the factor reward term $\zeta_h(t)$ has been canceled due to the assumption of the same factor intensity requirement for the fixed overhead production cost and the entry cost. From this condition, we can determine the unique value of φ_h^* that depends only on the parameters of the model. The mass of entrants in the economy is $M_h^{\theta^m}$ (which is proportional to the number of workers $L_h^m(t)$) and the mass of active firms in the home country is defined as $M_h = [1 - G(\varphi_h^*)]M_h^{\theta^m}$. Given the optimal pricing rule and productivity distribution, we can transform the aggregate price index as:

$$P_h(t)^{1-\sigma} = M_h \left(\frac{\epsilon}{\epsilon-1}\right)^{1-\sigma} \zeta_h(t)^{1-\sigma} \chi \varphi_h^{*\sigma-1} \qquad \dots \qquad \dots \qquad \dots \qquad (14)$$

The price index is inversely related to the mass of active firms and the productivity cutoff. While it is positively related to the markup of the firms and factor rewards. Now, the next step in the characterisation of a closed economy equilibrium is to determine the equilibrium factor prices. As the total payments to the factors of production must be equal to the difference between the aggregate revenue and aggregate profit, therefore, the factor's market equilibrium condition is given as:

where $\overline{AR}_h(t) = M_h \overline{R}_h(t)$ and $\overline{\Pi}_h(t) = M_h \overline{\pi}_h(t)$ are the aggregate revenue and profit in the economy at time t. Note that the free entry condition ensures that the aggregate expected profit is equal to the aggregate entry cost, so the above condition becomes: $w_h(t) + r_h(t)\overline{K}_h^m(t) = \overline{AR}_h(t)$. From the labour and capital market-clearing conditions, we can determine the equilibrium wage rate and return, which are given as:

$$w_{h}(t) = \delta \overline{AR}_{h}(t) = \delta M_{h} \epsilon \chi \zeta_{h}(t) f_{h}$$

$$r_{h}(t) = \frac{(1-\delta)}{\overline{k}_{h}^{m}(t)} \overline{AR}_{h}(t) = \frac{(1-\delta)}{\overline{k}_{h}^{m}(t)} M_{h} \epsilon \chi \zeta_{h}(t) f_{h} \qquad \dots \qquad \dots \qquad (16)$$

The wage depends positively on the share of labour in the production function, the mass of active firms, and the price elasticity of demand. The positive relationship between the wage rate and the price elasticity of demand is due to the fact that an increase in the varieties leads to an increase in price elasticity. As a result, the firm will

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charge a lower markup and earn higher revenue, which generates a demand for wage increments. Accordingly, the mass of active firms is contingent upon the aggregate revenue and the average firm size:

$$M_h = \frac{\overline{AR}_h(t)}{\overline{R}_h} = \frac{w_h(t) + r_h(t)\overline{K}_h^m(t)}{\epsilon(\overline{\pi}_h(t) + \zeta_h(t)f_h)} \qquad \dots \qquad \dots \qquad \dots \qquad (17)$$

3.2. Entrepreneur's Problem

Due to linear preferences, the value of the discounted sum of consumption of the entrepreneur is given as:

$$U_{h}^{m}(\{K_{h}^{m}(s), L_{h}^{m}(s)\}_{s=t}^{\infty} | w(t)) = \sum_{s=t}^{\infty} \beta^{s-t} \left[q_{h}^{m}(\varphi_{h}, t) - \left(K_{h}^{m}(s+1) - (1-\psi)K_{h}^{m}(s)\right) - w(s)L_{h}^{m}(s) \right]$$

The first-order condition of the above maximisation problem gives the capital stock for the next period:

$$\beta \left\{ \varphi_h (1-\delta) \left(L_h^m (t+1) \right)^{\delta} \left(K_h^m (t+1) \right)^{-\delta} + (1-\psi) \right\} = 1$$

Or, in capital-labour ratio form:

$$k_h^m(t+1) = \left(\frac{1-\beta(1-\psi)}{\beta\varphi_h(1-\delta)}\right)^{\delta} \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad (18)$$

Finally, the equilibrium in the case of a closed economy can be characterised by the zero-profit productivity cutoff, the factor prices, the aggregate price index, and the aggregate revenue $\{\varphi_h^*, P_h(t), \overline{AR}_h(t), w(t), r(t)\}$. These quantities are determined by the free entry condition (Equation 13), the optimal pricing formula (Equation 8), and the factor market clearing condition (Equation 16). Given the distribution of capital stock at time *t* among the middle-class $[K_h^m(t)]$ and the sequence of capital stock for each entrepreneur by equation (18), we can define all the endogenous variables in the model in terms of $\{\varphi_h^*, P_h(t), \overline{AR}_h(t), w(t), r(t)\}$.

Proposition 1: The number of varieties that an economy can support is proportional to the market size (in terms of population) and a larger market with a larger number of varieties has a higher price elasticity of demand.

Following Desmet and Parente (2014), reconsider the labour market clearing condition as:

$$M_h = \frac{w_h \bar{L}_h}{\epsilon \delta \chi \zeta_h(t) f_{hh}}$$

While deriving the wage rate in (16), we assumed $\overline{L}_h = 1$. The above equation shows that the mass of active firms increases as the labour supply increases. Since each firm produces a single variety of differentiated goods, therefore, the number of varieties also increases. Now, reconsider the price elasticity of demand as, $\epsilon = \sigma - \frac{\sigma-1}{M_h}$, which shows that an increase in the number of active firms will increase the elasticity of demand as well. Thus, a larger economy will have a higher price elasticity. By replacing price elasticity formulae in the above equation, we can present the positive relationship between the labour supply and mass of active firms straightforwardly as:

$$M_h = \frac{w_h \bar{L}_h + \delta \chi \zeta_h(t) f_{hh}(\sigma - 1)}{\delta \sigma \chi \zeta_h(t) f_{hh}}$$

Furthermore, the increase in the price elasticity of demand leads to a fall in the markup $\left(\frac{\epsilon}{\epsilon-1}\right)$ of the firm. The optimal pricing rule in Equation (8) indicates a negative relationship between markup and price changed by the firm. Resultantly, the price charged by the firm also reduces and the firm earns more revenue and captures a larger market share. For this reason, a large economy not only holds a larger number of varieties, but the average size of firms is also large.

4. OPEN-ECONOMY EQUILIBRIUM WITH COSTLY TRADE

Now, we consider the case of trade between the home country h and foreign country f and firms from the foreign country are technologically superior to firms from the home country at time t. For the sake of brevity, I assume that the firms from the home country are unable to upgrade technology in this section. This assumption will be relaxed in the next section and we will discuss the implications of technology adoption by firms from the home country there.

Trade among countries involves transport cost and trade taxes. The transport cost is iceberg type and to send one unit of the differentiated good to a foreign market f, the domestic firm ships $\tau_{hf} > 1$ unit of the variety, with $\tau_{hh} = 1$. The trade taxes are defined by the elite policymaker such that the tax $\eta_{fh}(t) = (1 + tr_{fh}(t))$ imposes on all imports from the foreign country and the subsidy $\gamma_{hf}(t) = (1 + sb_{hf}(t))$ provides to all domestic firms that export to foreign country. Whereas $\eta_{fh}(t) > 1$ indicates an import tariff and $\eta_{fh}(t) < 1$ indicates an import subsidy, while $\gamma_{hf}(t) > 1$ indicates an export subsidy and $\gamma_{hf}(t) < 1$ indicates an export tax. Following Costinot, et al. (2016), we also assume that the elite in the home country h are strategic and impose taxes to maximise their own welfare. Whereas foreign country f is passive and does not impose taxes. In this regard, the trade policy precedes the entry of firms into the economy.

4.1. Trade Policy Making

The policy options available to the elite policymakers in the home country involve only the trade policy and no other tools of taxation are available. The revenue generated from trade taxation at time t is used for the lump-sum transfers to labour-class $T^{l}(t) \ge 0$, entrepreneurs $T^{e}(t) \ge 0$, and elite $T^{e}(t) \ge 0$. The lump-sum transfer assumption also indicates that a negative transfer (lump-sum tax) is not possible. The budget constraint¹¹ of the government at time t is:

$$\theta^{e}T^{e}(t) + \theta^{m}T^{m}(t) + T^{l}(t) \ge \left\{ \left(\eta_{fh} - 1 \right) \overline{AR}_{fh} + \left(1 - \gamma_{hf} \right) \overline{AR}_{fh} \right\} \qquad \dots \quad (19)$$

The timing of the trade policymaking is such that the elite policymakers announce the import tax $\eta_{fh}(t+1)$ and export subsidy $\gamma_{hf}(t+1)$ that will apply at the next date

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¹¹Here, we exclude the revenue extraction motives of the policymakers and assume that policymakers have full capacity to raise and redistribute trade tax revenues. For revenue extraction motive of taxation see, Acemoglu (2009).

at time t. Hence, trade policy precedes the decision of entrepreneurs, and they choose the capital stocks for the next period $[k_h^m(t+1)]$ and decide how much labour to hire $[L_h^m(t+1)]$ after observing the announced trade policy for the next period. Since the entrepreneurs are fully informed about the next period's trade policy rates, therefore, the hold-up problem will not be an issue in these settings. Furthermore, let $F^t = \{\eta_{fh}(s), \gamma_{hf}(s), T^l(s), T^m(s), T^e(s)\}_{s=t}^{\infty}$ denotes a feasible sequence of policies.

4.2. Firm's Behaviour

Given the transport cost τ_{hf} and export subsidy $\gamma_{hf}(t)$, the price charged by a firm that belongs to the home country *h* at the domestic market and the foreign market at time *t* is given as:

Similarly, a foreign importing firm charged price $p_{fh}(\tilde{\varphi}_f, t) = \tau_{fh}\eta_{fh}(t)\left(\frac{\epsilon}{\epsilon-1}\right)\frac{1}{\tilde{\varphi}_f}\zeta_f(t)$ in home country *h*. Nonetheless, $\tilde{\varphi}_f > \varphi_h$, as foreign importing firms are more productive than domestic firms. Moreover, the revenue and profit of a firm from home country *h* at time *t* is:

$$R_{h}(\varphi_{h},t) = \begin{cases} R_{hh}(\varphi_{h},t) = Y_{h}^{i}(t)P_{h}(t)^{\sigma-1} \left(\left(\frac{\epsilon}{\epsilon-1} \right) \frac{1}{\varphi_{h}} \zeta_{h}(t) \right)^{1-\sigma} & \text{if does not exports} \\ R_{hh}(\varphi_{h},t) \left(1 + \tau_{hf}^{1-\sigma} \gamma_{hf}(t)^{\sigma} \frac{Y_{f}^{i}(t)}{Y_{h}^{i}(t)} \left(\frac{P_{f}(t)}{P_{h}(t)^{\sigma-1}} \right)^{\sigma-1} \right) & \text{if exports.} \end{cases}$$
(21)

$$\pi_{h}(\varphi_{h},t) = \begin{cases} \frac{1}{\epsilon}R_{hh}(\varphi_{h},t) - f_{hh}\zeta_{h}(t) & \text{if does not exports} \\ \frac{1}{\epsilon}R_{hh}(\varphi_{h},t)\left(1 + \tau_{hf}^{1-\sigma}\gamma_{hf}(t)^{\sigma}\frac{Y_{f}^{i}(t)}{Y_{h}^{i}(t)}\left(\frac{P_{f}(t)}{P_{h}(t)^{\sigma-1}}\right)^{\sigma-1}\right) - (f_{hh} + f_{hf})\zeta_{h}(t) & \text{if exports.} \end{cases}$$
(22)

where $f_{hh} < f_{hf}$ indicates that the fixed overhead cost of production is higher in the case of serving the foreign market than serving the domestic market. A firm export to the foreign country *h* at time *t* only if $\frac{R_{hf}(\varphi_{h},t)}{\epsilon} > \zeta_{h}(t)f_{hf}$, which shows that the revenue accrued in the foreign market must cover the additional fixed cost of production.

4.3. Entry and Exit

Due to costs associated with serving other countries' markets, not all firms active in the domestic market of a country would be able to participate in the export business. Therefore, in the case of costly trade, there are two minimum productivity cutoffs: (i) the productivity cutoff to serve the domestic market only φ_{hh}^* (zero-profit cutoff), and (ii) the productivity cutoff to serve the foreign market as well φ_{hf}^* (export cutoff). Like equation (11), the productivity cutoffs of firms from the home country is determined by the zero-profit conditions and given as:

$$\begin{cases} Y_h^i(t)P_h(t)^{\sigma-1} \left(\left(\frac{\epsilon}{\epsilon-1}\right)\frac{1}{\varphi_{hh}^i}\zeta_h(t)\right)^{1-\sigma} = \epsilon\zeta_h(t)f_{hf} & for \ Domestic \ Market \\ Y_f^i(t)P_f(t)^{\sigma-1}\gamma_{hf}(t)^{\sigma}\tau_{hf}^{1-\sigma} \left(\left(\frac{\epsilon}{\epsilon-1}\right)\frac{1}{\varphi_{hf}^i}\zeta_h(t)\right)^{1-\sigma} = \epsilon\zeta_h(t)f_{hf} \ for \ for \ eign \ market. \end{cases} \quad \dots \quad (23)$$

Hence, firms with a productivity level $\varphi_{hh}^* \leq \varphi < \varphi_{hf}^*$ serve the only domestic market of the home country, and firms with a productivity level $\varphi_{hf}^* \geq \varphi$ serve both domestic as well as foreign market. We can also define the zero-profit cutoff $\tilde{\varphi}_{ff}^*$ and export cutoff $\tilde{\varphi}_{fh}^*$ for foreign firms in the same fashion. Although the foreign country does not pursue any trade policy, due to the presence of transport costs the zero-profit cutoff is less than the export cutoff $\tilde{\varphi}_{ff}^* < \tilde{\varphi}_{fh}^*$. In a particular market, for instance, the home country's market at time t, domestic firms with minimum productivity φ_{hh}^* compete with foreign importing firms with minimum productivity $\tilde{\varphi}_{fh}^*$. It is straightforward to show that these two productivity cutoffs in an individual market are inversely related. By considering the ratio of revenues of domestic and foreign importing firms, we have:

$$\varphi_{hh}^* = E \tilde{\varphi}_{fh}^* \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad (24)$$

where $E \equiv -\left(\frac{1-\varsigma}{\varsigma}\right)^{\sigma-1} \eta_{fh}(t)^{-\frac{\sigma}{1-\sigma}} \tau_{fh}$ with ς as the share of expenditure on the domestic varieties out of the total expenditures. The nature of the relationship between productivity cutoffs indicates that in the event of moving from autarky to trade, the zero-profit cutoff φ_{hh}^{*} for domestic firms raises. This rise in zero-profit cutoff makes marginal domestic firms quit the market. Thus, domestic firms especially firms on the margin, prefer higher trade restrictions and that is the import tariff in this model. The proposition below describes the relationship between productivity cutoffs and trade policy.

Proposition 2: A change in the trade policy of the home country affects the productivity cutoffs in both countries, such that:

$$\frac{\partial \varphi_{fh}^*}{\partial \eta_{fh}(t)}, \frac{\partial \varphi_{hf}^*}{\partial \eta_{fh}(t)} > 0 > \frac{\partial \varphi_{ff}^*}{\partial \eta_{fh}(t)}, \frac{\partial \varphi_{hh}^*}{\partial \eta_{fh}(t)}, \frac{\partial \varphi_{hh}^*}{\partial \eta_{fh}(t)}, \frac{\partial \varphi_{hf}^*}{\partial \gamma_{hf}(t)} < 0 < \frac{\partial \varphi_{ff}^*}{\partial \gamma_{hf}(t)}, \frac{\partial \varphi_{hh}^*}{\partial \gamma_{hf}(t)}, \frac{\partial \varphi_{hh}^*}{\partial \gamma_{hf}(t)}, \frac{\partial \varphi_{hh}^*}{\partial \gamma_{hf}(t)}, \frac{\partial \varphi_{hh}^*}{\partial \gamma_{hf}(t)}$$

For Proof, see Appendix-A.

The proposition shows that an increase in import tariff by the home country h leads to an increase in import cutoff φ_{fh}^* since the import tariff and import cutoff are positively related. This increase in import cutoff makes less foreign importing firms to participate in import business in their home country h. However, due to the trade balance condition, the increase in import cutoff for the home country also increases the export cutoff for domestic firms. Resultantly, a higher trade barrier by the home country leads to a reduction in international trade participation. The same is true in the case of export tax.

The expected revenue of a firm that serves both markets is now:

$$\bar{R}_h(t) = \chi \epsilon \zeta_h(t) (f_{hh} + m_{hf} f_{hf})$$

where $m_{hf} = \frac{1-G(\varphi_{hf}^*)}{1-G(\varphi_{hh}^*)} = \left(\frac{\varphi_{hh}^*}{\varphi_{hf}^*}\right)^{\alpha}$ is the export participation rate. Moreover, the free entry condition again requires that the expected profit to be equal to the entry cost, which states as:

$$(\chi - 1)(f_{hh} + m_{hf}f_{hf})\varphi_{hh}^*^{-\alpha} = f_h^{ent}\underline{\varphi}_h^{-\alpha}$$

While the aggregate price index can now transform as:

$$P_{h}(t)^{1-\sigma} = M_{h} \left(\frac{\epsilon}{\epsilon-1}\right)^{1-\sigma} \zeta_{h}(t)^{1-\sigma} \chi \varphi_{hh}^{*\sigma-1} + m_{fh} M_{f} \left(\frac{\epsilon}{\epsilon-1}\right)^{1-\sigma} \zeta_{f}(t)^{1-\sigma} \tau_{fh}^{1-\sigma} \eta_{fh}(t)^{1-\sigma} \chi \tilde{\varphi}_{fh}^{*\sigma-1} \qquad \dots \quad (25)$$

The total factor payment is again determined by Equation (15) and factor prices are determined by the market-clearing conditions. The factor prices are now:

$$w_{h}(t) = \delta M_{h} \chi \epsilon \zeta_{h}(t) (f_{hh} + m_{hf} f_{hf}) \qquad \dots \qquad \dots \qquad \dots \qquad (26)$$
$$r_{h}(t) = \frac{(1-\delta)}{K_{h}^{m}(t)} M_{h} \chi \epsilon \zeta_{h}(t) (f_{hh} + m_{hf} f_{hf}) \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad (26)$$

Finally, the trade balance requires imports of a country must equal to the exports of the country. The trade balance condition for the home country h is given as:

$$\frac{1}{\gamma_{hf}(t)} m_{hf} M_h f_{hf} \zeta_h(t) = m_{fh} M_f f_{fh} \zeta_f(t) \qquad \dots \qquad \dots \qquad \dots \qquad (27)$$

Proposition 3: Firms from the home country resist trade openness due to:

- The negative relationship between a firm's markup and the number of varieties available in the market, and
- The foreign importing firms are more productive.
- However, trade openness increases the welfare of consumers due to the procompetition effect.

The proof of the first part of the proposition is in the text above. However, the welfare in the economy after trade enhances due to two effects, as discussed by Edmond, et al. (2012), the pro-competitive effect and the Ricardian effect. The pro-competitive effect captures the effect of a reduction in the aggregate price index due to the fall in the price of domestic varieties. Trade openness increases the number of varieties available in the market and domestic firms are compelled to reduce their markups and reduce prices of domestic varieties. The Ricardian effect encompasses the traditional arguments of welfare increase due to productivity gain.

4.4. Entrepreneur's Problem

The entrepreneur's problem can be described as provided $[k_h^m(t)]$, F^t and w(t) are given at the equilibrium and factor markets are clear, $\{[k_h^m(s+1), L_h^m(s)]\}_{s=t}^{\infty}$ maximises the utility of the entrepreneur, which is:

$$U_{h}^{m}(\{K_{h}^{m}(s), L_{h}^{m}(s)\}_{s=t}^{\infty}|F^{t}, w(t)) = \sum_{s=t}^{\infty} \beta^{s-t} \left[\left(q_{hf}^{m}(\varphi_{h}, t) + \left(1 - \gamma_{hf}(s) \right) q_{hf}^{m}(\varphi_{h}, t) \right) - \left(K_{h}^{m}(s+1) - (1-\psi)K_{h}^{m}(s) \right) - w(s)L_{h}^{m}(s) + T^{m}(s) \right]$$

Now, the first-order condition that gives the capital stock for the next period is:

$$\beta \left\{ \varphi_{hf}(1-\delta) \left(L_h^m(t+1) \right)^{\delta} \left(K_h^m(t+1) \right)^{-\delta} \left(2 - \gamma_{hf}(t+1) \right) + (1-\psi) \right\} = 1 \quad \dots \quad (28)$$

In terms of the capital-labour ratio:

By comparing the above equation with Equation (18), we can see that in the case of the open economy, the capital level selected by the entrepreneur for the next period depends upon the export tax as well. If $\gamma_{hf}(t+1) < 1$ that is the case of export tax, then the capital stock selected by the entrepreneur for the next period is less than capital stock in the case of autarky. While in the case of export subsidy, $\gamma_{hf}(t+1) > 1$, the capital stock in Equation (25) is higher than the autarky.

4.5. Elite's Problem

The primary objective of trade policymaking by the elite is to keep political power with themselves and maximises their utility by transferring the maximum amount of trade tax revenue to themselves. Accomoglu (2007) rationalises such behavior of the elite on the revenue extraction and political consolidation basis. Resultantly, the elite transfer all revenue to themselves with $\theta^m T^m(t) = 0$ and $T^l(t) = 0$. The consumption function of the elite is given as:

$$C_h^e(t) = \max\{T^e(t)\}\$$

The government budget constraint holds in equality:

$$T^{e}(t) = \frac{1}{\theta^{e}} \left(\eta_{fh}(t) - 1 \right) A \overline{R}_{fh}(t) + \frac{1}{\theta^{e}} \left(1 - \gamma_{hf}(t) \right) A \overline{R}_{hf}(t)$$

The maximisation problem of the elite can then be written recursively:

$$W_h^e(\eta_{fh}(t), \gamma_{hf}(t), [K_h(t)]) = \max_{\eta_{fh}(t+1), \gamma(t+1)} \{T^e(t) + \beta V_h^e(\eta_{fh}(t+1), \gamma_{hf}(t+1), [K_h(t+1)])\}$$

To characterise the equilibrium trade policy sequence, note that $T^{e}(t)$ depends only on the trade policy at time t. The utility-maximising tariff and subsidy rates for the elite are given by the first-order conditions:

$$\beta \left(\frac{1}{\theta^e} \left(\eta_{fh}(t+1) - 1 \right) \frac{\partial A\bar{R}_{fh}(t+1)}{\partial \eta_{fh}(t+1)} + \frac{1}{\theta^e} A\bar{R}_{fh}(t+1) \right) = 0$$

$$\beta \left(\frac{1}{\theta^e} \left(1 - \gamma_{hf}(t+1) \right) \frac{\partial A\bar{R}_{hf}(t+1)}{\partial \gamma_{hf}(t+1)} + \frac{1}{\theta^e} A\bar{R}_{hf}(t+1) \right) = 0$$

These conditions give (see appendix B):

$$\eta_{fh}(t+1) = \frac{\alpha\sigma}{\alpha\sigma - \sigma + 1} \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad (30)$$

$$\gamma_{hf}(t+1) = \frac{\alpha\sigma}{\alpha\sigma + \sigma - 1} \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad (31)$$

The equations above indicate that the equilibrium trade policy pair selected by the elite involves an import tariff $\eta_{fh}(t + 1) > 1$ an export tax $\gamma_{hf}(t + 1) < 1$. Furthermore, the elasticity of substitution between the varieties of differentiated goods and the shape parameter of Pareto distribution are emerged as crucial elements to determine the level of the policy rate. The comparative statistics indicate that:

$$\frac{\partial \eta_{fh}(t+1)}{\partial \alpha} = -\frac{\sigma(\sigma-1)}{(\alpha\sigma-\sigma+1)^2} < 0, \frac{\partial \eta_{fh}(t+1)}{\partial \sigma} = \frac{\alpha}{(\alpha\sigma-\sigma+1)^2} > 0$$

$$\frac{\partial \gamma_{hf}(t+1)}{\partial \alpha} = \frac{\sigma(\sigma-1)}{(\alpha\sigma+\sigma-1)^2} > 0, \quad \frac{\partial \gamma_{hf}(t+1)}{\partial \sigma} = -\frac{\alpha}{(\alpha\sigma+\sigma-1)^2} < 0$$

The derivatives in the above equations indicate an opposite relationship between import tariff and export tax with the Pareto shape parameter. The negative relationship between import tariff and the Pareto shape parameter is due to the market selection sensitivity. A large value of α indicates a lower productivity dispersion, which makes heterogeneous firms more sensitive to the variations of import tariffs and market selection. Resultantly, due to the existence of high market selection sensitivity, the elite selects a lower tariff in case of having a high value of α . Similarly, a positive relationship between export tax and Pareto parameter also means a lower ad-valorem export tax in case of having a high value of α , since $\gamma_{hf}(t + 1) < 1$.

However, import tariff links positively to the elasticity of substitution between the differentiated varieties. A higher elasticity means domestic varieties are close substitutes for imported varieties. Therefore, applying a higher level of import tariff would not affect consumer welfare ruthlessly. Similarly, having a negative relationship with export tax also shows a higher level of ad-valorem tax in the case of the high value of σ .

The Markov perfect equilibrium (MPE) in the case of the open economy can be characterised by the cutoff productivity, the factor prices, the aggregate price index, and the aggregate revenue, import tariff. and export tax $\{\varphi_{hh}^{*}, \varphi_{hf}^{*}, \varphi_{fh}^{*}, \varphi_{fh}^{*}, P_{h}(t), P_{f}(t), \overline{AR}_{h}(t), w(t), r(t), \eta_{fh}(t+1), \gamma_{hf}(t+1)\}.$ These quantities are determined by the free entry condition (Equation (23)), optimal pricing formula (Equation (20)), and factor market clearing condition (Equation (26)). The sequence of capital stock for each entrepreneur is now determined by Equation (29), import tariff by Equation (30), and export tax by Equation (31).

5. TECHNOLOGY ADOPTION: DECISION TO ADOPT OR RESIST VIA LOBBY FOR TRADE RESTRICTIONS

Now assume the possibility that a firm from the home country can adopt new technology that improves her marginal product by $(1 + \lambda)$ factors, which implies that the productivity with new technology is $\tilde{\varphi}_h = \varphi_h(1 + \lambda)$. However, the adoption involves a fixed cost Γ which reflects the R&D cost of the adoption. The firm that uses new technology produces with the production function:

$$\tilde{q}_{h}(\tilde{\varphi}_{h},t) = \tilde{\varphi}_{h}\left(\left(L_{h}^{l}(t)\right)^{\delta}\left(K_{h}^{m}(t)\right)^{1-\delta} - f_{h} - \Gamma\right)$$

The price charged by the firm is $\tilde{p}_h(\tilde{\varphi}_h, t) = \left(\frac{\tilde{\epsilon}}{\tilde{\epsilon}-1}\right) \frac{1}{\tilde{\varphi}_h} \zeta_h(t)$, where $\tilde{\epsilon}$ is the price elasticity of demand and in the case of technology adoption by one firm is given as:

$$\tilde{\epsilon} = \sigma - (\sigma - 1) \frac{\tilde{p}_{hh}(v,t)}{\left((\mathsf{V}-1) \left(p_{hh}(v,t) \right)^{1-\sigma} + \left(\tilde{p}_{hh}(v,t) \right)^{1-\sigma} \right)^{\frac{1}{1-\sigma}}}$$

The revenue and profit accrue by a firm that adopts new technology is:

$$\tilde{R}_{h}(\tilde{\varphi}_{h},t) = \begin{cases} \tilde{R}_{hh}(\tilde{\varphi}_{h},t) & \text{if does not exports} \\ \tilde{R}_{hh}(\tilde{\varphi}_{h},t) \left(1 + \tau_{hf}^{1-\sigma}\gamma_{hf}(t)^{\sigma} \frac{Y_{f}^{i}(t)}{Y_{h}^{l}(t)} \left(\frac{P_{f}(t)}{P_{h}(t)^{\sigma-1}}\right)^{\sigma-1} \right) & \text{if exports.} \end{cases}$$

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$$\tilde{\pi}_{h}(\tilde{\varphi}_{h},t) = \begin{cases} \frac{1}{\tilde{\epsilon}}\tilde{R}_{hh}(\tilde{\varphi}_{h},t) - (f_{hh} + \Gamma)\zeta_{h}(t) & \text{if does not exports} \\ \frac{1}{\tilde{\epsilon}}\tilde{R}_{hh}(\tilde{\varphi}_{h},t) \left(1 + \tau_{hf}^{1-\sigma}\gamma_{hf}(t)^{\sigma} \frac{Y_{f}^{f}(t)}{Y_{h}^{h}(t)} \left(\frac{P_{f}(t)}{P_{h}(t)^{\sigma-1}}\right)^{\sigma-1}\right) - \left(f_{hh} + f_{hf} + \Gamma\right)\zeta_{h}(t) & \text{if exports.} \end{cases}$$

5.1. Entry and Exit

Analogous to zero-profit and export cutoffs, we can also develop a zero-profit condition for the firm to adopt new technology. Firms with productivity above that technology adoption cutoff can adopt new technology in the home country. The technology adoption cutoff is given as:

$$\begin{cases} Y_h^i(t)P_h(t)^{\sigma-1}\left(\left(\frac{\tilde{\epsilon}}{\tilde{\epsilon}-1}\right)\frac{1}{\tilde{\varphi}_{hh}^i}\zeta_h(t)\right)^{1-\sigma} = \tilde{\epsilon}(f_{hh}+\Gamma)\zeta_h(t) & for \ Domestic \ Market \\ \end{cases} \\ Y_f^i(t)P_f(t)^{\sigma-1}\gamma_{hf}(t)^{\sigma}\tau_{hf}^{1-\sigma}\left(\left(\frac{\tilde{\epsilon}}{\tilde{\epsilon}-1}\right)\frac{1}{\tilde{\varphi}_{hf}^i}\zeta_h(t)\right)^{1-\sigma} = \tilde{\epsilon}(f_{hh}+f_{hf}+\Gamma)\zeta_h(t) \ for \ for \ eign \ market. \end{cases}$$

Firms with a productivity level $\varphi \ge \tilde{\varphi}_h^*$ can adopt new technology and firms with the productivity level $\varphi_h^* \le \varphi < \tilde{\varphi}_h^*$ are unable to bear the technology adoption cost and keep operating with old technology.

5.2. Selection of Technological Up-gradation

The adoption of an updated technology involves a fixed cost Γ and the fact that $\zeta_h f_h < \zeta_h (f_h + \Gamma)$, ensures that for sufficient low levels of productivity, we have $\tilde{\pi}_h(\tilde{\varphi}_h) < \pi_h(\varphi_h)$, and updating technology is not a viable option when keep operating with old technology is more profitable than adopting new technology, i.e., whenever:

$$\varphi_h^* < \varphi_h < \tilde{\varphi}_h$$

From zero profit condition:

$$\begin{split} \varphi_h^* &= \frac{Y_h^{i}^{\sigma-1}}{P_h} \Big(\frac{\epsilon}{\epsilon-1}\Big) \zeta_h (\epsilon \zeta_h f_{hh})^{\frac{1}{\sigma-1}} \\ \tilde{\varphi}_h^* &= \frac{Y_h^{i}^{\sigma-1}}{P_h} \Big(\frac{\tilde{\epsilon}}{\tilde{\epsilon}-1}\Big) \zeta_h \Big(\tilde{\epsilon} \zeta_h (f_{hh} + \Gamma)\Big)^{\frac{1}{\sigma-1}} \end{split}$$

Therefore,

$$\left(\frac{\epsilon}{\tilde{\epsilon}} \left(\frac{\epsilon}{\epsilon-1}\right)^{\sigma-1} - \left(\frac{\tilde{\epsilon}}{\tilde{\epsilon}-1}\right)^{\sigma-1}\right) f_{hh} < \Gamma$$

The above equation indicates that given the cost of technology adoption is greater than the relative benefits (in terms of markup) of technology adoption, firms will not adopt more productive technology. The relative benefits of adopting new technology again link with the price elasticity of demand. In the case of large markets, the relative benefits of adopting new technology will be higher and firms prefer to adopt new technologies. Furthermore, as shown in the figure the profit increase linearly with productivity and more productivity technology increases productivity by $(1 + \lambda)$ factor. This means the slope of $\tilde{\pi}(\tilde{\varphi}_h, t)$ is greater than $\pi(\varphi_h, t)$. However, at point A, we have $\pi_h(\varphi_h, t) = \tilde{\pi}_h(\tilde{\varphi}_h, t)$. By utilising the definitions of the profit function and eliminating common terms, we have:

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where D measures the size of the market. The above equation explicitly shows the critical variables in determining technology adoption in an economy are (i) the cost of adoption, (ii) the market size, and (iii) the level of productivity increment. The cost of technology adoption $\zeta_h \Gamma$ has a positive link technology cutoff. An increase in the cost of technology adoption increases the technology adoption cutoff and fewer firms operating in the home country h enable to adopt new technology. While market size negatively affects technology adoption cutoff. An increase in market size encourages more firms to adopt new technology. As we have seen in proposition 1 that a large market has a large number of varieties and firms. The availability of a large number of varieties in the market makes demand more elastic with respect to price. The high elasticity of demand induces firms to adopt new technology to increase productivity. As the productivity and price charged by the firm are inversely related. Therefore, having higher productivity ensures a lower price for the differentiated variety of firms. Besides, the existence of large firms in a large market also supports rapid technology adoption because large firms can bear the fixed cost of adoption more smoothly than small firms. The last variable that plays a critical role is the factor by which productivity increases after paying adoption costs. We can comprehend this factor straightforwardly with the analogy of rungs of a ladder. If paying adoption costs and adopting new technology leads the firm to a higher rung on the technology ladder, then firms prefer to upgrade technology. However, if adoption leads to the next rung of the ladder and that rung is not far from the rung where the firm is standing, then firms might want to stay on the initial rung and avoid the cost of adoption. Comin and Hobijn (2009) have also shown that technology diffusion is slower when new technology has close predecessors.



Proposition 4: The technology adoption decision of the firms also depends upon the market size: firms in a large market adopt new technologies more rapidly than firms in a small market.

Proof, In the text above.

5.3. The Possibility of Block Technology Adoption by Lobbying

Now, consider the possibility of lobbying by heterogeneous firms for trade policy in the home country h. Two fundamental rationales for considering the possibility of lobbying by the firms are markup motivation and anti-competition motivation. Since the markup of firms is dependent upon the number of varieties in the market as discussed in section 2.3. Therefore, lobbying for a higher trade restriction in the form of a higher trade tariff on imports keeps the number of varieties available in the domestic market low. To maintain their markup and shares in the market, lobbying by domestic firms is a natural outcome in these settings. Secondly, in the event of trade openness, the less productive domestic firms must compete with higher productive foreign importing firms in the domestic market. This competition favors foreign importing firms as they charged lower prices. Hence, domestic firms also try to avoid such kind of competition and lobby to place higher trade barriers.

To what extent firms are capable to lobby and influence the elite policymaker in policy selection, rests on the degree of democracy and the size of the total industry of the home country. Firms in a weak democratic country are more prone to lobby for higher regulations, which yields a slow technology diffusion, Comin and Hobijn (2009). While a small industry with a small number of firms is more effective to slow down technology diffusion via lobbying, Bridgman, et al. (2007). In short, firms will not adopt new technology and lobby for trade restrictions when firms are small and there is weak democracy in the economy, Weymouth (2012).

The lobbying mechanism considered here is based on classical Grossman and Helpman (1994), which involves monetary offerings by the firm to the elite policymakers in the form of bribes.¹² The individual firm pays a fixed cost for lobbying $\zeta_h(t)b_h$ and the industry overcomes the free-rider problem by punishing the firm that fails to pay the bribe. Firms in the home country *h* offer a bribe $B = M_h \zeta_h(t) b_h$ to the elite policymakers at time *t* to get maximum trade protection from the foreign importing firm at time t + 1. Elite devises trade policy and receives a bribe in case of implementing policy according to the desire of firms. Acemoglu and Robinson (2006) show that the elite policymaker also intends to block new technology due to incumbency advantage erosion. Hence, the objective function of the elite is now:

 $C_h^e(t) = \max\{T^e(t) + B\}$

While the firm's objective function is:

$$V_h^m(t) = \max\{\hat{\pi}_h(\varphi_h, t) - \zeta_h(t)b\}$$

Where $\hat{\pi}_h(\varphi_h, t)$ is the operating profit. We can define the equilibrium trade policy and bribe level as:

Lemma-1: a Markov perfect equilibrium involves $\{\eta_{fh}^*(t), \gamma_{hf}^*(t)\}$, (B^*) such that:

(1) $\zeta_h(t)b^*$ is feasible for all firms in the home country h

¹²See, Mitra (1999) for endogenous lobby formation decision of an industry in the classical Grossman & Helpman (1994) protection for sale framework. While Bombardini (2008) introduces the heterogeneity aspect of firms in the analysis and formulates the optimal lobby criterion that regulates the lobby participation decision of firms.

- (2) $\{\eta_{fh}^*(t), \gamma_{hf}^*(t)\}$ maximises $\{T^e(t) + B\}$ on F^t , given $\eta_{fh}^*(t), \gamma_{hf}^*(t) \in F^t$
- (3) $\{\eta_{fh}^*(t), \gamma_{hf}^*(t)\}$ maximises $\{\hat{\pi}_h(\varphi_h, t) \zeta_h(t)b^* + T^e(t) + B^*\}$ on F^t for every firm
- (4) For every firm k there exists $F_{-k}^t \in F^t$ that maximises $\{T^e(t) + B\}$ on F^t such that $\zeta_h(t)b_{-k}^* = 0$

The first condition places the feasibility restriction on the bribe for each firm in the industry, and condition (2) indicates that the elite maximises their own utility given the amount of bribe offered. The third condition elaborates the fact that the equilibrium policy vector must maximise the joint objective functions and the last condition is about the non-payment of bribes conditional on the policy-level choice of the elite. From condition (3), the first-order conditions are:

$$\frac{\partial \hat{\pi}_{h}(\varphi_{h},t)}{\partial \eta_{fh}^{*}(t)} - \frac{\partial \zeta_{h}(t)b}{\partial \eta_{fh}^{*}(t)} + M_{h} \frac{\partial \zeta_{h}(t)b}{\partial \eta_{fh}^{*}(t)} + \frac{\partial T^{e}(t)}{\partial \eta_{fh}^{*}(t)} = 0 \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad (33)$$

$$\frac{\partial \hat{\pi}_{h}(\varphi_{h},t)}{\partial \gamma_{hf}^{*}(t)} - \frac{\partial \zeta_{h}(t)b}{\partial \gamma_{hf}^{*}(t)} + M_{h} \frac{\partial \zeta_{h}(t)b}{\partial \gamma_{hf}^{*}(t)} + \frac{\partial T^{e}(t)}{\partial \gamma_{hf}^{*}(t)} = 0$$

From condition (2), the first-order condition of the elite is:

$$M_{h} \frac{\partial \zeta_{h}(t)b}{\partial \eta_{fh}^{*}(t)} + \frac{\partial T^{e}(t)}{\partial \eta_{fh}^{*}(t)} = 0$$

$$M_{h} \frac{\partial \zeta_{h}(t)b}{\partial \gamma_{hf}^{*}(t)} + \frac{\partial T^{e}(t)}{\partial \gamma_{hf}^{*}(t)} = 0$$

$$(34)$$

By summing over all firms (33) will become:

$\frac{\partial \widehat{\Pi}_{h}(\varphi_{h},t)}{\partial \eta_{fh}^{*}(t)} = M_{h} \frac{\partial \zeta_{h}(t)b}{\partial \eta_{fh}^{*}(t)}$				
$\frac{\partial \hat{\Pi}_{h}(\varphi_{h},t)}{\partial x^{*}(t)} = M_{h} \frac{\partial \zeta_{h}(t)b}{\partial x^{*}(t)}$	 	 	 	(35)
$\partial \gamma_{hf}(t) = \partial \gamma_{hf}(t)$				

Substitute (35) into (34):

$$\frac{\partial \hat{\Pi}_{h}(\varphi_{h},t)}{\partial \eta_{fh}^{*}(t)} + \frac{\partial T^{e}(t)}{\partial \eta_{fh}^{*}(t)} = 0$$

$$\frac{\partial \hat{\Pi}_{h}(\varphi_{h},t)}{\partial \gamma_{hf}^{*}(t)} + \frac{\partial T^{e}(t)}{\partial \gamma_{hf}^{*}(t)} = 0$$

Compared to the first-order conditions of the elite's problem in section 4.5, the first terms of the above equations are not present there. These terms indicate that the trade policy at this political equilibrium differs from section 4.5. Proposition 3 states that an increase in the tariff revenue will lead to a low variety in the market that enables domestic firms to charge higher markup. Accordingly, the change in operating profits of the firms from the home country due to change in the tariff is positive, i.e., $\frac{\partial \hat{n}_h(\varphi_h,t)}{\partial \eta_{fh}^*(t)} = M_h \hat{\pi}_{hh}(\varphi_h,t) \eta_{hf}^*(t) ((\sigma-1)) > 0$. By denoting the political equilibrium tariff by $\eta_{fh}^p(t)$, we know that $\eta_{fh}^p(t) > \eta_{fh}(t)$. Similarly, $\frac{\partial \hat{n}_h(\varphi_h,t)}{\partial \gamma_{hf}^*(t)} = \frac{M_h \hat{\pi}_{hf}(\varphi_{h,t})}{\gamma_{hf}^*(t)} \left((\sigma-1) + \frac{\alpha}{\sigma^{-1}}\right) > 0$. Therefore, at the political equilibrium $\gamma_{hf}^p(t) > \gamma_{hf}(t)$, which indicates the ad-valorem export tax is lower than in section 4.5.

Proposition 5: In the case of a small market with weak democracy, the

heterogeneous firms can influence the trade policy-making and lobby for a higher import restriction to maintain their market shares. However, in the event of large markets with strong democracy where influencing trade policy by lobbying is difficult to achieve, firms refrain from lobbying and adopt new technology more rapidly.

The decision to adopt advanced technology or block technology diffusion via lobby depends upon the relative costs of both in a small market. In the event when the net benefits of lobbying are more than the net benefits of technology adoption, firms will adopt lobbying. The net benefits of lobbying are the difference in operating profit without lobbying and operating profit with lobbying minus the lobby cost. At a firm's level the net benefits are $\{\hat{\pi}_{hf}^{lb}(\varphi_h,t) - \hat{\pi}_{hf}^{wl}(\varphi_h,t) - \zeta_h(t)b_h\}$ where lb and wl in the superscript indicate operating profits with a lobby and without a lobby, respectively. However, the net benefits of adopting new technology are $\{\hat{\pi}_{hf}(\tilde{\varphi}_h,t) - \hat{\pi}_{hf}(\varphi_h,t) - \zeta_h(t)\Gamma\}$. The cost of new technology adoption $\zeta_h(t)\Gamma$ is fixed, while the cost of lobby i.e., the amount of bribe $\zeta_h(t)b_h$ hinges upon how much political power the policy-maker pedals. In weak democracy, the policymaker can change the policy level without facing any strong opposition. Thus, the cost of the lobby will be lower than the cost of the lobby in a strong democracy where policymakers face the backlash of the opposition for the policy decisions. Also, in weak democracy, the institutional mechanism for legislation is not so effective, and bending orders and legislations are easy, for example, the statutory regulatory orders (SRO) that we have discussed in section 1.1. Hence, the cost of technology adoption is much higher than the cost of lobby $\Gamma > b_h$ in a weak democracy. Moreover, the size of firms is also small in small economies, and firms in the small economy might not be able to bear the adoption cost. Resultantly, they are more prone to lobby.

6. DISCUSSION AND CONCLUSION

Technology has been identified as the key factor to promote productivity, which is the engine of growth and prosperity. Countries with updated or new technology are experiencing higher productivity and higher per capita income. While countries lagging in catching up with the technology ug-gradation are also those who are having lower productivity and per capita income. Firms are the main source of technology adoption and therefore technology up-gradation happens through firms. Literature has shown that in developing countries firms are operating at a far distance from the technological frontier. Now the pertinent question is why a large divide among firms on the technological frontier exists even though we have recognised the fact that technology is the key. The study in hand envisioned that this divide exists due to the political and market institutions of the society. In a society where policy-making is not democratic, the firms have less appeal to adopt new technologies since they can seek protection from the competition. While in the event of more democratic policymaking settings, firms cannot exert influence on policymaking and are prone to more competition. Therefore, adopt technology more rapidly. Similarly, if the market size that a firm is serving is large then the firm will adopt new technology swiftly compared to a firm serving a small market without competition. These results emerged from the basic model developed in the study. Another important result that emerges from the model is that firms adopt technology when the productivity gains from adoption are relatively large and new technology is much superior to obsolete technology the firm is using.

Appendices

APPENDIX-A Proof of Proposition-2

To prove proposition 2, we follow Felbermayr, et al. (2013). From the zero-profit conditions, the relative productivity cutoffs of firms competing in the home country h:

$$\frac{\eta_{fh}^{-\sigma} \left(\frac{\varphi_{fh}}{\tau_{fh}}\right)^{\sigma-1}}{(\varphi_{hh})^{\sigma-1}} = \frac{f_{fh}}{f_{hh}}$$

By differentiating after taking the log and holding transport cost constant gives:

$$\left(\frac{\sigma-1}{\sigma}\right)\left(\dot{\varphi}_{fh}-\dot{\varphi}_{hh}\right)=\dot{\eta}_{fh}$$

where the dot above the variable denotes the percentage change in the variable. This expression indicates that any change in tariff rate affects both productivity cutoffs in the market *h*. The variation in tariff rate is positively related to import cutoff and negatively to domestic cutoff. However, the trade balance condition dictates a positive association between φ_{hf}^* and φ_{fh}^* , which is given by:

$$\varphi_{hf}^* = Q \varphi_{fh}^*$$
 where $Q = \frac{\varphi_h}{\underline{\varphi}_f} \left(\frac{f_{fh}}{f_{hf}/\gamma_{ij}} \frac{f_h^{ent}}{f_h^{ent}} \right)^{\alpha} > 0$

So, this positive relationship between both productivity indicates that if the import cutoff of foreign firms to serve market h falls, then the export cutoff for domestic firms to serve foreign market f also falls.

The negative relationship between φ_{fh}^* and φ_{hh}^* is given by Equation (24):

$$\varphi_{hh}^* = E \tilde{\varphi}_{fh}^*$$
 where $E \equiv -\left(\frac{1-\varsigma}{\varsigma}\right)^{\sigma-1} \eta_{fh}^{-\frac{\sigma}{1-\sigma}} \tau_{fh}$

Therefore, the fall of import cutoff for foreign firms in the home country due to decrease in tariff rate increases the zero-profit cutoff of domestic firms to serve the domestic market. On the other hand, this also decreases import productivity cutoff in foreign country f, which increase domestic productivity cutoff φ_{ff}^* .

Similarly, in the case of export subsidy, the relative productivity cutoffs in the foreign country f lead to:

$$\frac{(\sigma-1)}{\sigma} \left(\dot{\varphi}_{ff} - \dot{\varphi}_{hf} \right) = \dot{\gamma}_{hf}$$

Thus, any change in the export subsidy rate of the home country h affects exporting cutoff negatively and the foreign country's domestic cutoff positively. While we can complete the rest of the analysis for export subsidy by following the above steps.

APPENDIX-B

Derivation of Import tariff and Export Subsidy

From the maximisation problem, the first-order conditions are given as:

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$$\frac{\partial V_h^e}{\partial \eta_{hf}(t+1)} = \beta \left(\frac{1}{\theta^e} \left(\eta_{fh}(t+1) - 1 \right) \frac{\partial A\bar{R}_{fh}(t+1)}{\partial \eta_{fh}(t+1)} + \frac{1}{\theta^e} A\bar{R}_{fh}(t+1) \right) = 0$$
$$\frac{\partial V_h^e}{\partial \gamma_{hf}(t+1)} = \beta \left(\frac{1}{\theta^e} \left(1 - \gamma_{hf}(t+1) \right) \frac{\partial A\bar{R}_{hf}(t+1)}{\partial \gamma_{hf}(t+1)} + \frac{1}{\theta^e} A\bar{R}_{hf}(t+1) \right) = 0$$

Solving for import tariff and export subsidy yields:

$$\left(\eta_{fh}(t+1)-1\right) = -\frac{\frac{A\bar{R}_{fh}(t+1)}{\partial A\bar{R}_{fh}(t+1)}}{\frac{\partial A\bar{R}_{fh}(t+1)}{\partial \eta_{fh}(t+1)}} \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad (B.I)$$

$$\left(1 - \gamma_{hf}(t+1)\right) = -\frac{A\bar{R}_{hf}(t+1)}{\frac{\partial A\bar{R}_{hf}(t+1)}{\partial \gamma_{hf}(t+1)}} \qquad \dots \qquad \dots \qquad \dots \qquad \dots \qquad (B.II)$$

We can write the aggregate revenues in terms of the parameters of the model explicitly as:

$$\begin{split} A\bar{R}_{fh}(t+1) &= M_{fh}^{e} \chi \underline{\varphi}_{f}^{\alpha} Y_{h}^{i}(t+1) P_{h}(t+1)^{\sigma-1} \left(\frac{\epsilon}{\epsilon-1}\right)^{1-\sigma} \zeta_{f}(t+1)^{1-\sigma} \tau_{fh}(t+1)^{1-\sigma} \eta_{fh}(t+1)^{-\sigma} \varphi_{fh}^{*}^{\sigma-\alpha-1} \\ A\bar{R}_{hf}(t+1) &= M_{hf}^{e} \chi \underline{\varphi}_{h}^{\alpha} Y_{f}^{i}(t+1) P_{f}(t+1)^{\sigma-1} \left(\frac{\epsilon}{\epsilon-1}\right)^{1-\sigma} \zeta_{h}(t+1)^{1-\sigma} \tau_{hf}(t+1)^{1-\sigma} \gamma_{hf}(t+1)^{\sigma} \varphi_{hf}^{*}^{\sigma-\alpha-1} \end{split}$$

First, we will solve for import Tariff.

$$\begin{split} \frac{\partial A\bar{k}_{fh}(t+1)}{\partial \eta_{fh}(t+1)} &= M_{hf}^{e} \chi \underline{\varphi}_{f}^{\alpha} Y_{h}^{i}(t+1) P_{h}(t+1)^{\sigma-1} \left(\frac{\epsilon}{\epsilon-1}\right)^{1-\sigma} \zeta_{f}(t+1)^{1-\sigma} \tau_{fh}(t+1)^{1-\sigma} \eta_{fh}(t+1)^{1-\sigma} \eta_{fh}(t+1)^{1-\sigma}$$

Similarly, we can also solve for export subsidy as:

 13 By considering the mass of importers in the country and the Pareto distribution productivity from zero profit condition.

$$\begin{split} &\varphi_{fh}^{*} = \frac{Y_{h}^{i}(t+1)^{\sigma-1}}{P_{h}(t+1)} \eta_{fh}(t+1)^{\frac{\sigma}{\sigma-1}} \left(\frac{\epsilon}{\epsilon-1}\right) \tau_{fh}(t+1) \zeta_{f}(t+1) \left(\epsilon \zeta_{f}(t+1) f_{fh}\right)^{\frac{1}{\sigma-1}} \\ &\varphi_{hh}^{*} = \frac{Y_{h}^{i}(t+1)^{\sigma-1}}{P_{h}(t+1)} \left(\frac{\epsilon}{\epsilon-1}\right) \zeta_{h}(t+1) (\sigma \zeta_{h}(t+1) f_{hh})^{\frac{1}{\sigma-1}} \\ &\varphi_{fh}^{*} = \eta_{fh}(t+1)^{\frac{\sigma}{\sigma-1}} \frac{\tau_{fh}(t+1) \zeta_{f}(t+1)}{\zeta_{h}(t+1)} \left(\frac{\zeta_{f}(t+1) f_{fh}}{\zeta_{h}(t+1) f_{hh}}\right)^{\frac{1}{\sigma-1}} \varphi_{hh}^{*} \\ &ln \varphi_{fh}^{*} = \frac{\sigma}{\sigma-1} ln \eta_{fh}(t+1) + \frac{1}{\sigma-\alpha-1} ln Z \\ &\frac{\partial ln \varphi_{fh}^{*}}{\partial ln \eta_{h}(t+1)} = \frac{\sigma}{\sigma-1} \end{split}$$

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$$\begin{split} &\frac{\partial A\bar{k}_{hf}(t+1)}{\partial \gamma_{hf}(t+1)} = M_{hf}^{e} \chi \underline{\varphi}_{h}^{\alpha} Y_{f}^{i}(t+1) P_{f}(t+1)^{\sigma-1} \left(\frac{\epsilon}{\epsilon-1}\right)^{1-\sigma} \zeta_{h}(t+1)^{1-\sigma} \tau_{hf}(t+1)^{1-\sigma} \gamma_{hf}(t+1)^{1-\sigma} \gamma_{hf}(t+1) = \frac{\alpha \sigma}{\alpha \sigma + \sigma - 1}$$

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$${}^{14} ln\varphi_{hf}^* = -\frac{\sigma}{\sigma-1} ln\gamma_{hf(t+1)} + \frac{1}{\sigma-\alpha-1} lnZ'$$

$${}^{\partial ln\varphi_{hf}^*}_{\partial ln\gamma_{hf}(t+1)} = -\frac{\sigma}{\sigma-1}$$

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