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Essays on the Effects of Structural Reforms

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Abstract

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This dissertation studies the effects of structural reforms. In Chapter 1, I analyze the distributional consequences of structural reforms based on a theoretical model, for to my best knowledge, existing studies on the issue are empirical ones only. I build up a tractable framework, which measures the impacts of the reforms on inequality by the Gini coefficient and the labor share in GDP that are determined endogenously. The framework incorporates endogenous firm entry as in Bilbiie, Ghironi, and Melitz (2012), labor market friction as in Mortensen and Pissarides (1994), and translog preferences as in Feenstra (2003). And it is extended with simple heterogeneity in households by distinguishing them between the household of workers and that of entrepreneurs. The main results of the chapter are as follows. First, product market reform represented by the reduction of the regulatory entry costs improves income equality in any measures. As the employment rate goes up after the reform, the overall income concentration falls, and it causes the Gini coefficient to decline. Also, the labor share rises by the combined effects of the increase in overall wage and the decrease in markup, following the influx of new entrants. Second, less strict employment protection represented by lowering the costs related to firing employees rather lowers the Gini coefficient more than the product market reform does, though this reform has little negative impact on the labor share. Third, less generous unemployment benefits certainly worsen inequality in any measures. It is because the reform directly widens the income gap between

the unemployed and the employed, and limits wage increase since the lower replacement rate reduces workers' outside option.

Chapter 2[1] investigates the effects of product market reform in granular economies. We set up a baseline model by modifying the Ghironi and Melitz (2005) model, and later extend it with idiosyncratic shocks. First, we find out that the overall effects of the structural reforms are heterogeneous according to the degrees of granularity of countries. The reforms in granular economies are likely to be associated with larger long-run gain but with bigger short-run pain, compared to the reforms in non-granular economies. Second, the product market reform also affects the degree of granularity by changing the cutoff productivity and the number of operating firms. In the immediate aftermath of the reform, the economy rather becomes more granular than before as the number of operating firms decreases due to the jump of cutoff productivity caused by fierce competition. However, the number of firms gradually recovers, making the economy less granular over time. Third, in the extended model with idiosyncratic shocks, we find out that aggregate volatility temporarily increases, while it eventually decreases in the long-run. Also, the magnitude of impacts of the reforms on aggregate volatility is larger in granular economies.

[1]Co-authored with Fabio Ghironi, Department of Economics, University of Washington, Seattle, WA 98105-3330, U.S.A.

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DEDICATION

to the Lord Almighty who has made all things possible for me

Chapter 1

THE DISTRIBUTIONAL CONSEQUENCES OF STRUCTURAL REFORMS

1.1 Introduction

Despite the broad consensus that structural reforms can contribute to long-run economic growth, the reforms have been hardly welcomed by the public[1]. The main reasons for the opposition are first, so-called "short-term pain" of the reform such as reform-driven layoffs in its immediate aftermath, and second, the fear of worsening inequality. Unlike the former which has been studied actively in the literature of structural reforms, the latter, the impact of the reforms on inequality is not clear yet due to limited research. Earlier papers on this issue such as Card et al. (2003) and Bhanumurthy et al. (2004) cover a specific reform measure and/or a country only. Recently, Causa et al. (2015, 2016) conduct more comprehensive analysis based on the OECD cross-country evidence, but as empirical studies[2], they still have limits to the capacity in studying the short- to medium-run dynamics of the distributional impacts as well as the mechanism through which the reforms affect income distribution.

On this backdrop, this chapter analyzes how structural reforms affect income distribution with a theoretical model. I build up a tractable framework based on Cacciatore and Fiori (2016), which incorporates endogenous firm entry as in Bilbiie, Ghironi, and Melitz (2012), labor market friction as in Mortensen and Pissarides (1994), and translog preferences as in

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[1]The following news headlines show how difficult the implementation of structural reforms is around the world: *"Macron faces first major strike as unions oppose planned reforms."* (Bloomberg, Mar. 22, 2018); *"Argentine truckers block capital streets to protest Macri reforms."* (Reuters, Feb. 21, 2018); *"India's voters bite back against Prime Minister Modi's economic reforms."* (CNBC, Dec. 18, 2017); *"South Korean unions ramp up pressure on Moon over labor reform."* (Financial Times, Jun. 26, 2017).

[2]To my best knowledge, there is no theoretical analysis on the distributional consequences of structural reforms in the existing literature.

Feenstra (2003). I extend the model with simple heterogeneity in households by distinguishing them between the household of workers and that of entrepreneurs, to enable inequality analysis while maintaining model tractability. In this setup, there exists income inequality at an individual- and a household-level as shown in Figure 1.1. Within the working household, there is individual earnings dispersion due to the *ex-post* heterogeneity, and it is measured by the Gini coefficient, the traditional indicator of inequality. Also, there is income inequality across households, which is represented by the labor share in total income because labor income is held by the working household while non-labor income is held by the household of entrepreneurs.

The main finding based on the theoretical model is that structural reforms do not necessarily worsen inequality but have heterogeneous distributional effects according to reform measures as well as time horizon. First, the product market reform rather improves equality, for the reform promotes competition among firms in the product market and decreases overall return on investment while it raises employment and wages. Second, one of the labor market reforms, making it easier to fire employees, surprisingly decreases the dispersion of labor income measured by the Gini index, while it slightly lowers the labor share in GDP. Third, another labor market reform, the reduction in unemployment benefits, unquestionably worsens inequality, as it widens not only the gap between the unemployed and the employed but also the gap between workers and investors. Fourth, a reform package made by implementing the above reforms simultaneously leads to significant adverse impacts in the short-run but eventually improves equality as the reform package bring gains in the long-term. So, this research suggests that policymakers need to smooth out the immediate disequalizing effects of the reforms by implementing the labor market reforms, particularly the less generous unemployment benefit, later than the product market reform. This sequencing would enhance the public reception of the reforms until the long-term benefits materialize.

The rest of the chapter is organized as follows. Section 1.2 describes the details of the model. Section 1.3 explains calibration strategies and grounds for the choices of parameter values. Section 1.4 introduces the inequality measures used in this paper. Section 1.5 investigates the short- to long-term distributional impacts of each structural reform measure and identify primary drivers behind the results. Section 1.5 studies the distributional effects under an alternative, more realistic taxation scenario. Lastly, Section 1.7 attempts to derive policy implications on the desirable sequence of the reforms.

1.2 The Model

1.2.1 Households

Household Heterogeneity

There are two types of households: workers and entrepreneurs. This distinction is inherent and there is no movement between the households. The household of workers consists of a unit mass of members who can supply only labor to make a living. Although they are *ex-ante* identical, there is *ex-post* heterogeneity in individual earnings depending on their employment status and job matches. The other household consists of a unit mass of entrepreneurs who owns firms and invests in physical capital. To avoid the problem of keeping track of one's return to investment, members of this household are assumed to share the total income equally. Also, following Merz (1995), each household is regarded as a large family and full consumption insurance within each household is assumed.

This simplicity accompanies with a few concessions. The Gini coefficient, the main measure in the model indicates inequality in labor income only. Even though the relative share of labor and non-labor income in GDP is also taken into consideration to check the entire distributional consequences, it still has a limit to some extent, because non-labor income is assumed to be equally shared by entrepreneurs. However, if both measures, the Gini coefficient and the labor share in GDP are used in a complementary manner, in other words, if the change in the labor share is interpreted as an additional source of income inequality, then the simple heterogeneity in households can be a reasonable choice for studying inequality. According to empirical studies like OECD (2011), capital income is more unevenly distributed than labor income. So, *ceteris paribus*, a decrease in labor share is associated with an increase in the degree of inequality.

The simple distinction between the households not only enables inequality analysis but also provides several benefits. A concern over assuming household heterogeneity is that it usually sacrifices tractability of the framework significantly. But this simple heterogeneity offers enough layers and sources of income inequality while preserving tractability as well. It makes this setup reasonable for the analysis on distributional impacts, considering that the purpose of this study is not about finding out where the current level of inequality originates, but about investigating how the reforms make changes to the given level of inequality. Next, it clearly shows the income distribution between economic classes, particularly between employees and employers, and between labor and capital which has been received much attention traditionally.

The Working Household

The unit mass of working household supplies labor to make a living. If a member is matched to a job i of which productivity $z_{i,t}$ at a firm ω, she receives wage payment $w_{\omega,t}(z_{i,t})$ and pays income tax according to the tax rate τ_t. Unlike the standard setup in the literature with the assumption of a lump-sum tax, I apply a proportional tax with a single rate over wages to be able to identify individual disposable incomes and the effect of taxation on income distribution. On the other hand, if one is unemployed, she stays at home and makes h_p amount of home production. Also, she is exempted from tax and rather receives unemployment benefit u_b until she finds a job. As in Cacciatore and Fiori (2016), the household cannot choose how many members work, but it is determined by the labor matching process. Hence, though members are *ex-ante* homogeneous, their *ex-post* employment status and wages are heterogeneous and endogenously determined by economic conditions. The household maximizes the expected intertemporal utility function

$$E_t \sum_{s=t}^{\infty} \beta^{s-t} \frac{C_{W,s}^{1-\gamma}}{1-\gamma} \tag{1.1}$$

where β is the discount factor, and $C_{W,t} = C^M_{W,t} + h_p(1 - L_t)$ is total consumption of the working household which consists of the consumption of market goods, denoted with $C^M_{W,t}$, and home-produced goods by unemployed members, represented by $h_p(1 - L_t)$. The maximization is subject to the following budget constraint for the consumption of market goods

$$C^M_{W,t} = (1 - \tau_t)\tilde{w}_t L_t + u_b(1 - L_t) \tag{1.2}$$

where $\tilde{w}_t$ is the average wage of employed household members. The constraint shows that total earnings are the sum of disposable wage incomes of the employed and the unemployment benefits given to the unemployed. Here, the total unemployment benefit is assumed to be fully financed by the wage tax revenue, $\tau_t \tilde{w}_t L_t = u_b(1 - L_t)$. This can be understood as following the benefit principle because the unemployment benefits are only for the unemployed in the working household.[3] Then, the household's budget constraint for total consumption boils down to

$$C_{W,t} = \tilde{w}_t L_t + h_p(1 - L_t) \tag{1.3}$$

The Entrepreneur Household

The other household consists of a unit mass of entrepreneurs who invests in physical capital, K_t and holds mutual fund shares, x_t. For simplicity, the investment is jointly executed by the household members, and the total income from the investment is shared equally and spent for the household's common consumption. As previously stated, investment income is not taxable. This household also maximizes the expected intertemporal utility function

[3] Later, I also consider an alternative taxation scenario, in which all kinds of income are taxable. Refer to the Section 1.6.

$$E_t \sum_{s=t}^{\infty} \beta^{s-t} \frac{\left(C_{E,s}^M\right)^{1-\gamma}}{1-\gamma} \tag{1.4}$$

subject to the following budget constraint for consumption of market goods, $C_{E,t}^M$

$$C_{E,t}^M + e_t(N_t + N_{E,t})x_{t+1} + I_t = (d_t + e_t)N_t x_t + r_t K_t \tag{1.5}$$

where e_t is real price of a claim to the future dividend stream of the mutual fund, N_t and $N_{E,t}$ are the number of firms and that of entrants, respectively, x_t is the mutual fund shareholding at the beginning of period t, d_t is the mutual fund dividend which is equal to the profit of each firm, I_t is investment in physical capital, and r_t is the rental rate of physical capital. Capital accumulation obeys the following law of motion under one period time-to-build lag as well as convex adjustment costs in physical investment for generating empirically observed pattern of aggregate investment.

$$K_{t+1} = (1-\delta_K)K_t + I_t\left[1 - \frac{1}{2}\nu\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right] \tag{1.6}$$

where δ_K is the depreciation rate of capital and $\nu > 0$ is a scale parameter.

Then, from the first order conditions of entrepreneur household's utility maximization problem, the Euler equation for shareholdings is given by

$$e_t = (1-\delta)E_t\left[\beta_{t,t+1}(d_{t+1} + e_{t+1})\right] \tag{1.7}$$

where $\beta_{t,t+1} = \beta(C_{E,t+1}^M / C_{E,t}^M)^{-\gamma}$. And the Euler equation for capital accumulation is as follows

$$\zeta_t = E_t\left[\beta_{t,t+1}\Big(r_{t+1} + (1-\delta_K)\zeta_{t+1}\Big)\right] \tag{1.8}$$

where ζ_t is a shadow value of capital.

Translog Preferences

Following Feenstra (2003), I assume the translog form for the consumption aggregator $C_t^M = C_{W,t}^M + C_{E,t}^M$ because the standard constant elasticity of substitution (CES) preferences significantly limit changes in the labor share by making the markup constant. Under the translog preferences, however, the markup becomes time-varying, particularly depending on the number of firms which is endogenously affected by the product market reform. The unit expenditure function on the basket of market goods C_t^M is given by

$$lnP_t = \frac{1}{2\sigma}\left(\frac{1}{N_t} - \frac{1}{\tilde{N}}\right) + \frac{1}{N_t}\int_{\omega\in\Omega_t} lnp_{\omega,t}d\omega + \frac{\sigma}{2N_t}\int_{\omega\in\Omega_t}\int_{\omega\prime\in\Omega_t} lnp_{\omega t}\big(lnp_{\omega,t} - lnp_{\omega\prime,t}\big)d\omega d\omega\prime \quad (1.9)$$

where σ is the price-elasticity of spending share on an individual good and $\tilde{N}$ is the total number of products conceivably available, which is different from N_t, the number of available products at time t.

1.2.2 Firms

A continuum of monopolistically competitive firms produces different varieties. Following Ghironi and Melitz (2005), I assume that a firm is regarded as a production line for individual good. Each firm has a continuum of jobs in a firm, and a job is filled by one worker. Idiosyncratic job productivity $z_{i,t}$ is a per-period i.i.d. draw from a time-invariant distribution, whereas there is no firm-specific productivity. Hence, the productivity of a firm ω is determined by the average productivity of jobs within the firm.

CES Production Function

A filled job i in a firm ω produces $Z_t z_{i,t}(\alpha_K \tilde{k}^{\phi}_{\omega,t} + \alpha_L)^{\frac{1}{\phi}}$ amount of output, where Z_t is aggregate productivity and $\tilde{k}_{\omega,t} = k_{\omega,t}/l_{\omega,t}$ denotes the amount of physical capital allocated to the job. Then, the production of the firm ω is given by the following CES production function

$$y_{\omega,t} = Z_t \tilde{z}_{\omega,t}(\alpha_K k^{\phi}_{\omega,t} + \alpha_L l^{\phi}_{\omega,t})^{\frac{1}{\phi}} \tag{1.10}$$

where ϕ determines the substitutability of the inputs, and α_K and α_L are capital and labor share in production respectively. This CES production function is more appropriate for the inequality analysis than the Cobb-Douglas function, for it allows flexible changes in the labor share together with the time-varying markup. The average job productivity within the firm ω is defined by

$$\tilde{z}_{\omega,t} = \frac{1}{1 - G(z^c_{\omega,t})} \int_{z^c_{\omega,t}}^{\infty} z \, dG(z) \tag{1.11}$$

where $z^c_{\omega,t}$ is an endogenously determined threshold productivity. A job with lower productivity than the threshold is destroyed, and the firm incurs a firing cost F. Jobs can also be terminated with exogenous probability λ.

Labor Friction

Labor matching process is set as in Mortensen and Pissarides (1994). To post a vacancy, a firm pays fixed costs κ, and the vacancy is filled by constant returns to scale matching technology $M_t = \chi U_t^{\epsilon} V_t^{1-\epsilon}$ where χ is matching efficiency, $U_t \equiv 1 - L_t$ is the mass of unemployed members, V_t is the total number of vacancies posted at period t, and ϵ denotes matching function elasticity. Newly created matches are assumed to become productive after one period. Then, the law of motion of employment in a firm ω is given by

$$l_{\omega,t} = (1-\lambda)(1-G(z^c_{\omega,t}))(l_{\omega,t-1} + q_{t-1}v_{\omega,t-1}) \tag{1.12}$$

where $q_t \equiv M_t/V_t$ represents matching rate. The surplus of a job match is divided between the employee and the firm by an exogenous bargaining weight η. The bargained wage is defined by

$$\begin{aligned} w_{\omega,t}(z_{i,t}) = (1-\eta)(h_p + u_b) + \eta \Bigg\{ \varphi_{\omega,t}\left(\frac{\partial y_{\omega,t}}{\partial l_{\omega,t}} \frac{z_{i,t}}{\tilde{z}_{\omega,t}} - \frac{\partial y_{\omega,t}}{\partial k_{\omega,t}} \frac{k_{\omega,t}}{l_{\omega,t}} \right) + \kappa \frac{V_t}{U_t} \\ + \Big[1 - (1-s_t) E_t \tilde{\beta}_{t,t+1} \Big] F + (1-s_t) E_t \tilde{\beta}_{t,t+1} \Big[(1-G(z^c_{t+1}))\varphi_{t+1} \frac{\partial y_{t+1}}{\partial k_{t+1}} \frac{k_{t+1}}{l_{t+1}} \Big] \Bigg\} \end{aligned} \tag{1.13}$$

where $\varphi_{\omega,t}$ denotes the marginal cost of production of the firm ω, $s_t \equiv M_t/U_t$ is job-finding probability, and $\tilde{\beta}_{t,t+1} \equiv (1-\delta)(1-\lambda)\beta(C^M_{E,t+1}/C^M_{E,t})^{-\gamma}$, following the notations in Cacciatore and Fiori (2016).

Profit Maximization

Under the translog preferences, a firm ω faces the following demand for its product

$$y_{\omega,t} = \sigma ln\left(\frac{\bar{p}_t}{p_{\omega,t}}\right)\frac{P_t Y_t}{p_{\omega,t}} \tag{1.14}$$

where Y_t is aggregate demand, $p_{\omega,t}$ is the nominal price of the good ω, and $\bar{p}_t$ denotes the maximum price that the firm can set while keeping a positive market share.

Then, a firm ω chooses the threshold productivity $z^c_{\omega,t}$, the real price of the good $\rho_{\omega,t}$, the amount of physical capital $k_{\omega,t}$, the number of workers $l_{\omega,t}$, and the number of vacancy postings $v_{\omega,t}$ to maximize the present discounted value of real profits

$$\max E_t\left[\sum_{s=t}^{\infty} \beta_{t,s}(1-\delta)^{s-t} d_{\omega,s}\right] \tag{1.15}$$

subject to (1.10), (1.12), and (1.14) constraints, and $\beta_{t,s} \equiv \beta(C^M_{E,t+s}/C^M_{E,t})^{-\gamma}$. And the firm ω's per-period real profit $d_{\omega,t}$ is given by

$$d_{\omega,t} = \rho_{\omega,t}y_{\omega,t} - r_t k_{\omega,t} - \tilde{w}_{\omega,t}l_{\omega,t} - \kappa v_{\omega,t} - G(z^c_{\omega,t})(1-\lambda)(l_{\omega,t-1} + q_{t-1}v_{\omega,t-1})F \tag{1.16}$$

where $\tilde{w}_{\omega,t} \equiv \int_{z^c_{\omega,t}}^{\infty} w_{\omega,t}(z)dG(z)/[1-G(z^c_{\omega,t})]$ is the average wage of jobs in the firm.

By combining the first-order conditions with respect to $l_{\omega,t}$ and $v_{\omega,t}$, the following job creation equation is obtained with the Lagrange multiplier $\varphi_{\omega,t}$ of the constraint (1.10)

$$\frac{\kappa}{q_t} = E_t\left\{\tilde{\beta}_{t,t+1}\left[\left(1-G(z^c_{\omega,t+1})\right)\left(\varphi_{\omega,t+1}\frac{\partial y_{\omega,t+1}}{\partial l_{\omega,t+1}} - \tilde{w}_{\omega,t+1} + \frac{\kappa}{q_{t+1}}\right) - G(z^c_{\omega,t+1})F\right]\right\} \tag{1.17}$$

which equalizes the marginal benefit and the marginal cost of a vacancy posting. And the first-order condition with respect to $z^c_{\omega,t}$ yields the following job destruction equation

$$\varphi_{\omega,t}\frac{y_{\omega,t}}{l_{\omega,t}}\frac{z^c_{\omega,t}}{\tilde{z}_{\omega,t}} - w_{\omega,t}(z^c_{\omega,t}) + \frac{\kappa}{q_t} = -F \tag{1.18}$$

which implies the net value of a job with $z^c_{\omega,t}$ is equal to zero. The first-order condition with respect to $p_{\omega,t}$ yields $\rho_{\omega,t} = \mu_{\omega,t}\varphi_{\omega,t}$, where time-varying markup $\mu_{\omega,t} = 1 + ln(\bar{p}_t/p_{\omega,t})$. Last, the first-order condition with respect to $k_{\omega,t}$ implies $\varphi_{\omega,t}(\partial y_{\omega,t}/\partial k_{\omega,t}) = r_t$, which equalizes the marginal revenue and the marginal cost of capital.

Endogenous Firm Entry

I assume endogenous entry as in Bilbiie, Ghironi, and Melitz (2012). There is an unbounded mass of prospective entrants who are forward-looking and can anticipate the expected future profits. Upon entry, firms have to pay sunk entry costs f_R imposed by regulatory barriers to entry, and recruit workers to fill their jobs. Firms will enter as long as their present discounted value of the expected stream of profits equals to entry costs. So, the free entry condition is

$$e_{\omega,t} = f^E_{\omega,t} \equiv f_R + \kappa v^E_{\omega,t} \tag{1.19}$$

where $e_{\omega,t} = E_t\big[\sum_{s=t+1}^{\infty} \beta_{t,s}(1-\delta)^{s-t} d_{\omega,s}\big]$ denotes expected post-entry value. Firms exit the market only when an exogenous shock with a probability δ hits them. So, the number of firms at period t is given by the following the law of motion

$$N_t = (1-\delta)(N_{t-1} + N_{E,t-1}) \tag{1.20}$$

1.2.3 Symmetric Equilibrium

As Cacciatore and Fiori (2016) prove, producers' decisions are determined only by aggregate conditions under i.i.d. idiosyncratic job productivity and linear costs for hiring and firing workers. Then, every firm chooses the same cutoff productivity and the same mass of employees no matter whether it is an incumbent or an entrant. Therefore, the model features a symmetric equilibrium, implying firm values, prices, and quantities at the equilibrium are identical across firms.

In the symmetric equilibrium, the markup becomes a function of the number of firms N_t as in Bilbiie et al. (2012)

$$\mu_t = 1 + \frac{1}{\sigma N_t} \tag{1.21}$$

which implies that the endogenous markup decreases as more firms compete in the market. The equilibrium price index is also defined by a function of N_t

$$\rho_t = \exp\left(-\frac{1}{2}\frac{\bar{N} - N_t}{\sigma \bar{N} N_t}\right) \tag{1.22}$$

Total amount of physical capital and that of employment is given by $K_t = N_t k_t$ and $L_t = N_t l_t$, respectively. And total vacancies are the sum of the vacancies posted by incumbents and new entrants: $V_t = N_t v_t + N_{E,t} v_{E,t}$, where the vacancy posting of the entrants includes initial labor requirement for starting business $v_{E,t} = v_t + l_t/q_t$. From those aggregate equilibrium conditions, the following law of motion

$$L_t = (1-\lambda)(L_{t-1} + q_{t-1}V_{t-1}) \tag{1.23}$$

is for employment at the aggregate level. Finally, aggregate resource constraint is obtained as follows

$$Y_t = C^M_{W,t} + C^M_{E,t} + I_t + N_{E,t} f_R + \kappa V_t + \frac{G(z^c_t)}{1 - G(z^c_t)} L_t F \tag{1.24}$$

from the budget constraints of the two types of households and equilibrium aggregate conditions.

1.3 Calibration

The model can be solved only numerically under specific parameter values due to its nonlinearity of the equilibrium conditions. So, I calibrate the model by following the conventional values of parameters used in the relevant literature as well as the strategy to match the features of the eurozone macroeconomic data from 1995 to 2013 as in Cacciatore and Fiori (2016). Also, I modify and add a few parameters according to the changes and new features of the model.

First, I set the two parameters of the lognormal distribution for idiosyncratic job productivity: the lognormal mean $\mu_z = 0$ and the lognormal shape $\sigma_z = 0.2$. According to Clementi and Gallegati (2005), the choice of lognormal distribution can be reasonable, for the empirical income distributions are consistent with a two-parameter lognormal function, particularly for the low-middle income group. The lognormal parameters, especially the latter, have significant influences on the distribution of wage and ultimately on the Gini coefficient, for the wage is a function of job productivity. One important caveat here is the lognormal shape parameter needs to be higher than 0.2 to replicate the Gini coefficient in the Euro area. However, the value also affects the variability of unemployment relative to GDP and the transition dynamics. Therefore, I take a value as high as possible to approach the empirical Gini coefficient, while it still does not create problems in the dynamics.

As for the parameters in the CES production function, I set the elasticity of substitution in production ϕ with -0.3 by following empirical studies on the Euro area in Klump et al. (2012). In order to match the labor share to 61 percent of GDP which is the average labor share in the Euro area, I set the labor share in production α_L and capital share in production α_K as 0.4 and 0.6, respectively. The share parameters α_L and α_K together with the elasticity ϕ play an important role in determining the labor share in GDP.

Regarding the three exogenous policy variables, the regulatory entry costs f_R is set such that the total cost paid by entrants is 1.99 percent of GDP, following the procedure taken by Cacciatore and Fiori (2016). And I calibrate the unemployment benefit u_b at 62 percent of the average wage $\tilde{w}$ in line with the replacement rate in the Euro area while the firing costs F is set to match the target area's average unemployment rate, 9 percent.

Next, I calibrate the following parameters according to the conventional values in the literature. I set the discount factor $\beta = 0.99$, the risk aversion $\gamma = 1$, and the exogenous firm exit rate $\delta = 0.025$. Regarding the parameters related to the labor market friction, I use the matching efficiency $\chi = 0.43$ and the exogenous job separation $\lambda = 0.025$. And the workers' bargaining power $\eta = 0.6$ and matching function elasticity $\epsilon = 0.6$ are set with an identical value to meet the Hosios condition. I set the parameters for the translog aggregator: the mass of products $\tilde{N} = 100$ and variety elasticity $\sigma = 3.12$. The depreciation rate of capital and the adjustment cost scale are set by $\delta_K = 0.025$ and $\nu = 1.5$. Aggregate productivity Z is normalized as one. The vacancy posting costs $\kappa = 0.19$ and home production $h_p = 0.66$ are also set to match the Euro area macro data. Table 1.1 summarizes the calibration result.

1.4 Inequality Measures

the Gini Coefficient

Based on the setup and the calibration, one of the inequalities in the model, individual earnings inequality within the working household, can be measured by the Gini coefficient calculated with the after-tax wage distribution across the employed members, the unemployment benefit, and the employment rate. First, I draw a Lorenz curve with simulated data from the above system as shown in 1.2, of which concept is displayed in Figure 1.3. As unemployed members U_t equally receive the lowest earning which is the unemployment benefit u_b, the far-left part of the Lorenz curve becomes a straight line with its slope $u_b/\tilde{w}L_t$. However, the right part of the Lorenz curve is a concave upward curve as usual, because each employed member earns a different wage $w_t(z)$ based on one's job productivity and pays tax according to the endogenous tax rate τ_t. The distribution of disposable income can be obtained from the job productivity distribution as well as information on wage and tax. Then, the endogenous, time-varying Gini coefficient is calculated by computing the area below the Lorenz curve.

As a starting point, it is known that the Gini coefficient in a world with only two levels of income is simply the difference between the portion of the rich group in total income and that of the group in population, which is $b-a$ in Figure 1.4, and the Gini coefficient is greater than $b-a$ if the Lorenz curve is a smooth curve. I call the difference "Income concentration", for it represents how much income is concentrated in the relatively rich group, that is the employed in the model. Since the Lorenz curve generated by the model simulation consists of linear and curved parts as displayed in Figure 1.3, the Gini index will be slightly larger than the difference, $b - a$. It means the Gini coefficient is determined not only by the income concentration but also by the dispersion of after-tax wage, which shapes the curvature of the Lorenz curve.

Therefore, any changes in the Gini coefficient after exogenous policy shocks are made through two channels as follows. First, changes in the "income concentration" can cause the Gini coefficient to vary. As the employed who is a relatively richer group in the model takes a larger portion of income, the degree of inequality measured by the Gini coefficient also rises. In the model, the portion of the employed in total income can be expressed by

$$1 - \frac{u_b(1 - L_t)}{\tilde{w} L_t} = 1 - \left(\frac{u_b}{\tilde{w}}\right)\left(\frac{1 - L_t}{L_t}\right) \tag{1.25}$$

and the portion of the employed in population is just L_t. So, the income concentration (IC) is defined by

$$\mathrm{IC}_t = 1 - \left(\frac{u_b}{\tilde{w}}\right)\left(\frac{1 - L_t}{L_t}\right) - L_t \tag{1.26}$$

which depends on the employment rate L_t and the benefit replacement ratio $(u_b/\tilde{w}_t)$. From the partial derivatives below,

$$\frac{\partial IC_t}{\partial L_t} < 0, \quad \frac{\partial IC_t}{\partial (u_b/\tilde{w}_t)} < 0 \tag{1.27}$$

we can find out that the increase in the employment rate leads to a reduction in the income concentration and that so does the increase in the replacement ratio. This result is intuitive and straightforward. As more people are incorporated into the rich group, in other words, as more household members are hired, the income becomes less concentrated. And, if the unemployment benefit grows faster than the average wage, it also alleviates income concentration by raising the share of the poor group in total income.

Second, the dispersion of after-tax wage $(1-\tau_t)w_t(z)$ represented by the curvature of the Lorenz curve also affects the Gini coefficient. The dispersion depends on three variables: the tax rate τ_t, the threshold productivity z_t^c, and the wage $w_t(z)$. Since the closed form solution of the dispersion cannot be found, the following derivatives are obtained from simulations

$$\frac{\partial \sigma_{wage,t}}{\partial \tau_t} < 0, \quad \frac{\partial \sigma_{wage,t}}{\partial z_t^c} < 0, \quad \text{and} \quad \frac{\partial \sigma_{wage,t}}{\partial w_t(z)} > 0 \tag{1.28}$$

where $\sigma_{wage,t}$ denotes the dispersion of after-tax wage measured by its standard deviation, and $w_t(z)$ is all the wage components other than job productivity in the equation (1.13). The first result is straightforward because the dispersion of after-tax wage falls under a higher tax rate. With respect to the cutoff productivity, its increase leads to the decrease in the dispersion, for the threshold is the lower bound of the wage distribution and determines the lowest wage for the employee matched to the least productive job. Hence, its increase reduces the wage gap between employees. Lastly, an overall increase in the wage components widens the difference between the wage of a job with low productivity and that with high productivity, for the latter increases faster than the former.

the Labor Share in GDP

Next, the other inequality in the model, the income inequality across the households, is measured by the labor and the non-labor share (the sum of capital and profit income shares) in GDP. Those shares are given by

$$\text{labor share} = \frac{\tilde{w}_t L_t}{Y_t^I}, \quad \text{non-labor share} = \frac{N_t d_t + r_t K_t}{Y_t^I} \tag{1.29}$$

where $Y_t^I \equiv \tilde{w}_t L_t + N_t d_t + r_t K_t$ is the NIPA definition of GDP as total income. Using the result from Karabarbounis and Neiman (2013), the labor share under the CES production function in the model is approximately given by

$$S_{L,t} \equiv \frac{\tilde{w}_t L_t}{GDP_t} \approx \frac{1}{\mu_t}\left[\frac{1}{1+\left(\frac{r_t}{\tilde{w}_t}\right)\left(\frac{K_t}{L_t}\right)}\right] \tag{1.30}$$

where $S_{L,t}$ denotes the labor share. So, the labor share depends on the markup, the labor-capital ratio, and the relative factor prices. The derivatives are

$$\frac{\partial S_{L,t}}{\partial \mu_t} < 0, \quad \frac{\partial S_{L,t}}{\partial (L_t/K_t)} > 0, \quad \text{and} \quad \frac{\partial S_{L,t}}{\partial (\tilde{w}_t/r_t)} > 0 \tag{1.31}$$

which implies that if the markup μ_t goes up, the labor share falls because entrepreneurs take a larger share as profit increases, and that if labor is relatively more used in production than before or if the wage increases faster than the rental rate of capital, then the labor share rises since the total labor income is the product of wage $\tilde{w}_t$ and the amount of labor L_t.

1.5 Analysis under the Baseline Model

1.5.1 Steady States

First, by comparing the two inequality measures in initial and new steady states, I analyze the distributional impacts of structural reforms applied by a perfect foresight, permanent cut in policy variables. I assume policy variables are lowered to their corresponding U.S. levels following the convention in the literature. Table 1.3 and Table 1.4 display the Gini coefficient and the labor share in the initial and the new steady states, respectively.

Product Market Reform

Product market reform represented by the reduction of the regulatory entry costs in the model improves income equality in any measures. First, the reform makes the Gini coefficient fall slightly as shown in Table 1.3. After lowering barriers to entry, the product market becomes more competitive by the influx of new entrants. It makes the labor market tighter and raises employment as well as wages. Also, as the unemployment rate decreases, the required tax rate to finance the unemployment benefits goes down as well. These effects raise after-tax wage dispersion and put upward pressure on the Gini coefficient. However, as the employed group gets bigger in size, the overall income concentration falls, causing the Gini coefficient to go down. The reduction in the income concentration has a bigger impact than the adverse impact from the widened wage dispersion.

Second, the product market reform increases the labor share as displayed in Table 1.4. As stated in the model section, the markup falls when the number of firms in the economy increases. So, the reform lowers the markup significantly by boosting competition among firms, and in turn, the lowered markup leads to bigger labor share in total income. Even though there are changes in relative factor prices and the labor-capital ratio as well, the two effects mostly offset each other, because they move in opposite directions. Therefore, the change in the markup becomes a major determinant of the labor share.

Labor Market Reforms

The type of labor market reforms to be considered first is less strict employment protection which is represented by lowering the costs related to firing employees. Contrary to the general perception, this reform rather lowers the Gini coefficient, and more surprisingly, the decrease in the Gini coefficient is bigger than that in the case of the product market reform. Lowering the firing costs lets firms have an incentive to terminate relatively low productive jobs. This causes cutoff productivity to rise and limits the wage increase. So, the wage dispersion among the employed rather falls, unlike the product market reform which leads to an increase in the dispersion. On top of that, the reform results in more employment at the new steady state, which reduces income concentration. So, easier firing makes a bigger fall of the Gini coefficient than the product market reform. Though this reform has a little negative impact on the labor share as shown in Table 1.4, the magnitude is almost negligible because the change toward less labor-intensive production is offset by the increase in the labor costs. Therefore, overall easier dismissal contributes to income equality.

On the contrary, the next type of labor market reforms, less generous unemployment benefits worsens inequality in both inequality measures. As displayed in Table 1.3, this reform raises the Gini coefficient significantly, compared to the other reforms. Since the lower replacement rate ($u_b/\tilde{w}$) reduces workers' outside option, overall wages determined by negotiation between the employers and the employees fall, making firms increase employment by filling even jobs with low productivity. Despite the equalizing effect from the increased employment, the income concentration rises because the unemployment benefit cut directly widens the gap between the unemployed and the employed. In addition, both the less unemployment benefit and the lower unemployment rate significantly reduce the individual tax burden, causing the wage dispersion to increase. Hence, via both channels, the Gini coefficient rises after the reform. Regarding the impact on the labor share, it is also limited because the unfavorable impact on labor is offset by the decrease in the markup to some extent.

1.5.2 Transition Dynamics

Next, I elaborate on the short- to medium-run distributional consequences of the above three reform measures as well as the mix of them. Since the sizes of the shocks are big, transition dynamics can be obtained by solving the non-linear system by using a Newton-Raphson method as in Laffargue (1990).

Product Market Reform

Figure 1.5 displays the impulse responses to the product market reform represented by a permanent decrease in regulatory entry costs. Lower entry barrier encourages new firms to enter the product market, leading to overall downsizing of firms and the rise of cutoff productivity. To finance the establishment of new firms, the entrepreneur-household has to retrench in consumption expenditures and physical capital investment. This makes aggregate demand to shrink, and in turn, it causes so-called "short-term pain" of the reform such as the temporary falls in consumption, GDP, and employment in the aftermath of the reform. On the other hand, the reform has a positive impact on income equality, especially in terms of the Gini coefficient. Since the initial surge of unemployment raises the required tax rate, it reduces the individual earnings dispersion together with the immediate, sharp increase in the cutoff productivity. Also, the labor share gradually goes up mainly due to the declining markup.

Over time, so-called "long-term gains" of the reform emerge. As the number of firms eventually increases, active job creation takes place across firms and raises the average wage. So, the economy recovers with solid rebound of consumption, employment and GDP above the initial steady-state levels. During the period, the labor share keeps rising by the reduction in the markup and by the steady recovery of employment and overall wages. But the Gini coefficient, which sharply declined in the immediate aftermath of the reform, slowly goes up and approach its initial steady-state level, for the reversals of unemployment and the tax rate result in the rebound of the Gini coefficient.

Labor Market Reforms

Figure 1.6 plots the transition dynamics in response to the first type of labor market reforms: a permanent reduction in firing costs. Lower firing costs accompany immediate adverse impact on employment, because firms terminate low productive job matches right after the reform, leading to the surge of threshold productivity. So, the labor share falls reflecting the unfavorable changes to workers. But the Gini coefficient decreases in the short-run because the tax rate needs to be raised significantly in order to finance increased claims for unemployment benefits.

However, the above short-run result caused by instantaneous job destruction is eventually taken over by a positive impact of the reform on job creation. Since the reform enhances the expected profits from new job matches, firms want to hire more workers, and in turn, the economy's employment rate goes up gradually. The increases in the employment and the wage boost aggregate demand as well as the labor share, resulting in economic recovery over time. Together with the fall of the Gini coefficient, it brings a better outcome in terms of equality.

Next, the other labor market reform, a permanent cut in unemployment benefits, displays clear distinction from the above reforms in the transition dynamics shown in Figure 1.7. Unlike the other reforms, it does not cause the so-called "short-term" pains in terms of GDP, employment, etc., but accompanies strong, negative impact on income inequality from the immediate aftermath of the reform on. Less generous unemployment benefits basically weaken the bargaining power of the workers by lowering their outside option, resulting in the fall of the average wage. It boosts job creation without causing unemployment even in the early stage of the reform and generates an instantaneous expansionary effect in consumption, investment, and GDP. However, this unemployment benefit cut causes the earnings dispersion between the unemployed and the employed to increase and lowers tax rate significantly. Therefore, the Gini index shows an initial spike and the labor share falls due to the lower average wage.

However, as the expansionary effects in consumption, investment and production eventually subdue, the sharp adverse impact on income distribution lessens over time. A noticeable dynamic is the increase in the number of firms accompanied by the rebound of wages. Since the economic expansion and the unemployment benefit cut provide a favorable environment for entrepreneurs, new firms enter, and the labor market becomes tighter. So, the labor share rebounds with the recovery of overall wages while the Gini coefficient descends from its initial peak.

1.6 Analysis under the Alternative Taxation Scenario

In this section, I consider an alternative taxation scenario, in which all kinds of income are taxable. This scheme is more realistic, for the U.S. government finances social security and unemployment benefits with payroll taxes that are equally paid by employers and employees. So, the total unemployment benefits are now assumed to be equally paid by both households:

$$\frac{u_b U_t}{2} = \tau_{W,t}\tilde{w}_t L_t = \tau_{E,t}\big[(d_t + e_t)N_t + r_t K_t\big] \tag{1.32}$$

where $\tau_{W,t}$ and $\tau_{E,t}$ are the tax rates for workers and entrepreneurs respectively. This makes changes in the budget constraints of the two households:

$$C^M_{W,t} = (1 - \tau_{W,t})\tilde{w}_t L_t + u_b(1 - L_t) \tag{1.33}$$

$$C^M_{E,t} + e_t(N_t + N_{E,t})x_{t+1} + I_t = (1 - \tau_{E,t})\big[(d_t + e_t)N_t x_t + r_t K_t\big] \tag{1.34}$$

and the Euler equations also change accordingly as follows

$$e_t = (1 - \delta)(1 - \tau_{E,t+1})E_t\big[\beta_{t,t+1}(d_{t+1} + e_{t+1})\big] \tag{1.35}$$

$$\zeta_t = E_t\Big\{\beta_{t,t+1}\big[(1 - \tau_{E,t+1})r_{t+1} + (1 - \delta_K)\zeta_{t+1}\big]\Big\} \tag{1.36}$$

Table 1.5 displays the changes in the Gini index and the labor share in response to each structural reform measure. In general, the new taxation scheme improves the distributional consequences of all the reform measures: the Gini index falls more while the labor share increases more. Since the working household is asset-poor and hand-to-mouth consumers, sharing the tax burden with entrepreneurs has a direct impact on the economy, especially, on aggregate demand and employment. Hence, this enhances the performance of the reforms and brings a better outcome in terms of equality. An exception is a slight decrease in the labor share after the product market reform. Unlike the labor market reforms, this reform requires entrepreneurs' massive initial investment for new firms, so the new tax burden for the unemployment benefits can undermine the overall performance of the reform, leading to a lower labor share.

1.7 Reform Package and Policy Implication

Now, based on the short- to medium-term effects of individual reform measures, I consider transition dynamics of the reform package which consists of all the three reform measures, as displayed in Figure 1.8 and 1.9. In the short run, the reform package brings immediate adverse impacts on income distribution: the Gini coefficient rises, and the labor share falls in the aftermath of the reform. This instantaneous disequalizing effect is mainly caused by the reduction in the benefit replacement rate, which works right away by widening the gap between the unemployed and the employed. However, as the long-term gains of the reforms, particularly the reduction in the regulatory costs and the firing costs, emerge over time, the labor share eventually rises and go beyond the pre-reform level while the increase in the Gini coefficient becomes soothed rapidly.

This simulation result sheds light on the reason of public opposition and concern over structural reforms and suggests a desirable sequence of the reforms. As discussed above, structural reforms do not necessarily worsen inequality in the long-run. Rather, certain reform measures can contribute to income equality. But the main problem is that the reduction in the unemployment benefit brings immediate adverse effects on inequality, whereas the other reforms take time to generate equalizing effects. Considering the public tends to focus on the short-term result of economic policies, careful sequencing of reforms is required to smooth out the short-term disequalizing impact over time so that the acceptability of structural reforms can be enhanced.

Therefore, it would be desirable that policymakers first lower regulatory barriers to entry and later loosen employment protection. The unemployment benefits can be reduced as the previous reforms start to reap gains. The rationale behind the sequence of structural reforms is straightforward. The lower entry barrier induces entrepreneurs to active establishments of new businesses, which creates enough job opportunities. This is important as a cushion for the possible unemployment increase following the easier firing. And by maintaining generous unemployment benefit in the meantime, those who are fired after the labor market reform can be supported by the social safety net. Finally, after identifying the positive gains from the first two reforms, we would be able to lessen the unemployment benefit.

1.8 Conclusions

I have studied the distributional consequences of the structural reforms based on a full general equilibrium model with simple heterogeneity in households and under different taxation scenarios. The main finding is that the reforms do not necessarily worsen inequality but show different distributional impacts according to reform measures and time horizon. First, the product market reform rather reduces inequality, for it promotes firms' competition and decreases overall return on investment while it increases employment and wages. Second, the less strict employment protection decreases the dispersion of labor income measured by the fall of the Gini index, but at the same time, it decreases the labor share a little. Third, the unemployment benefit cut worsens inequality with no doubt, as it widens the gap between the unemployed and the employed as well as the gap between workers and investors. Fourth, simultaneously implemented reform package leads to significant adverse impacts in the immediate aftermath of the reforms but eventually rather improves equality as the reforms bring the long-term gains. So, this study suggests that policymakers can smooth out the immediate disequalizing effects of the reforms by implementing the labor market reforms, particularly the less generous unemployment benefit, later than the product market reform. This sequencing would enhance the public reception of structural reforms until the long-term benefits are realized.

1.9 Tables and Figures

Table 1.1: Calibration

Labor share in production	$\alpha_L = 0.4$	Capital share in production	$\alpha_K = 0.6$
Elasticity of substitution in prod.	$\phi = -0.3$	Mass of products	$\tilde{N} = 100$
Discount factor	$\beta = 0.99$	Risk aversion	$\gamma = 1$
Exogenous firm exit	$\delta = 0.025$	Exogenous job seperation	$\lambda = 0.025$
Depreciation rate	$\delta_K = 0.025$	Adjustment cost scale	$\nu = 1.5$
Variety elasticity	$\sigma = 3.12$	Matching efficiency	$\chi = 0.43$
Workers' bargaining power	$\eta = 0.6$	Matching function elasticity	$\epsilon = 0.6$
Aggregate productivity	$Z = 1$	Firing cost	$F = 0.197$
Sunk entry cost	$f_R = 3.68$	Vacancy posting cost	$\kappa = 0.19$
Home production	$h_p = 0.66$	Unemployment benefit	$u_b = 1.64$
Lognormal mean	$\mu_z = 0$	Lognormal shape	$\sigma_z = 0.2$

Table 1.2: Steady States before and after the Reforms

	initial	f_R cut	F cut	$u_b/\tilde{w}$ cut
Gini	0.084	-0.24%	-0.96%	3.70%
Labor share	0.613	2.49%	-0.06%	-0.03%
Y (output)	5.081	3.45%	0.60%	1.91%
$\tilde{z}$ (productivity)	1.021	-0.03%	0.16%	-0.04%
L (labor)	0.905	1.09%	0.43%	1.93%
K (capital)	41.37	4.91%	0.67%	2.05%
N (firms)	3.196	30.32%	0.36%	1.03%
w (wage)	3.442	4.88%	0.11%	-0.04%
d (profit)	0.148	-37.24%	0.45%	0.65%
μ (markup)	1.10	-2.12%	-0.03%	-0.09%
τ (tax rate)	0.068	-12.41%	-4.55%	-26.52%

Notes: The numbers in the table are percentage changes from the initial steady-states.

Table 1.3: Changes in the Gini Coefficient

		Initial	f_R cut	F cut	$u_b/\tilde{w}$ cut
Gini		**0.0838**	**0.0836 (-0.24%)**	**0.0830 (-0.95%)**	**0.0869 (+3.70%)**
IC		**0.0266**	**0.0252 (-5.26%)**	**0.0258 (-3.01%)**	**0.0272 (+2.26%)**
	L	0.9054	0.9153 (+1.09%)	0.9093 (+0.43%)	0.9228 (+1.93%)
	$u_b/\tilde{w}$	0.6507	0.6432 (-1.15%)	0.6506 (-0.015%)	0.5974 (-8.19%)
σ_{wage}		**0.9029**	**0.9756 (+8.05%)**	**0.8732 (-3.29%)**	**0.9893 (+9.57%)**
	z^c	0.5299	0.4966 (-6.28%)	0.5918 (+11.67%)	0.4097 (-22.69%)
	τ	0.0680	0.0596 (-12.41%)	0.0649 (-4.55%)	0.0500 (-26.52%)
	$\tilde{w}$	3.4415	3.6095 (+4.88%)	3.4451 (+0.11%)	3.4401 (-0.04%)

Notes: Initial and new steady-states with percentage changes in the brackets.

Table 1.4: Changes in the Labor Share

	initial	f_R cut	F cut	$u_b/\tilde{w}$ cut
Labor share	**0.6132**	**0.6284 (2.49%)**	**0.6128 (-0.06%)**	**0.6130 (-0.03%)**
μ	1.1000	1.0767 (-2.12%)	1.0996 (-0.03%)	1.0990 (-0.09%)
L/K	0.0219	0.0211 (-3.65%)	0.0218 (-0.24%)	0.0219 (-0.12%)
$\tilde{w}/r$	95.273	99.924 (4.88%)	95.375 (0.11%)	95.234 (-0.04%)

Notes: Initial and new steady-states with percentage changes in the brackets.

Table 1.5: Distributional Impacts under Different Taxation Schemes

Tax	Measure	initial	f_R cut	F cut	$u_b/\tilde{w}$ cut
labor income	Gini	0.084	-0.24%	-0.96%	3.70%
	Labor share	0.613	2.49%	-0.06%	-0.03%
all kinds of income	Gini	0.086	-0.70%	-1.16%	2.21%
	Labor share	0.610	2.34%	0.01%	0.35%

Notes: The numbers in the table are percentage changes from the initial steady-state.

Figure 1.1: The Layers of Inequality

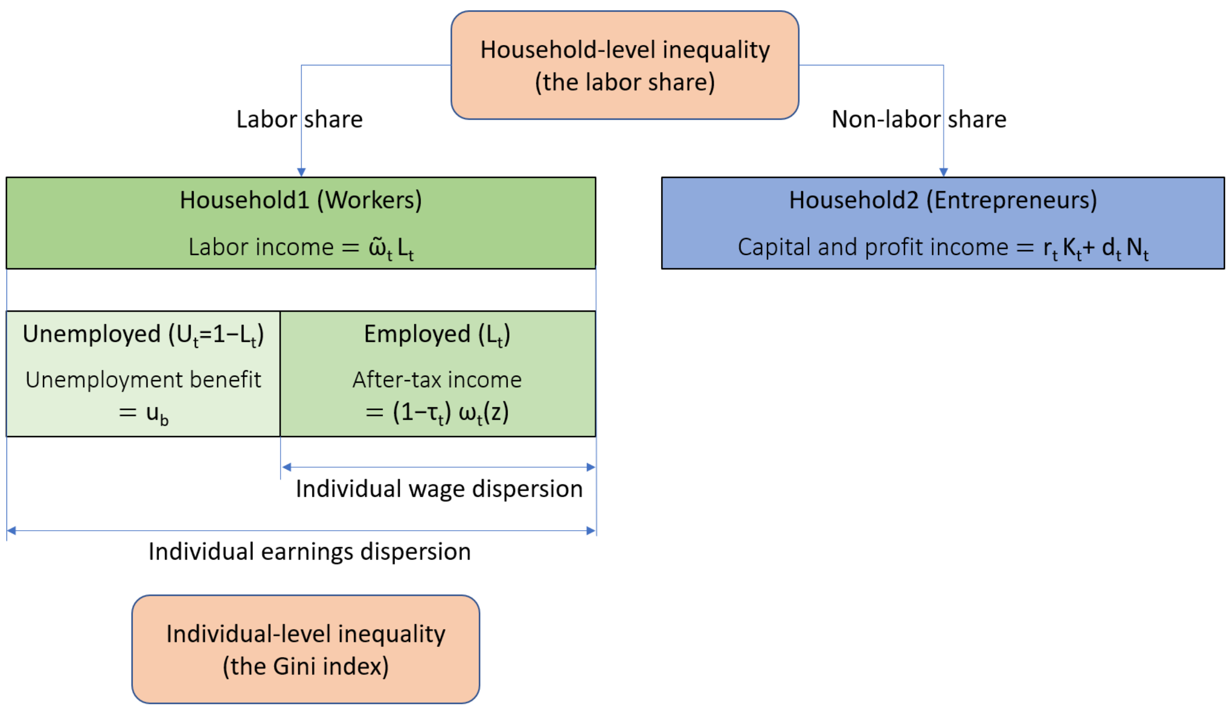


Figure 1.2: The Lorenz Curve Generated from the Model Simulation

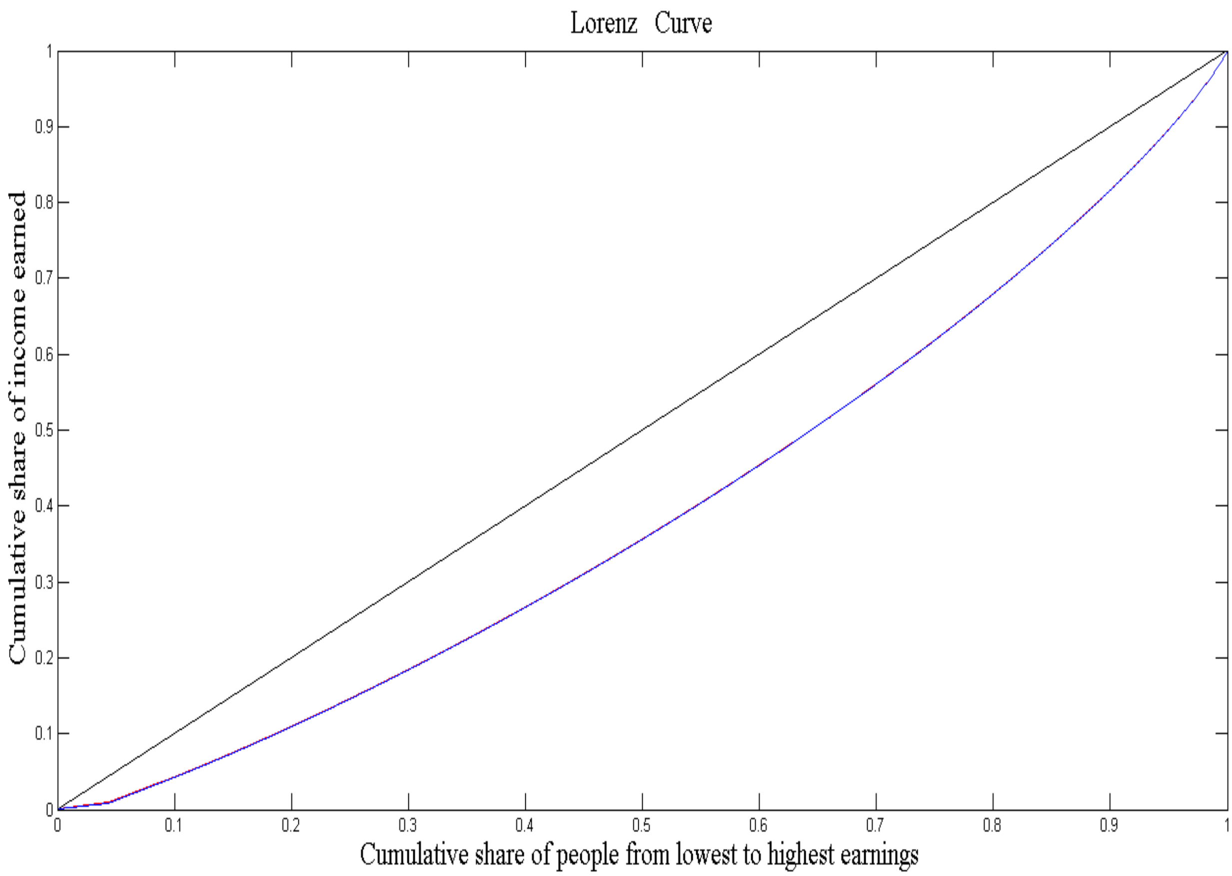


Figure 1.3: The Construction of the Lorenz Curve in the Model

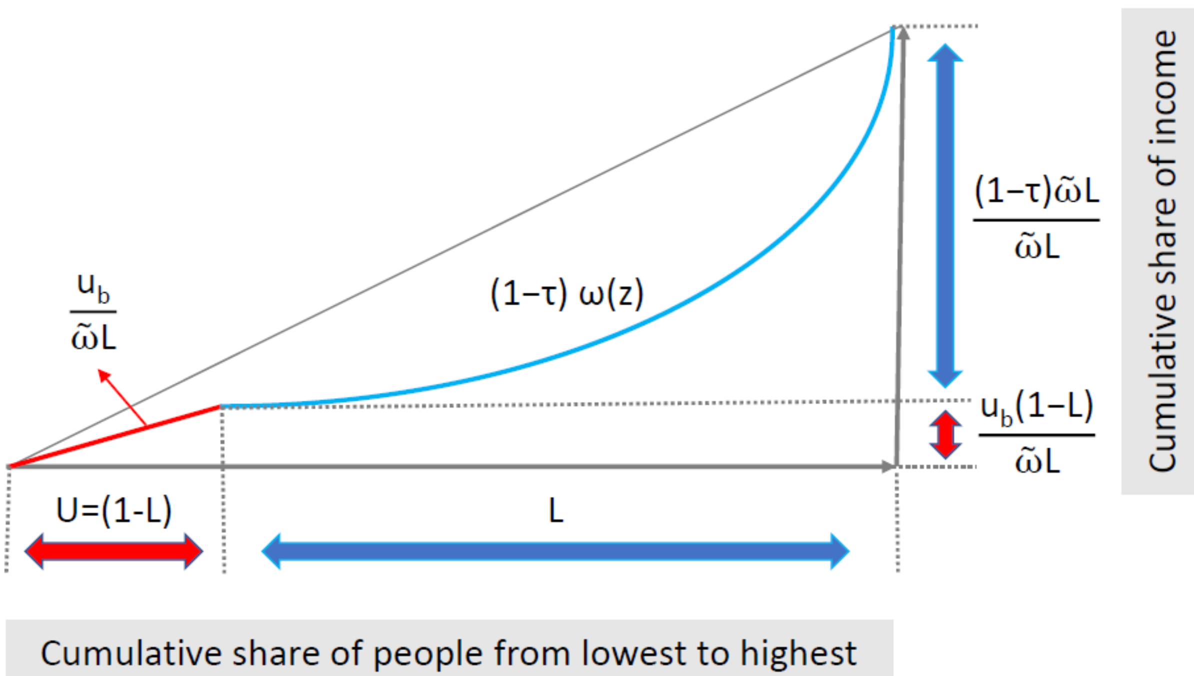
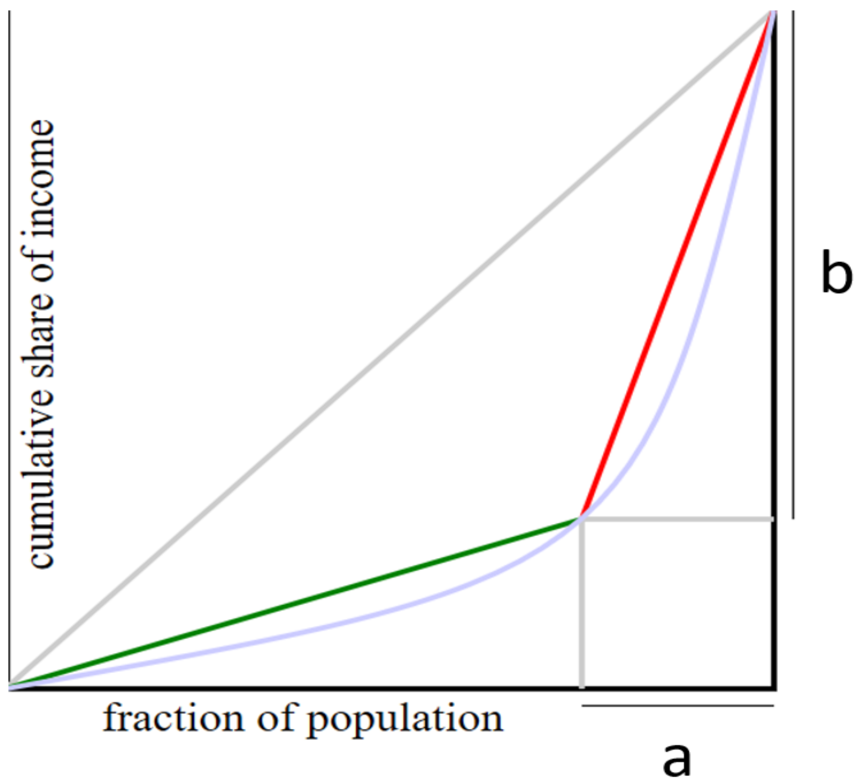
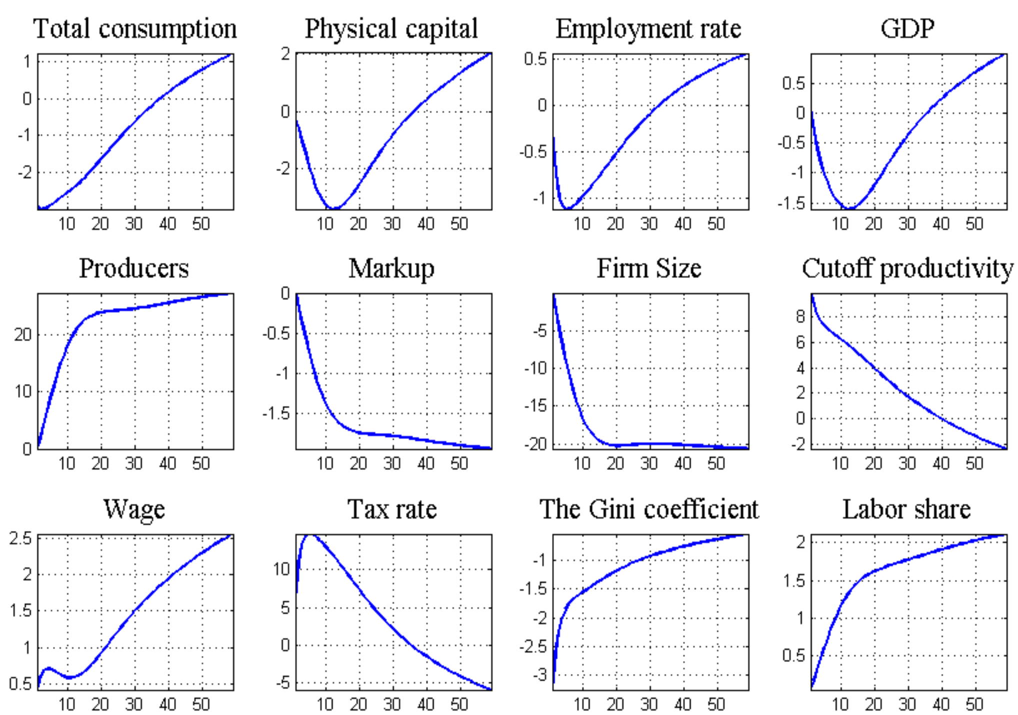


Figure 1.4: The Gini Coefficient with Two Levels of Income



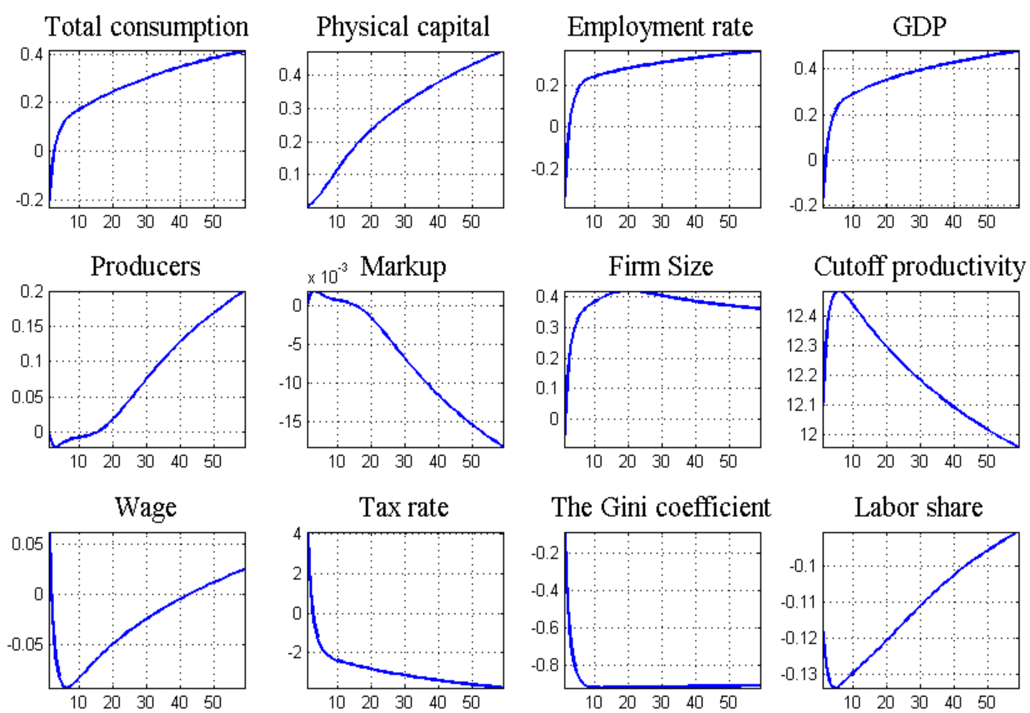
Note: The above image is modified from the original source, Wikimedia Commons (Author: Woodstone)

Figure 1.5: Impulse Response to Product Market Reform: Entry Cost Reduction



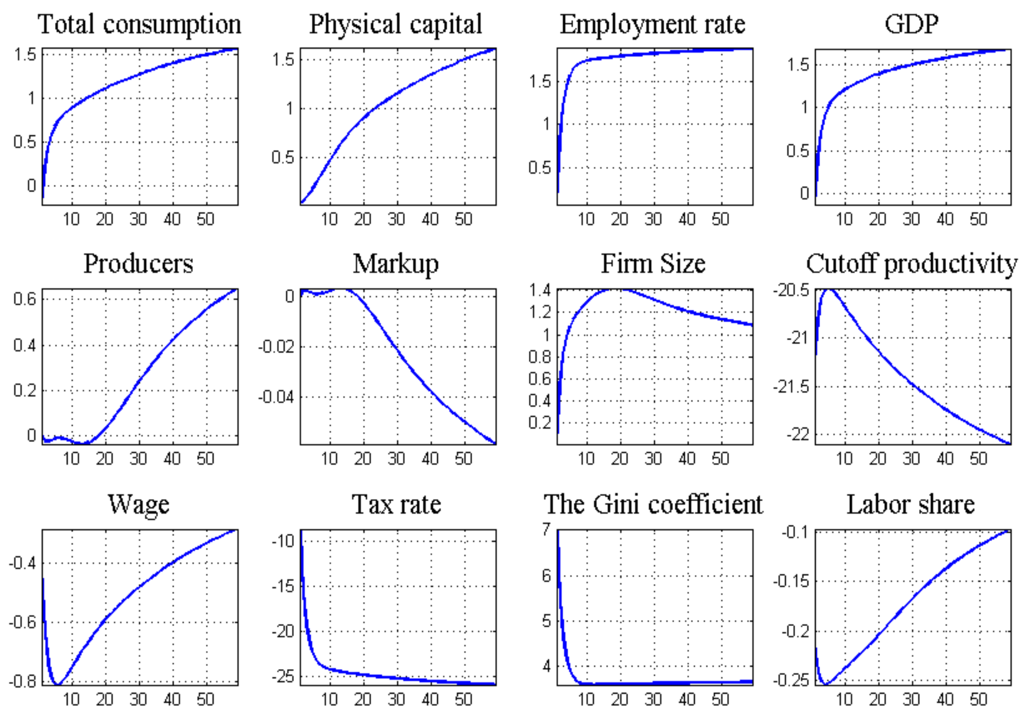
Notes: The variables are in percentage deviations from the steady-state.

Figure 1.6: Impulse Response to Labor Market Reform: Firing Cost Reduction



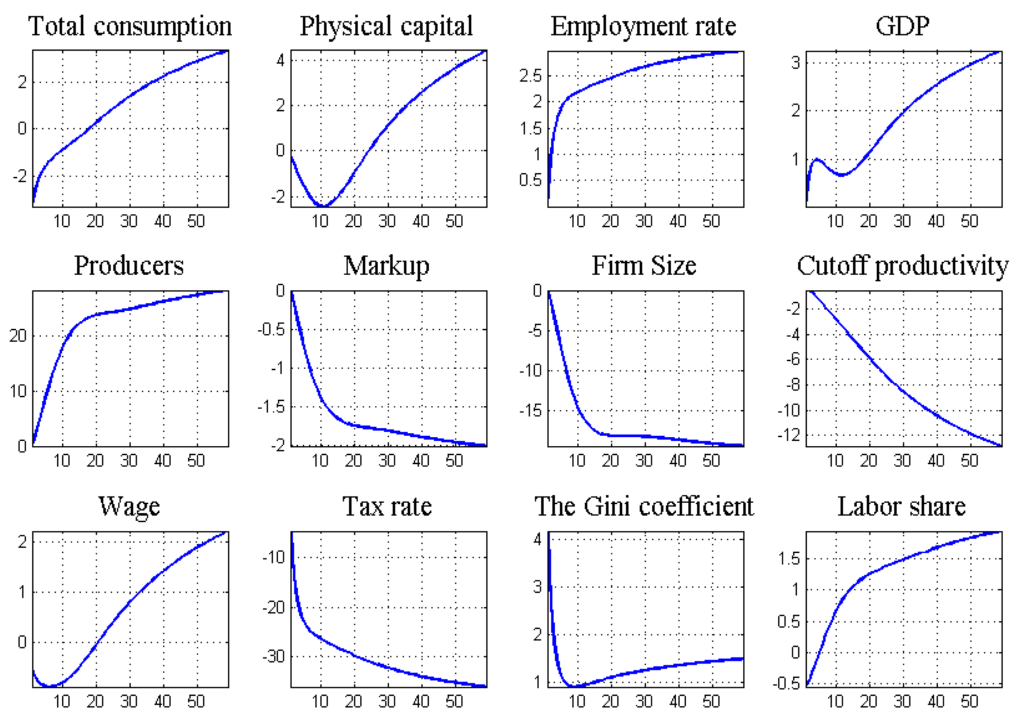
Notes: The variables are in percentage deviations from the steady-state.

Figure 1.7: Impulse Response to Labor Market Reform: Unemployment Benefit Cut



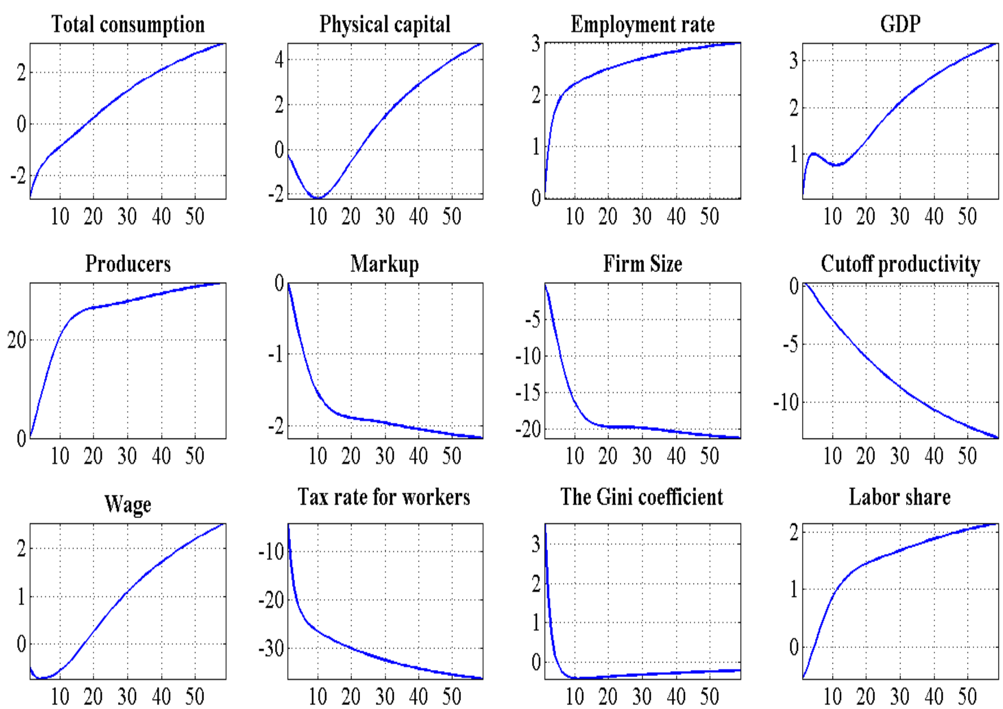
Notes: The variables are in percentage deviations from the steady-state.

Figure 1.8: Impulse Response to the Reform Package(1)



Notes: The above impulse responses are under the baseline model, and variables are in percentage deviations from the steady-state.

Figure 1.9: Impulse Response to the Reform Package(2)



Notes: The above impulse responses are under the alternative taxation scenario, and variables are in percentage deviations from the steady-state.

Chapter 2

STRUCTURAL REFORMS IN GRANULAR ECONOMIES

2.1 Introduction

Structural reforms designed to increase market flexibility are often advocated as part of policy menu to boost economic performance and have been repeatedly called by the president of the ECB Mario Draghi and the managing director of the IMF Christine Lagarde. The current literature on structural reforms emphasizes the importance of initial conditions of countries implementing the reforms because short- and long-term effects of reforms significantly vary depending on the conditions. For example, Cacciatore et al. (2015, 2016a, 2016b and 2017) show product and labor market reforms in different scenarios for business cycles and their interaction with macro policy.

In line with the literature, we study the effects of product market reform under different degrees of granularity as another important initial condition. During the Asian financial crisis in 1997-98, the IMF provided bailout funds for crisis-hit countries tying the funds to economic reforms, the "Structural Adjustment Package". As shown in Figure 2.1, after the structural reforms, transition appeared costly in the countries, particularly in Korea which is a prime example of granular economies. Our results suggest that reforms in more granular economies are likely to be associated with larger long-run gain, but more short-run pain than those in less granular ones. In a granular economy, the average size of entrants is bigger given its fat-tailed distribution of firm size, and so is the marginal impact of new entry on firms' survival. Therefore, the product market reform leads to a larger reduction of the number of operating firms[1] as well as consumption at the immediate aftermath of

[1] We intentionally distinguish between operating firms and total firms in an economy. In our setup, only some fraction of firms operates at any period due to the existence of cutoff productivity under fixed operating costs.

reforms in the granular economy. However, since this relatively tougher survival condition enhances the average productivity of firms more in the economy, the productivity gain brings larger benefits over time as the total number of firms increases. A recent empirical study by Marrazzo and Terzi (2017), which suggests that emerging economies experience bigger short-term pain from their reforms but reap more benefits than advanced countries in the long-run, is very relevant to our result considering advanced countries are likely to be less granular than emerging ones.

More importantly, we shed light on the effect of the product market reform on the economy's granularity and further on aggregate volatility in response to idiosyncratic shocks. As Gabaix (2011) suggests, granularity requires fat-tailed distribution of firm size, and in this environment, idiosyncratic shocks to large firms have aggregate effects. Therefore, policy actions that affect the number and the size distribution of operating firms matter for the extent to which the economy is granular. Product market reform lowers entry barriers and induces an influx of new entrants, causing the economy less granular. On the other hand, it also creates fierce competition and makes less productive firms fall behind, leading to more concentration on larger and more productive firms. Depending on the magnitudes of these conflicting effects, the degree of granularity varies over time. We theoretically and empirically find out that the product market reform makes an economy become more vulnerable to idiosyncratic shocks in the short-run but more resistant to them in the long-run, and that the marginal impact of the reform on aggregate volatility is larger in a (more) granular economy regardless of time horizon. To show and support the results, we derive analytical formulas of the Herfindahl index, a typical measure of the degree of granularity, and the aggregate volatility and we also estimate a panel VAR for OECD countries. This is the first study which investigates the interrelationship between the product market reform and the granularity based on a full dynamic general equilibrium model with a continuum of heterogeneous firms.

The rest of the chapter is organized as follows. Section 2.2 presents some empirical findings, which motivate and support our theoretical study. Section 2.3 develops a simple theoretical framework as a baseline and Section 2.4 provides analytical solutions of the model as well as transition dynamics based on a calibrated model. Section 2.5 extends the baseline model with idiosyncratic shocks and Section 2.6 analyzes the impact of the product market reform on the aggregate volatility. Section 2.7 concludes.

2.2 Empirical Findings

2.2.1 Data Description

We use the OECD indicators of Product Market Regulation (PMR) from OECD Statistics database as our main indicator for product market regulation. The indicators are a comprehensive and internationally-comparable, and measure the regulatory and market environments in 34 OECD countries and in 13 non-OECD countries[2] including BRICs. Next, we calculate the Herfindahl-Hirschman index, another main indicator in this chapter as a measure of the degree of granularity, with the operating revenues of the top 25 firms in each country from the Mint Global database[3]. Other data: yearly GDP, GDP per capita and trade-to-GDP ratio, come from the World Development Indicators database, while quarterly GDP is from the OECD Statistics database.

An important caveat is that the available years of the two main indicators are limited. Since it is impossible to obtain credible time-series data of the Herfindahl index, we only have the index calculated with data at the latest available year of each firm, which is mostly 2017. Thus, the Herfindahl index can be regarded as the degree of market concentration as of 2017. Also, the OECD indicators of PMR are provided for the following 4 years only: 1998, 2003, 2008 and 2013, and available years vary across countries. To utilize all the available data, we take the average of each variable (except the Herfindahl index) over 1998-2013 and match the availability of the OECD indicators of PMR.

[2]The countries are: Brazil, Bulgaria, China, Croatia, Cyprus, India, Indonesia, Latvia, Lithuania, Malta, Romania, Russia, and South Africa.

[3]The Mint Global is a streamlined version of the Orbis database and contains comprehensive information on 275 million companies worldwide, mainly medium and large-sized firms. Though the Orbis covers more small-sized firms, the Mint Global is good enough for obtaining data of top 25 firms and much cheaper.

2.2.2 The Results of Empirical Analysis

First, we investigate the relationship between product market regulations, particularly legal barriers to entry, and the degree of granularity. As presented in Table 2.1, we regress the latest Herfindahl index against the legal barrier to entry which is a component of the OECD PMR indicators. Other variables such as trade-to-GDP ratio, GDP share in world GDP, and GDP per capita are also used following di Giovanni and Levchenko (2012). The coefficients of legal barriers to entry are significant under 5% or 10%, and R-squared of the regressions are over 0.34 in most cases, implying that if a country's legal barrier to entry is high, market concentration is likely to be high as well. Also, we find that the trade-to-GDP ratio is very significant mostly under 1% in line with di Giovanni and Levchenko (2012). Figure 2.2 is a partial regression plot from the regression in Table 2.1, displaying the relationship between the Herfindahl index and the average of the legal barriers to entry for a sample of 44 countries over the period 1998-2013, after netting out the impact of trade-to-GDP ratio during the period. Intuitively, countries with higher entry barriers tend to be more concentrated.

As a logical consequence of the above result, if rigid product market regulation is likely to raise the degree of granularity, it may lead to higher volatility as well. Figure 2.3 depicts another partial regression plot showing the relationship between aggregate volatility and product market regulation after netting out the impact of country size in the sample of 42 OECD and non-OECD countries over the period 1998-2013. The volatility is defined by the standard deviation of quarterly GDP growth rate over the period, and the country size is the portion of the country in world GDP. The country size and the PMR indicator are averages over the same period and logged. As expected, this figure suggests that more product market regulations are likely to be associated with bigger aggregate fluctuation of the country. The result is significant with a t-statistic of the product market regulation variable as 2.19 and R-squared over 0.43.

Last, since our research questions are whether short- to long-term results of structural reforms are different according to the degrees of granularity of countries, and if so, how different the results will be, we empirically estimate the impacts of the product market reform using a panel VAR following Cacciatore and Fiori (2016). They estimate a panel VAR with harmonized annual data for the sample of 21 OECD countries[4] over the period 1982-2005. We extend their data set[5] by adding the standard deviation of quarterly GDP each year over the same period and divide the set into two according to the countries' Herfindahl indexes. So, we consider four macroeconomic variables - the unemployment rate, real GDP, real investment and GDP volatility - and OECD indicator of regulatory impediments, which reflects barriers to entry. Figure 2.4 and 2.5 present impulse responses following a one-standard deviation reduction in product market regulation with continuous lines representing median responses and dashed lines representing 68 percent confidence bands. The impulse responses of both groups display so-called "Short-term pain and Long-term gain" of structural reforms in the current literature. The product market reform leads to a decrease in output as well as an increase in volatility in the immediate aftermath of the reform, but eventually brings an upturn in output and a decline of volatility. The notable difference between the groups is that relatively more granular group is likely to experience a bigger negative impact in the short-run in terms of larger GDP drop and volatility rise, followed by bigger positive effects in the medium-term as shown in Figure 2.4 and 2.5. This finding sheds light on the importance of granularity for short- to medium-term performances of structural reforms, which is the main idea of this chapter.

2.3 The Model

Our baseline model is set up by modifying the Ghironi and Melitz (2005) model. We simplify it as a closed economy version in order to focus on the pure effects of product market reforms and incorporate fixed production costs which enable endogenous changes in the firm-size

[4]The countries are: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and the United States.

[5]Refer to the Appendix of Cacciatore and Fiori (2016) for data description except for the GDP volatility that is added in this paper.

distribution. In the absence of fixed production costs, every monopolistically competitive firm in a closed economy earns positive profits regardless of its own productivity, implying that all firms continue production unless they are hit by exogenous exit shocks. So, the degree of granularity of the model economy is exogenously pinned down by the shape parameter of the Pareto distribution, because the size distribution of firms is time-invariant. On the other hand, once we include fixed production costs, there exist some firms that are unable to cover their fixed costs and only firms productive enough operate. The cutoff productivity changes depending on overall economic conditions as well as policy actions, leading to endogenous changes in the size distribution of operating firms. Thus, the degree of granularity in our model can endogenously vary over time. This major difference from the Ghironi and Melitz (2005) plays a key role in analyzing the impact of product market reforms on the granularity. We basically follow the setup in the Ghironi-Melitz (2005) except the above departures. Hence, this section focuses on the description of new features hereafter, and we refer readers to the article for details.

2.3.1 Household Preferences

The economy is populated by a unit mass of atomistic households. The representative household supplies one unit of labor inelastically in each period at the nominal wage rate W_t and maximizes the expected intertemporal utility from consumption:

$$E_t\left[\sum_{s=t}^{\infty}\frac{\beta^{s-t}C_s^{1-\gamma}}{1-\gamma}\right] \tag{2.1}$$

where $\beta \in (0,1)$ is the discount factor and $\gamma > 0$ is the inverse of the intertemporal elasticity of substitution. The household consumes the basket of goods C_t defined over a continuum of goods Ω: $C_t = \left(\int_{\omega\in\Omega} c_t(\omega)^{(\theta-1)/\theta} d\omega\right)^{\theta/(\theta-1)}$, while only a subset of goods $\Omega_t \subset \Omega$ is available at any given time t, and $\theta > 1$ is the elasticity of substitution across goods. Let $p_t(\omega)$ denote the nominal price of each good $\omega \in \Omega_t$, then the consumption-based price index for the economy is $P_t = \left(\int_{\omega\in\Omega} p_t(\omega)^{1-\theta} d\omega\right)^{1/(1-\theta)}$, and the household's demand for a good ω becomes $c_t(\omega) = (p_t(\omega)/P_t)^{-\theta} C_t$.

2.3.2 Production

There is a continuum of monopolistically competitive and heterogeneous firms, and each firm produces a differentiated good $\omega \in \Omega_t$ with different technologies indexed by firm-specific productivity z. The firm-specific productivity z is determined upon entry and remains fixed thereafter. After paying a sunk entry cost[6] of $f_{E,t}$ effective labor units, firms draw their productivity level z from a time-invariant Pareto distribution G(z) with support on $[z_{min}, \infty)$ and shape parameter $\kappa > \theta - 1$. Then, the size distribution of firms also becomes Pareto, for the size of a firm depends on its productivity z. So, the firm sizes are increasingly concentrated toward their lower bound z_{min} as the exogenous shape parameter κ increases.

With labor as the only factor of production, a firm with productivity z produces $Z_t z$ units of output per worker, where Z_t denotes aggregate labor productivity. As stated in the Ghironi and Melitz (2005), heterogeneity in productivities across firms translate into heterogeneity in the unit labor costs of production. In addition to the labor cost, production incurs a fixed cost of $f_{X,t}$ units of consumption[7].

Endogenous changes in the size distribution of operating firms In the presence of fixed production costs, a firm with productivity z produces if and only if its profit $d_t(z)$ is non-negative. Specifically, only firms with productivity higher than a cutoff level, $z_t^c = \inf\{z : d_t(z) > 0\}$, operate and produce goods at any given time t. Otherwise, the firm is assumed to be switched off without losing its sunk investment. So, firms make decisions on whether to produce or not in every period and permanently exit only when they are

[6] We interpret changes in $f_{E,t}$ as changes in product market regulations facing firms in the economy.

[7] The fixed cost $f_{X,t}$ is set as units of consumption instead of effective labor units to match an important empirical regularity. If it is set as effective labor units like the sunk entry costs, the number of operating firms becomes less than the initial number after the product market reform even in the long-run, which is not consistent with data.

hit by a "death" shock, that takes place with probability $\delta \in (0,1)$. As a reminder, the productivity distribution of all firms is represented by G(z) with lower bound z_{min} in the Ghironi and Melitz (2005), implying the distribution is time-invariant and set exogenously by its parameters. However, in our model, the productivity distribution of operating firms endogenously varies with the time-varying lower bound z_t^c depending on economic conditions at every period as shown in Figure 2.6. This plays a crucial role in generating endogenous changes in the degree of granularity, which is a major departure from the Ghironi and Melitz (2005). In this setup, the number of operating firms at time t is given by a time-varying portion of all firms in the economy $N_{o,t} = N_t[1 - G(z_t^c)] = N_t(z_{min}/z_t^c)^\kappa$.

As for the entry, there exists an unbounded mass of prospective entrants who can anticipate the stream of expected future profits correctly. So, prospective entrants compare their expected post-entry value and the entry cost and enter the market until the value and the cost are equalized. This leads to the free entry condition $\tilde{e}_t = w_t f_{E,t}/Z_t$, where the expected post-entry value $\tilde{e}_t$ is defined by the present discounted value of the expected profit stream $\{\tilde{d}_s\}_{s=t+1}^{\infty}$:

$$\tilde{e}_t \equiv E_t \sum_{s=t}^{\infty} \beta_{t,s}(1-\delta)^{s-t}(1 - G(z_s^c))\tilde{d}_s \tag{2.2}$$

We assume that there is a one-period time-to-build lag for the entrants and that the exit shock occurs after entry. Thus, the number of total firms at time t obeys the following law of motion $N_t = (1-\delta)(N_{t-1} + N_{E,t-1})$.

Firms set their prices as the same proportional markup $\theta/(\theta-1)$ over marginal cost under constant elasticity θ. So, the real price of a good produced by a firm with productivity z is set as:

$$\rho_t(z) \equiv \frac{p_t(z)}{P_t} = \frac{\theta}{\theta - 1}\frac{w_t}{Z_t z} \tag{2.3}$$

and its profit is given by:

$$d_t(z) = \frac{1}{\theta}\rho_t(z)^{1-\theta}Y_t^c - f_{X,t} \tag{2.4}$$

where aggregate demand for the consumption bundle $Y_t^c \equiv C_t + N_{o,t}f_{X,t}$ as the sum of household consumption and the use of the bundle by operating firms to cover fixed costs.

Firm averages are defined by following Melitz (2003). Since the productivity levels of operating firms at time t are distributed over $[z_t^c, \infty)$ given by G(z), the average productivity is defined as

$$\tilde{z}_t \equiv \left[\frac{1}{1-G(z_t^c)}\int_{z_t^c}^{\infty} z^{\theta-1}dG(z)\right]^{\frac{1}{\theta-1}} \tag{2.5}$$

and by letting $\nu \equiv \left[\kappa/(\kappa-\theta+1)\right]^{1/(\theta-1)}$, the average productivity is given by $\tilde{z}_t = \nu z_t^c$, which implies the average is proportional to the cutoff productivity. Then, the model is isomorphic to one where $N_{o,t}$ firms with the same productivity level $\tilde{z}$ produce, for the average summarizes all the relevance of the distribution of productivity levels for aggregate variables as shown in Melitz (2003). Next, the price index of the economy can be written as

$$1 = \tilde{\rho}_t^{1-\theta}N_{o,t} \tag{2.6}$$

where the average real price of products in the market is given by $\tilde{\rho}_t \equiv \rho_t(\tilde{z})$. Also, the average profit of operating firms is obtained with the average productivity as $\tilde{d}_t \equiv d_t(\tilde{z}_t)$.

2.3.3 Household Budget Constraint and Intertemporal Choices

The representative household enters period t with x_t shares in a mutual fund of firms. The mutual fund pays total profits from all the operating firms in each period, $N_{o,t}\tilde{d}_t$. During the period, the household purchases x_{t+1} mutual fund shares of all the incumbents and the new entrants, $N_t + N_{E,t}$. Even though only $N_{o,t+1}$ firms will operate and be able to pay dividends at time $t+1$, the household, who does not know which firms will survive from the exit shock and have higher productivity than the cutoff, must finance all the potential firms for next period's production. And the price of a claim to the future dividend payments of the mutual fund at time t is equal to the average price of claims to the future stream of profits, $\tilde{e}_t$.

Then, the household's period budget constraint is given by

$$C_t + \tilde{e}_t(N_t + N_{E,t})x_{t+1} = \Big[\big(1 - G(z_t^c)\big)\tilde{d}_t + \tilde{e}_t\Big]N_t x_t + w_t \tag{2.7}$$

which implies the household's income consists of the mutual fund dividends from operating firms, the revenue from selling its initial share holdings, and the wage, while the household allocates the income between current and future consumption by investing in mutual fund shares carried into next period. The household maximizes its expected intertemporal utility (2.1) subject to the budget constraint (2.7). From the maximization problem, the Euler equation for shareholdings is given by

$$\tilde{e}_t = \beta(1-\delta)E_t\Big[\Big(\frac{C_{t+1}}{C_t}\Big)^{-\gamma}(\tilde{e}_{t+1} + \Big(\frac{z_{min}}{z_{t+1}^c}\Big)^{\kappa}\tilde{d}_{t+1})\Big] \tag{2.8}$$

of which forward iteration together with the assumption of the absence of speculative bubbles yields the equation (2.2).

2.3.4 Aggregate Accounting

Aggregating the budget constraint (2.7) across households and imposing equity market equilibrium ($x_{t+1} = x_t = 1$) yields [8] the following aggregate accounting equation as

[8]We omit the transversality condition for mutual fund shares which is needed to ensure optimality.

$$Y_t^c + N_{E,t}\tilde{e}_t = w_t + N_{o,t}\tilde{d}_t \tag{2.9}$$

implying that aggregate consumption and investment must equal aggregate income from labor and profit in each period.

2.3.5 Summary

The main equilibrium conditions of the baseline model are summarized in Table 2.2. The system consists of 10 equations in 10 endogenous variables: w_t, $\tilde{e}_t$, $\tilde{d}_t$, N_t, $N_{E,t}$, $\tilde{z}_t$, z_t^c, Y_t^c, C_t, $\tilde{\rho}_t$. Also, the model features 3 exogenous variables: Z_t, $f_{E,t}$, $f_{X,t}$.

2.3.6 The Herfindahl Index

To track changes in the degree of granularity after the reform in a rigorous way, we derive the Herfindahl index[9], the standard measure of market concentration and granularity. The Herfindahl index at any given time t obtained from the model is given by

$$HHI_t = \frac{\theta(\kappa - \theta + 1)}{\kappa - 2(\theta - 1)} \frac{f_{X,t}}{Y_t^c} \tag{2.10}$$

if $\kappa > 2(\theta - 1)$ holds. The above equation of the Herfindahl index implies that higher aggregate consumption demand is associated with lower Herfindahl index and that higher fixed costs are related to higher concentration. The former is in line with di Giovanni and Levchenko (2012), who find the inverse relationship between the country size and the degree of granularity. The latter is intuitive, for heavy fixed costs are likely to cause only relatively larger and more productive firms to survive in the market. Also, we can reconfirm that the degree of granularity is affected not only by exogenous setting (represented by the Pareto shape parameter κ which determines the distribution of possible productivity draws) but also

[9] The details of its derivation are provided in the Appendix A.

by endogenous changes in the economy (represented by the aggregate consumption demand at the period).

2.4 Analysis under the Baseline Model

2.4.1 Steady States

First, we consider the long-run effects of product market reforms from the new steady-state. The key variables in which we are interested are the total number of firms N, the number of operating firms N_o, the cutoff productivity z^c, the household consumption C, and the average profit of operating firms $\tilde{d}$. The steady-state levels of the variables can be derived analytically as displayed in Table 2.4. The signs of partial derivatives of them with respect to the policy variable, entry costs f_E, are as follows

$$\frac{\partial N}{\partial f_E} < 0, \quad \frac{\partial N_o}{\partial f_E} < 0, \quad \frac{\partial z^c}{\partial f_E} < 0, \quad \frac{\partial C}{\partial f_E} < 0, \quad \frac{\partial \tilde{d}}{\partial f_E} = 0 \tag{2.11}$$

which imply that lowering entry costs eventually leads to higher cutoff, a larger number of firms and more consumption.

The intuition is straightforward. The number of total firms N in the economy increases as new firms N_E enter following the product market deregulation (reduction in sunk entry costs f_E). Increased competition raises the cutoff z^c as well as the average productivity $\tilde{z}$. Despite the higher cutoff, the expansion of total firms N prevails in determining the number of operating firms N_o. Thus, more operating firms with higher productivities lead to increase in production, wage, and consumption C. Meanwhile, the average profit $\tilde{d}$ stands still because bigger aggregate consumption demands Y^c and smaller market share per firm offset each other. We can also find that the reform reduces the Herfindahl index in the long run, for the larger number of operating firms N_o prevails on higher cutoff z^c in inducing lower concentration.

2.4.2 Transition dynamics

Now, we analyze short- to medium-term dynamics triggered by the product market reform and compare the dynamics in a granular scenario to those in a non-granular one. As shown in Table 2.3, we log-linearize the system of equilibrium conditions around the unique steady-state. With properly calibrated parameters, we solve for the dynamic responses to an exogenous policy shock.

Calibration We interpret periods as quarters and calibrate parameters. Following the standard choices in the business cycle literature, we set the discount factor $\beta = .99$ and the risk aversion coefficient $\gamma = 2$. The exogenous exit shock δ is equal to .025 as set in Ghironi and Melitz (2005) to match the yearly 10 percent job destruction rate from the U.S. empirical data. We also use the elasticity of substitution $\theta = 3.8$ following Ghironi and Melitz (2005). As for the fixed operation costs $f_{X,t}$ and the sunk entry costs $f_{E,t}$, we follow Collard-Wexler (2013) which reports the ratio of entry costs to fixed production costs as around 4.5. Then, we normalize the Pareto support z_{min} and the aggregate productivity Z to 1. The calibration results are summarized in Table 2.5.

Figure 2.7 shows transitional changes in response to 1% permanent reduction in entry costs as percent deviations from steady-state. The changes in the cutoff productivity z^c and the number of firms N are the key to understand the mechanism. Lower entry barriers f_E induce new firms N_E to enter the market, and households have to cut their consumption spending for financing the new entrants. Together with the influx of new firms, the sudden decrease in the consumption demand makes firms' survival tougher, leading to the immediate jump of the cutoff z^c. Since entry costs and the time-to-build lag transform N into a state variable that behaves like a capital stock, the number of operating firms N_o decreases in the short-run because the increase in z^c is immediate whereas the increase in N is gradual. Hence, the economy experiences contraction as well as more concentration of economic activity (higher degree of granularity measured by the Herfindahl index) in the immediate aftermath of reform.

However, as N piles up over time, the previously contracted production and real wages begin to rebound. This raises aggregate consumption demand and slows down the increase in z^c. So, the number of operating firms N_o also rebounds and eventually exceeds the initial steady-state level. Finally, with more operating firms N_o with higher average productivity $\tilde{z}$, the economy reaps the gains of reforms in terms of more variety, higher GDP, and lower degree of granularity.

Next, Figure 2.8 compares the transitional changes in response to the same permanent deregulation under different degrees of granularity set by different values of the Pareto shape parameter κ. Since an economy is granular if $\frac{\kappa}{\theta-1} < 2$ according to Gabaix (2011), we compare impulse responses under $\kappa = 2.9$ ($\frac{\kappa}{\theta-1} = 1.035$) and $\kappa = 11.2$ ($\frac{\kappa}{\theta-1} = 4$) as granular (red, solid line) and non-granular (blue, dotted line) cases respectively. Overall, the transition patterns are similar in both cases. But there are differences in the magnitude of the responses. What is notable here is that the different magnitudes generate crossings of the transition paths of the key variables in both cases: the number of operating firms, the consumption, and the Herfindahl index[10]. The crossings which occur around 4 years after the reform suggest that reforms in granular economies are likely to be associated with larger long-term gain, but also more acute short-term pain. The economic intuition is as follows. Given its fat-tailed distribution of firm size, the average size of entrants is bigger in a granular economy, and so is the marginal impact of new entry on firms' survival. It implies the initial jump of the cutoff productivity z_t^c is larger in the granular economy. Hence, the number of operating firms N_o declines more, which leads to more concentration (higher Herfindahl index) as well as larger reduction of consumption at the immediate aftermath of reforms compared to the non-granular economy.

However, as this relatively tougher survival condition enhances the average productivity $\tilde{z}$

[10] As stated in the section 2.3.6, the Herfindahl index in our model can be defined only under non-granular ranges of κ (when $\frac{\kappa}{\theta-1} > 2$). Thus, we draw an alternative case (green, solid line) that is non-granular but still very close to granular instead of the granular case.

of operating firms more in the granular economy, the productivity gain brings larger benefits over time as the total number of firms rises. Therefore, this bigger N_o and higher average productivity $\tilde{z}$ bring more expansionary effect, and market concentration falls more in the granular economy.

2.5 Model Extension

So far, we have studied how reforms are propagated and affect the distribution of firm size in absence of idiosyncratic volatility. It is necessary to understand how reforms can affect the environment in which idiosyncratic shocks may have aggregate effects. By affecting the number of operating firms N_o, cutoff productivity z^c, and the market concentration, reforms cause the extent to which the economy is granular to vary over time. Since the Herfindahl index initially rises before its eventual decrease, the impact of idiosyncratic shocks on the aggregate economy in a granular environment may initially be magnified before eventually becoming smaller. Next, we explore this intuition by extending the model to account for idiosyncratic volatility.

2.5.1 Idiosyncratic shock

To the baseline model, we incorporate an idiosyncratic shock $a_t(\omega)$, which is drawn from a time-invariant distribution at every period as in di Giovanni and Levchenko (2012). From now on, the productivity of a firm ω is time-varying, for it is determined not only by the firm-specific productivity $z(\omega)$ that is unchanging after drawn upon entry but also by the idiosyncratic shock $a_t(\omega)$ at time t. Then, the firm's profit-maximizing price is given by

$$\rho_t(\omega) = \frac{\theta}{\theta - 1} \frac{w_t}{Z_t z(\omega) a_t(\omega)} \tag{2.12}$$

Also, we take the following assumptions in di Giovanni and Levchenko (2012):

Assumption 1: The marginal firm is small enough that it does not take the impact of its own realization of $a_t(\omega)$ on the total expenditure (X_t) and the price level (P_t) of the economy into consideration.

Assumption 2: The marginal firm treats X_t and P_t as fixed.

As stated in di Giovanni and Levchenko (2012), the second assumption, which is needed to take X_t and P_t out of the expectation operator, leads to simplicity in analyses as well as computation without affecting main results. It is particularly true in the model economy, where aggregate outcomes are driven not by marginal firms but by large ones.

2.5.2 Discretization

In extending the baseline model to incorporate the idiosyncratic shock, there is an important problem with the assumption of a continuum of firms. Under the assumption, the model economy has mathematically an infinite number of firms, and thus the effect of any idiosyncratic shocks on aggregate volatility will average out.

To avoid this problem while maintaining the advantages of a continuous setup, we discretize the model inspired by Al-Najjar (1995). First, we modify the productivity distribution as a truncated Pareto distribution with lower bound z_{min} and upper bound z_{max}. Then, the productivity of operating firms at time t is distributed over $[z_t^c,\ z_{max}]$ given by the distribution G(z). By partitioning the firms according to their firm-specific productivities with an interval defined by $i_t = (z_{max} - z_t^c)/\bar{N}$, the mathematically infinite number of operating firms can be discretized into a very large, finite number $\bar{N}$ as shown in Figure (2.11). Each set of firms can be interpreted as a firm in which there is a set of product lines. Here, shocks are assumed to be idiosyncratic to each set. Then, the system is isomorphic to a model with a finite number $\bar{N}$ of firms.

Of course, one may ask why we do not model with a finite number of firms from the beginning. Our setup with a continuum of firms has some advantages in terms of model tractability and the derivations of the Herfindahl index and aggregate volatility as shown in Appendix A and B. For example, di Giovanni and Levchenko (2012) have to compute the Herfindahl index by repeating simulation exercises over 1,000 times and taking the median value of it. However, we can obtain the values of the Herfindahl index and the aggregate volatility from the theoretically derived solutions. So, our work provides a new, tractable way of granularity analysis, showing that one can analyze the effect of fat-tail distribution using a continuous model and that one can still study the relationship between idiosyncratic shocks and aggregate volatility by discretizing the framework properly.

2.5.3 Aggregate Volatility

Since the extended model becomes isomorphic to a model with $\bar{N}$ firms operating at any given time t under the above discretization, idiosyncratic shocks no longer average out but can generate aggregate fluctuations. Following Gabaix (2011) and di Giovanni and Levchenko (2012), the aggregate volatility is given by

$$\sigma^2_{GDP,t} = \sigma^2 \sum_{j=1}^{\bar{N}} \left(\frac{x_{j,t}}{X_t} \right)^2 \tag{2.13}$$

where σ is the standard deviation of the growth rate of individual firm sales, $x_{j,t}$ is the sales of the j-th firm, in other words, the j-th set of products, and $X_t \equiv P_t Y_t^c$ denotes the total sales of the economy at time t. From the equation of the demand for an individual product, the sale of a product ω within a set is given by

$$x_t(\omega) \equiv p_t(\omega) c_t(\omega) = \rho_t(\omega)^{1-\theta} X_t \tag{2.14}$$

and by applying the equation (2.12) of profit-maximizing price in the presence of idiosyncratic shocks, we obtain the market share of the product ω as

$$\frac{x_t(\omega)}{X_t} = \left(\frac{\theta}{\theta-1}\frac{w_t}{Z_t z(\omega) a_t(\omega)}\right)^{1-\theta} \tag{2.15}$$

And under normalization of the idiosyncratic shocks such that $E_a[a^{\theta-1}] = 1$, the expected market share of the product ω is given by

$$E_a\left[\frac{x_t(\omega)}{X_t}\right] = \left(\frac{\theta}{\theta-1}\frac{w_t}{Z_t z(\omega)}\right)^{1-\theta} \tag{2.16}$$

Then, we can calculate the market share of the j-th set of products by using the equation (2.16) and applying Jensen's inequality. So, the upper bound of expected aggregate volatility is given by

$$\sigma^2_{GDP,t} \;\leq\; \sigma^2\left(\frac{\theta}{\theta-1}\frac{w_t}{Z_t}\right)^{2(1-\theta)}\left[\frac{1}{2(\theta-1)-\kappa}\right]\left[\frac{\kappa(z_t^c)^\kappa}{1-(z_t^c/z_{max})^\kappa}\right]\left[\left(z_{max}\right)^{2(\theta-1)-\kappa}-\left(z_t^c\right)^{2(\theta-1)-\kappa}\right] \tag{2.17}$$

as shown in Appendix B. The aggregate volatility is affected by exogenous parameters such as the Pareto shape parameter κ, and by endogenous changes in the cutoff productivity z_t^c and the real wage w_t. The derivatives with respect to κ, z_t^c, and w_t are

$$\frac{\partial\sigma_{GDP}}{\partial\kappa} < 0, \quad \frac{\partial\sigma_{GDP}}{\partial z_t^c} > 0 \quad \text{and} \quad \frac{\partial\sigma_{GDP}}{\partial w_t} < 0$$

The first derivative confirms the result of Gabaix (2011) that *ceteris paribus*, more granular economy (firm-size distribution is fatter-tailed) is more volatile. Figure (2.9) displays aggregate volatility rises exponentially as $\kappa/(\theta-1)$ goes beyond the threshold of granularity. The second one with respect to the cutoff is also intuitive. As z_t^c increases, fewer firms can survive in the market, making the economy more granular and ultimately more volatile. As for the third derivative, a wage increase implies there are more firms operating and/or producing larger quantity in the economy. So, the wage increase is related to the decrease in granularity as well as volatility.

2.6 The Impact on Aggregate Volatility

Based on the extended model, we analyze the impact of the product market reform on the aggregate volatility of the economy. Figure 2.10 displays the impulse response of aggregate volatility (precisely, its upper bound) to the product market reform. The blue, dotted line is the case of $\kappa/(\theta-1) = 2.0035$, which is very close to the granular threshold[11], whereas the green, solid line is the case of $\kappa/(\theta-1) = 4$, which is far enough from the threshold. The former and the latter can be interpreted as relatively more and less concentrated economies, respectively.

As shown in the Figure, the product market reform causes the extent to which the economy is exposed to idiosyncratic shocks to vary over time. The impulse responses of aggregate volatility share the two main characteristics observed in those of the Herfindahl index under the baseline model: 1) an initial jump followed by a gradual decrease, and 2) larger short-term pain and long-term gain in the relatively more granular case, represented by the crossing of the impulse responses under different granularities. This confirms our intuition about the effect of the product market reform on the aggregate volatility in the baseline model.

The intuition behind the first characteristic is as follows. Aggregate consumption demand Y^c initially falls due to financing burden for new entrants, causing the cutoff productivity z_t^c to jump and the market share of large firms to rise. Thus, the economy becomes more volatile in the immediate aftermath of the reform. But over time, aggregate demand Y^c recovers as

[11]There is a caveat here. If we compare the impulse responses of strictly granular and non-granular cases, the results do not show a crossing as in Figure 2.10. Even though the long-run characteristic, the bigger fall of aggregate volatility in a granular economy, is still preserved, the short-run one, the bigger rise of aggregate volatility in the granular country, no longer exists. This may stem from the fact that the signs of the powers of z_{max} and z_t^c in the equation (2.17) flip as κ moves across the granular threshold, $\kappa < 2(\theta-1)$. We believe that the comparison between the values that do not cause the sign of the power to flip is fair, and this is why we choose the value of κ in Figure 2.10.

the economy grows thanks to gains of the reforms in the form of higher productivity and more production. So, the increase in the cutoff z_t^c is gradually subdued, whereas the real wage w_t rises under tighter labor market conditions. Therefore, the economy becomes more resistant to idiosyncratic shocks. The second characteristic, the marginal impacts of reform on the aggregate volatility are larger in a (more) granular economy regardless of time horizon, can be understood by the same intuition in the section 2.4.2 because the magnitudes of impulse responses of aggregate volatility depend on those of the cutoff z_t^c as well as the real wage w_t, which are already explained in the section.

2.7 Conclusions

We studied the effect of the product market reform in relation to the granularity based on a full general equilibrium setup. First, the short- to long-term impacts of the reform on productivity, consumption, and output are affected by the initial degree of granularity. In line with the existing literature of structural reforms, the product market reform is beneficial in the long-run, but the benefits are accompanied by transition costs in the short-run. We further found out that the degree of granularity affects the magnitude of short-term pain as well as long-term gain, specifically, the marginal impact of the reform is larger in more granular economies than in less granular ones. On the other hand, the degree of granularity is also affected by the product market reform. The economy becomes more concentrated in the immediate aftermath of the reform before getting less concentrated eventually. So, the changes in the degree of granularity after the reform suggests that the impact of idiosyncratic shocks on the aggregate economy may initially be magnified before eventually becoming smaller.

2.8 Tables and Figures

Table 2.1: OLS Regression Results

	(1)	(2)	(3)	(4)
Dep. Var: Log(Herfindahl index)				
Log(Legal barriers to entry)	0.536	0.866**	0.825*	0.802*
	(1.56)	(2.89)	(2.67)	(2.68)
Log(Trade-to-GDP ratio)		1.529***	1.715***	1.434**
		(4.26)	(3.67)	(3.98)
Log(GDP share)			0.0853	
			(0.63)	
Log(GDP per capita)				0.232
				(1.44)
Constant	5.451***	-1.104	-1.859	-2.952
	(29.05)	(-0.71)	(-0.94)	(-1.48)
Observations	44	44	44	44
R^2	0.0548	0.3450	0.3514	0.3774

Note: t statistics in parentheses. * significant at 10%, ** at 5%, *** at 1%

Table 2.2: Model Summary

$\tilde{e}_t = \beta(1-\delta)E_t\left[\left(\frac{C_{t+1}}{C_t}\right)^{-\gamma}(\tilde{e}_{t+1} + \left(\frac{z_{min}}{z^c_{t+1}}\right)^{\kappa}\tilde{d}_{t+1})\right]$	(1)
$\tilde{e}_t = w_t f_{E,t}/Z_t$	(2)
$N_t = (1-\delta)(N_{t-1} + N_{E,t-1})$	(3)
$\tilde{\rho}_t = \frac{\theta}{\theta-1}\frac{w_t}{Z_t\tilde{z}_t}$	(4)
$C_t + N_t\left(\frac{z_{min}}{z^c_t}\right)^{\kappa} f_{X,t} = w_t + N_t\left(\frac{z_{min}}{z^c_t}\right)^{\kappa}\tilde{d}_t - N_{E,t}\tilde{e}_t$	(5)
$\tilde{d}_t = \frac{1}{\theta}\tilde{\rho}_t^{1-\theta}Y^c_t - f_{X,t}$	(6)
$1 = \tilde{\rho}_t^{1-\theta}N_t\left(\frac{z_{min}}{z^c_t}\right)^{\kappa}$	(7)
$\tilde{z}_t = \nu z^c_t$	(8)
$z^c_t = \frac{\theta^{\frac{\theta}{\theta-1}}}{\theta-1}\frac{w_t}{Z_t}\left(\frac{f_{X,t}}{Y^c_t}\right)^{\frac{1}{\theta-1}}$	(9)
$Y^c_t = C_t + N_t\left(\frac{z_{min}}{z^c_t}\right)^{\kappa} f_{X,t}$	(10)

Note: $C, Y^c, \tilde{\rho}, N, N_E, w, \tilde{d}, \tilde{e}, z^c, \tilde{z}$ are the 10 endogenous variables determined by these equations. Other variables in the table are determined as described in the text.

Table 2.3: Log-Linearized System

$\hat{e}_t = E_t\Big[-\gamma(\hat{C}_{t+1}-\hat{C}_t)+\beta(1-\delta)\hat{e}_{t+1}+(1-\beta(1-\delta))\hat{d}_{t+1}-\kappa(1-\beta(1-\delta))\hat{z}^c_{t+1}\Big]$	(1)
$\hat{e}_t = \hat{w}_t + \hat{f}_{E,t} - \hat{Z}_t$	(2)
$\hat{N}_t = (1-\delta)\hat{N}_{t-1} + \delta\hat{N}_{E,t-1}$	(3)
$\hat{\rho}_t = \hat{w}_t - \hat{z}_t - \hat{Z}_t$	(4)
$\hat{Y}^c_t = \frac{\mathsf{w}}{\mathsf{Y^c}}\hat{w}_t + \frac{\mathsf{N}\tilde{\mathsf{d}}}{\mathsf{Y^c}}\left(\frac{z_{min}}{\mathsf{z^c}}\right)^{\kappa}(\hat{N}_t + \hat{d}_t - \kappa\hat{z}^c_t) - \frac{\mathsf{N_E}\tilde{\mathsf{e}}}{\mathsf{Y^c}}(\hat{N}_{E,t} + \hat{e}_t)$	(5)
$\hat{d}_t = \frac{\tilde{\mathsf{p}}^{1-\theta}\mathsf{Y^c}}{\theta\tilde{\mathsf{d}}}((1-\theta)\hat{\rho}_t + \hat{Y}^c_t) - \frac{f_X}{\tilde{\mathsf{d}}}\hat{f}_{X,t}$	(6)
$(1-\theta)\hat{\rho}_t + \hat{N}_t = \kappa\hat{z}^c_t$	(7)
$\hat{z}_t = \hat{z}^c_t$	(8)
$\hat{z}^c_t = \hat{w}_t - \hat{Z}_t + \frac{1}{\theta-1}(\hat{f}_{X,t} - \hat{C}_t)$	(9)
$\hat{Y}^c_t = \frac{\mathsf{C}}{\mathsf{Y^c}}\hat{C}_t + \frac{\mathsf{N}f_X}{\mathsf{Y^c}}\left(\frac{z_{min}}{\mathsf{z^c}}\right)^{\kappa}(\hat{N}_t + \hat{f}_{X,t} - \kappa\hat{z}^c_t)$	(10)

Note: Sans-serif fonts represent steady-states while "hat" does log deviations from them.

Table 2.4: Steady States

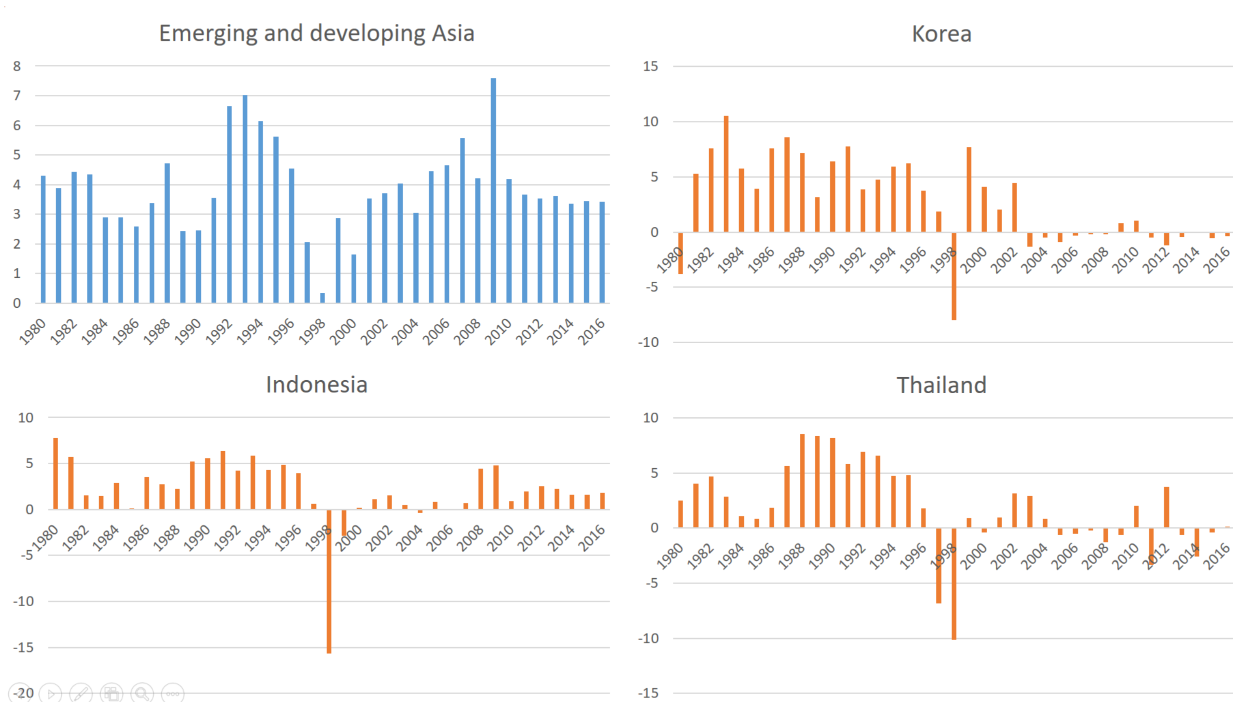
Variables	Steady states	Partial derivatives
$\tilde{d}$	$(\nu^{\theta-1}-1)f_X$	$\frac{\partial \tilde{d}}{\partial f_E}=0$
N	$\frac{\alpha Z}{f_E}$	$\frac{\partial N}{\partial f_E}<0$
N_o	$\left[(\alpha Z)^{\kappa+1}\frac{\zeta^{\kappa}}{f_X^{\kappa}f_E}\right]^{\frac{\theta-1}{\kappa(\theta-2)+(\theta-1)}}$	$\frac{\partial N_o}{\partial f_E}<0$
z^c	$\left[\frac{f_X^{\theta-1}}{\alpha\zeta^{\theta-1}f_E^{\theta-2}Z}\right]^{\frac{1}{\kappa(\theta-2)+(\theta-1)}}$	$\frac{\partial z^c}{\partial f_E}<0$
C	$(\theta\nu^{\theta-1}-1)\left[\frac{\zeta^{\kappa(\theta-1)}(\alpha Z)^{(\kappa+1)(\theta-1)}}{f_E^{\theta-1}f_X^{\kappa-\theta+1}}\right]^{\frac{1}{\kappa(\theta-2)+(\theta-1)}}$	$\frac{\partial C}{\partial f_E}<0$

Note: $\alpha=\frac{(1-\nu^{1-\theta})\beta(1-\delta)}{\theta(1-\beta(1-\delta))-(1-\beta)(1-\nu^{1-\theta})}>0$, $\zeta=\left(\frac{\theta-1}{\theta}\right)\left(\frac{1-\beta(1-\delta)}{\beta(1-\delta)}\right)\left(\frac{\nu}{\nu^{\theta-1}-1}\right)>0$

Table 2.5: Calibration

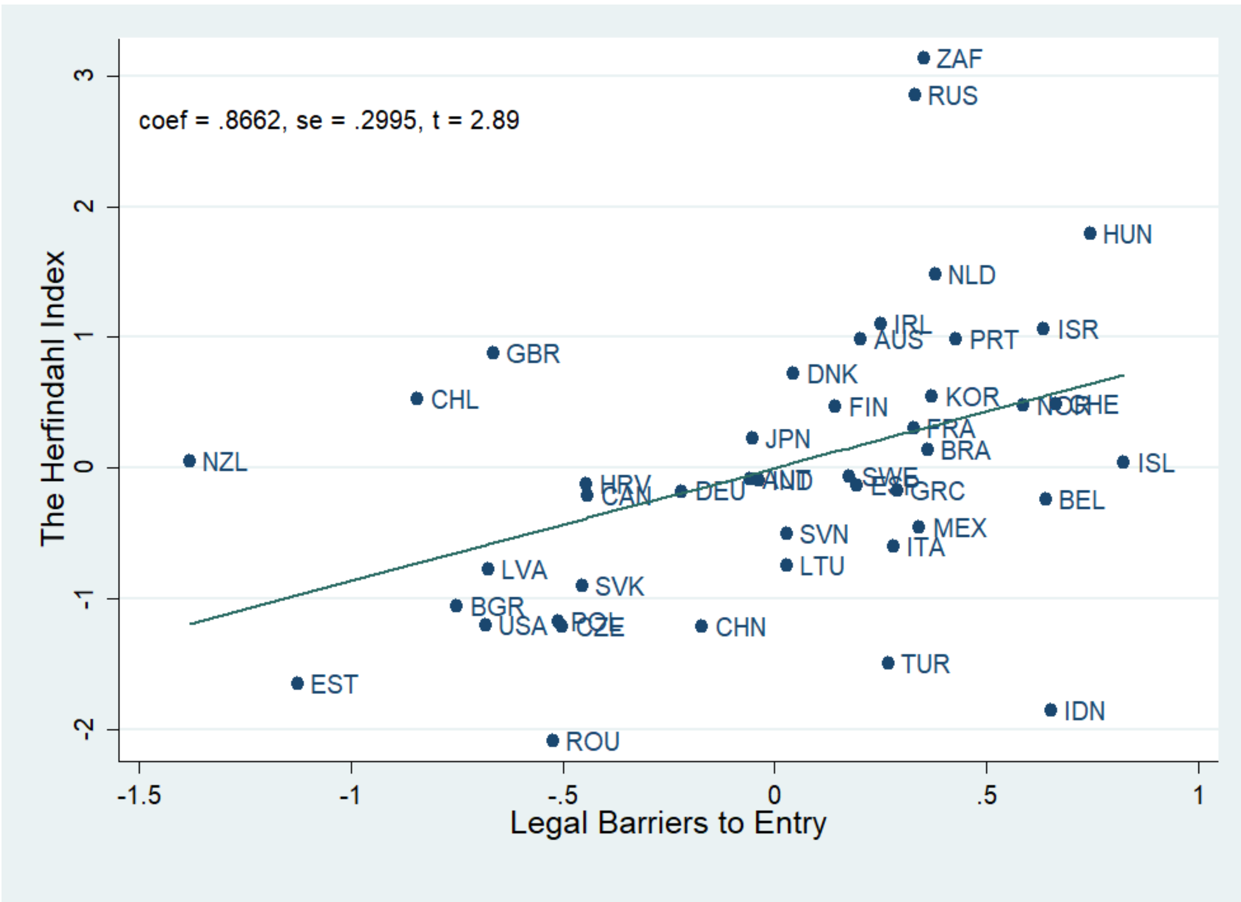
Parameter	Symbol	Value	Source
Elasticity of substitution	θ	3.8	Ghironi and Melitz (2005)
Risk aversion	γ	2	Standard in the literature
Discount factor	β	0.99	"
Exogenous producer exit probability	δ	0.025	"
Std. deviation of firm sales' growth rate	σ	0.1	di Giovanni and Levchenko (2012)
Fixed production cost	f_X	0.27	Collard-Wexler (2013)
Producer entry cost	f_E	1	Normalization
Pareto support	z_{min}	1	"
Aggregate productivity	Z	1	"

Figure 2.1: Growth Differentials before and after the Asian Crisis



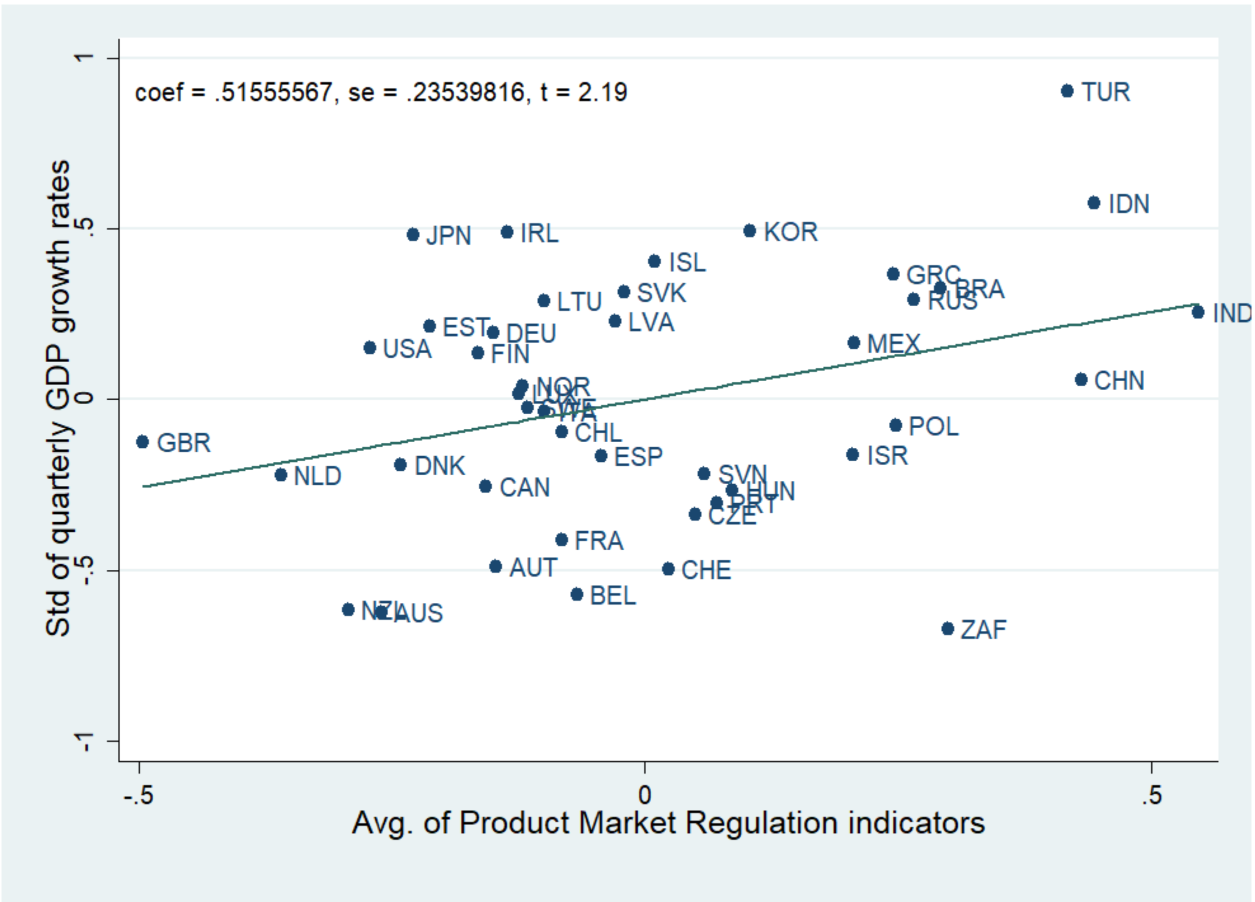
Notes: This figure shows the differentials of real GDP growth rates between the country and the world. (ex: differential (%) = "given year's GDP growth rate of Korea" − "that of the World"). A positive value of the differential implies that the country or region outperforms the world average in the year. Data source: The IMF World Economic Outlook database.

Figure 2.2: Legal Barriers to Entry and Market Concentration



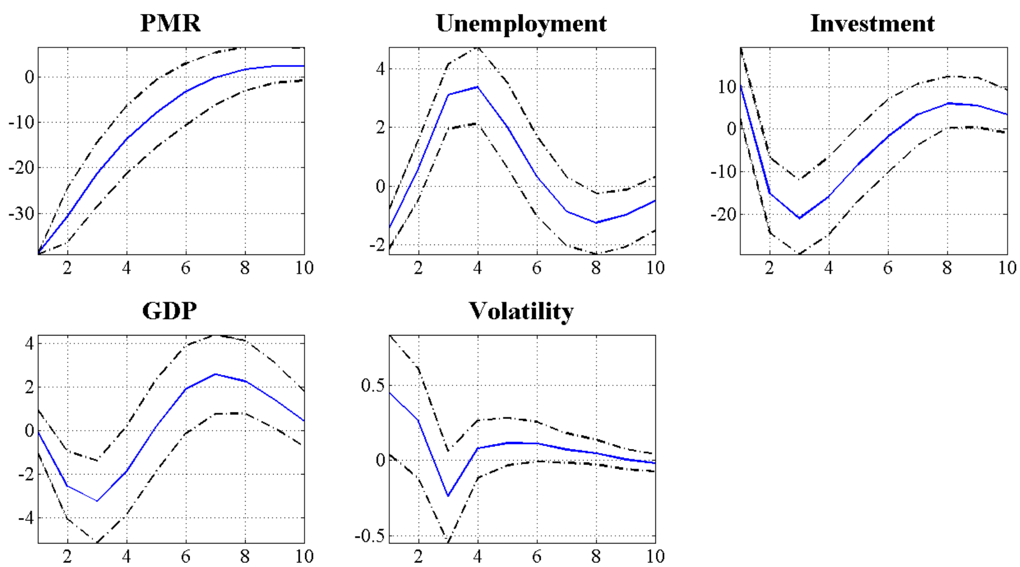
Notes: This is a partial regression plot showing the relationship between legal barriers to entry and the Herfindahl market concentration index in 44 countries. Both axes are in log scale. Sources: the OECD, the World Bank and the Mint Global.

Figure 2.3: Product Market Regulation and Volatility



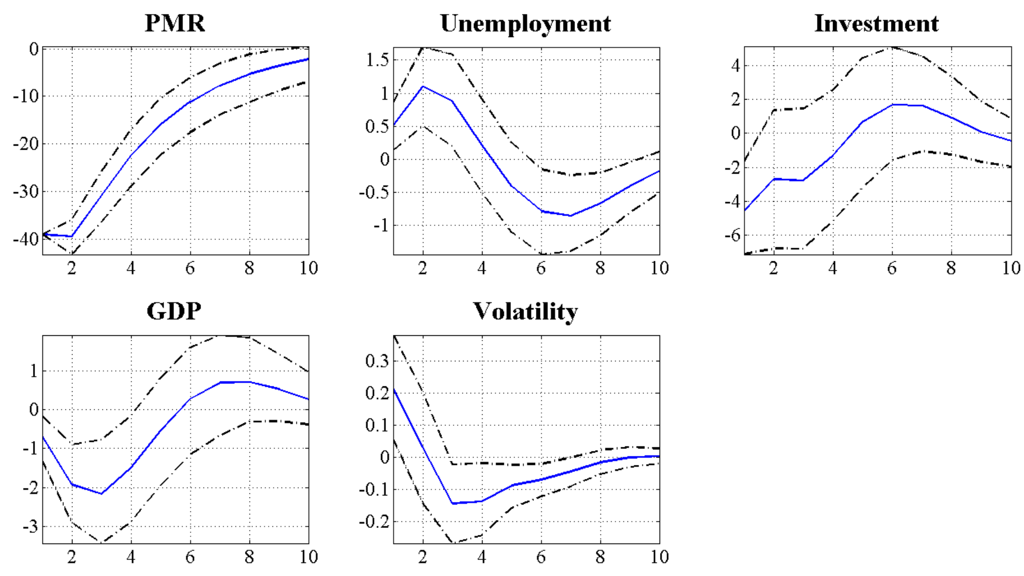
Notes: This figure reports the partial regression plot of aggregate volatility, measured as the standard deviation of the quarterly growth rate of GDP over 1998-2013, on the y-axis against the average of product market regulation index over the same period on the x-axis, after netting out the impact of country size (GDP share in world GDP). Data source: The OECD Statistics database.

Figure 2.4: Impulse Responses in Relatively More Granular Countries



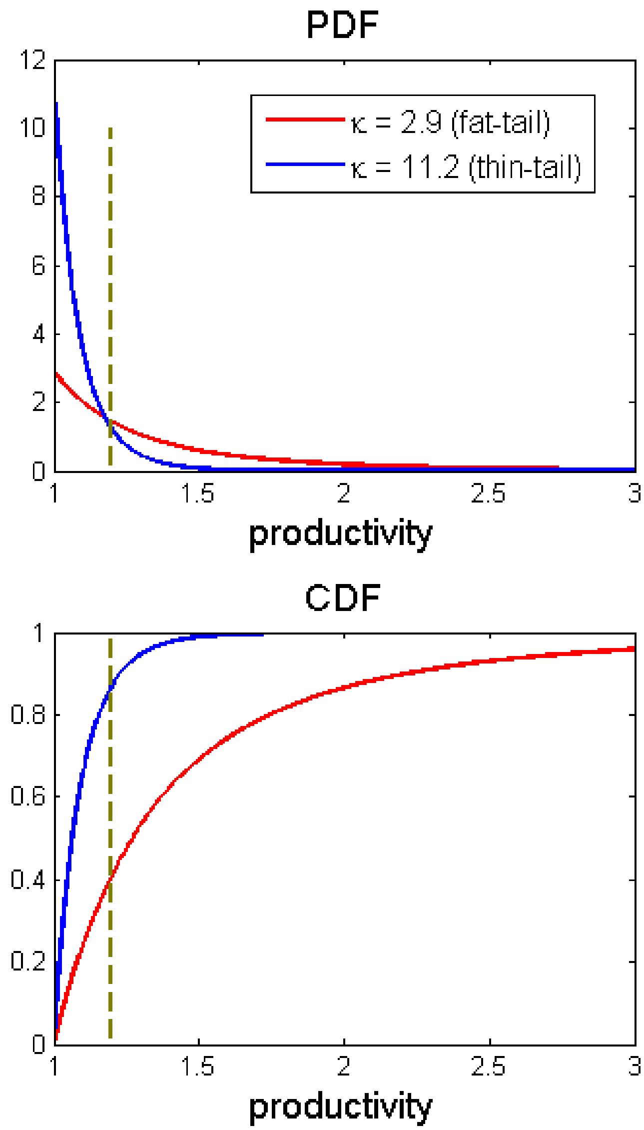
Notes: Panel VAR, impulse responses to Product Market Regulation (PMR) shocks. GDP and Investment are in percent from baseline; Unemployment rate and volatility are in deviations from baseline. Data source: Cacciatore and Fiori (2016) and the OECD Statistics database

Figure 2.5: Impulse Responses in Relatively Less Granular Countries



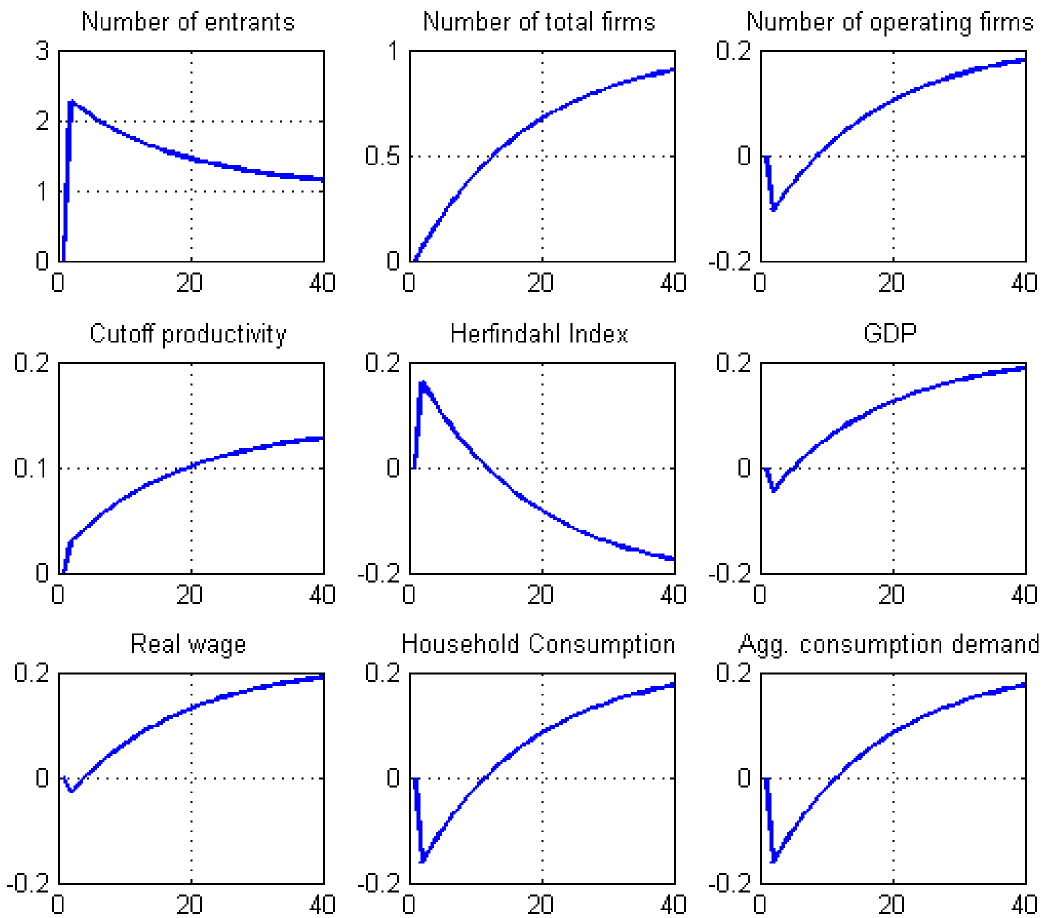
Notes: Panel VAR, impulse responses to Product Market Regulation (PMR) shocks. GDP and Investment are in percent from baseline; Unemployment rate and volatility are in deviations from baseline. Data source: Cacciatore and Fiori (2016) and the OECD Statistics database

Figure 2.6: PDF and CDF of Pareto Distribution



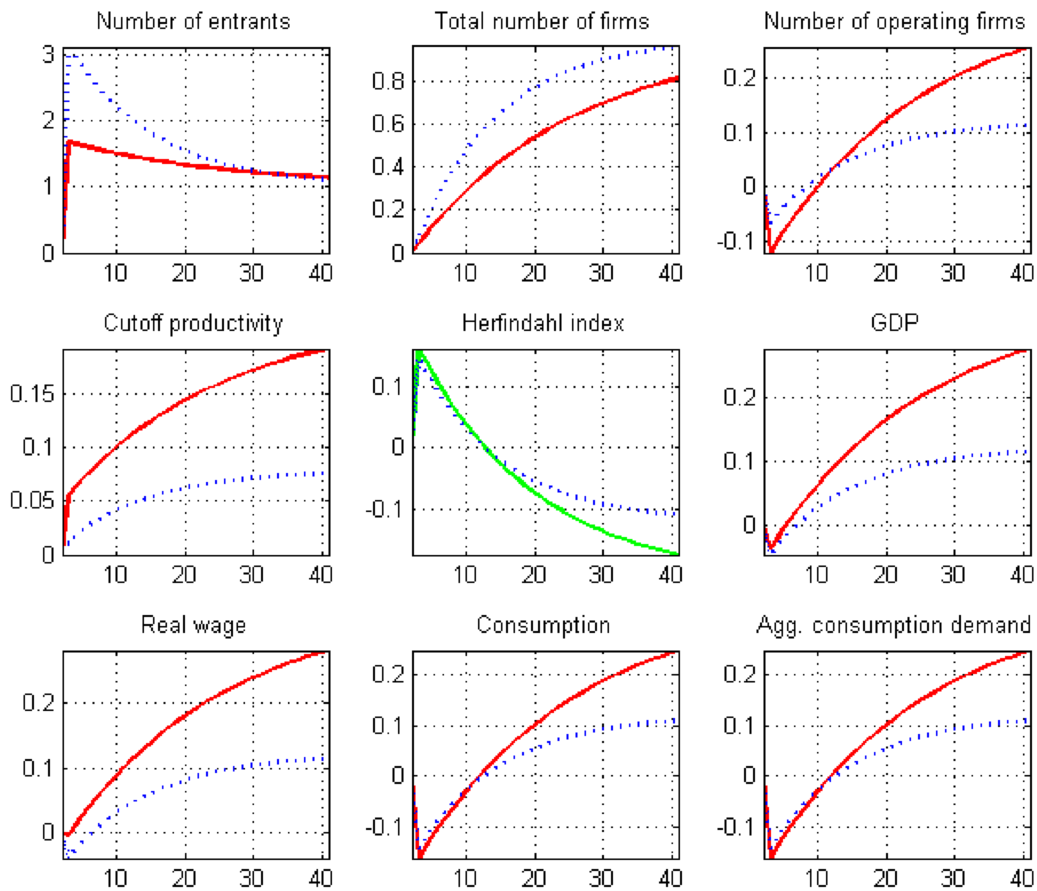
Notes: Blue(non-granular), Red(granular), and Yellow(cutoff productivity) under the value of $\theta = 3.8$.

Figure 2.7: Impulse Response to the Permanent Reduction in Entry costs



Notes: This IRF is under the value of $\kappa = 5.63$, and variables are in percentage deviations from the steady-state.

Figure 2.8: Impulse Response under Different Degrees of Granularity



Notes: Red(granular: $\kappa = 2.9$), Blue(non-granular: $\kappa = 11.2$), and Green(non-granular but very close to granular threshold: $\kappa = 5.63^{a}$). Variables are in percentage deviations from the steady-state.

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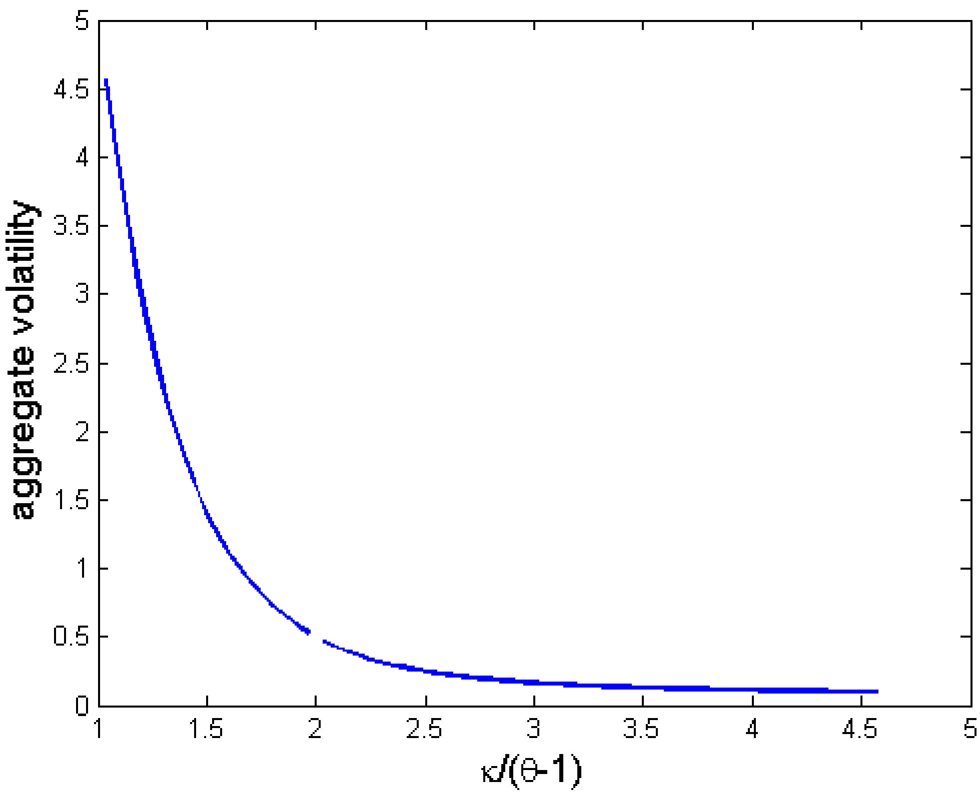
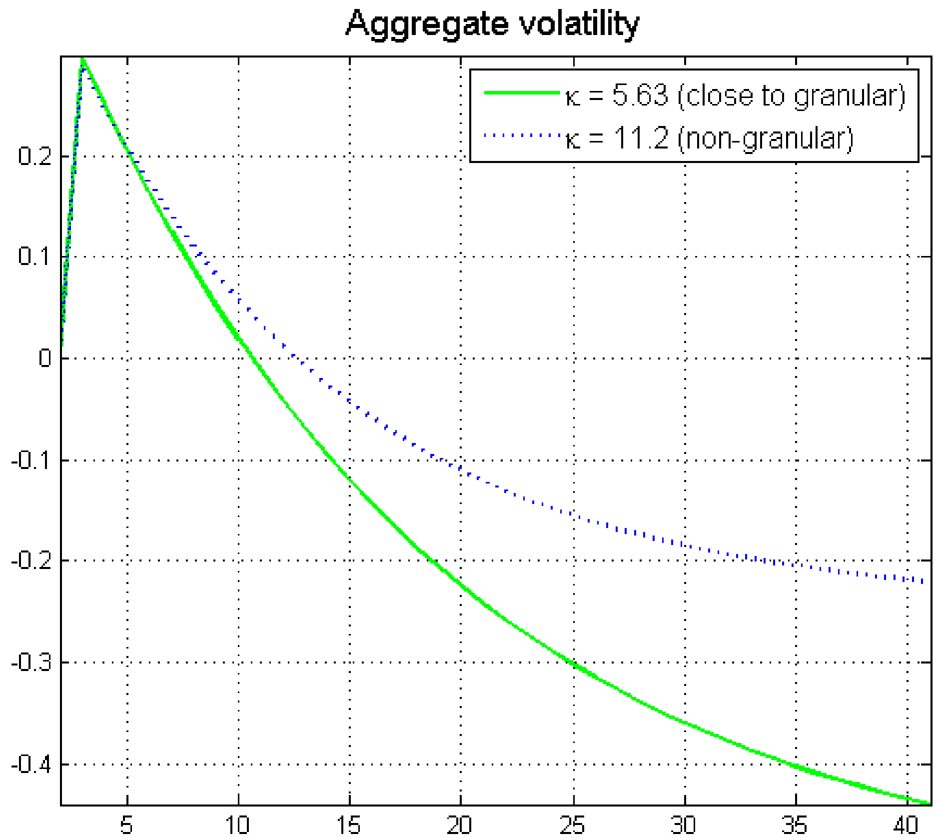
[a] Since the Herfindahl index is not defined if the value of κ is within the granular range, we use a value beyond the granular threshold.

Figure 2.9: Aggregate Volatility under Different Values of Shape Parameter κ



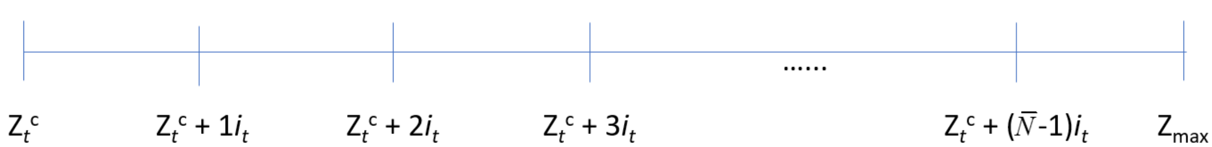
Notes: This figure displays volatilities calculated according to the equation (2.17) under different values of Pareto shape parameter κ. The granular threshold is $\kappa/(\theta-1) = 2$.

Figure 2.10: Impulse Response of Aggregate Volatility to the Product Market Reform



Notes: Blue(non-granular) and Green(non-granular but very close to granular threshold). Variable on the y-axis is percentage deviation from the steady-state.

Figure 2.11: Concept of Discretization



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Appendix A

DERIVATION OF THE HERFINDAHL INDEX

The Herfindahl index (HHI) is the sum of the squared market share of all firms in an economy. Under the assumption of a continuum of firms, the HHI of the baseline model economy at any given time t is defined by

$$HHI_t \equiv \int_{\omega} \left(\frac{x_t(\omega)}{X_t} \right)^2 d\omega \tag{A.1}$$

where $x_t(\omega)$ and X_t are the sale of an individual firm ω and the total sales of the economy, respectively. Since the demand for a firm ω's good is given by $y_t(\omega) = (p_t(\omega)/P_t)^{-\theta} Y_t^c$, the sale of the firm ω is

$$x_t(\omega) = \left(\frac{p_t(\omega)}{P_t} \right)^{1-\theta} X_t \tag{A.2}$$

where $x_t(\omega) \equiv p_t(\omega) y_t(\omega)$ and $X_t \equiv P_t Y_t^c$. The, the market share of a firm ω is simply $x_t(\omega)/X_t = \rho_t(\omega)^{1-\theta}$. By using the equation of profit-maximizing price (2.3), the market share can be rewritten as

$$\frac{x_t(\omega)}{X_t} = \left(\frac{\theta}{\theta - 1} \frac{w_t}{Z_t z(\omega)} \right)^{1-\theta} \tag{A.3}$$

and the HHI is given by

$$HHI_t = \int_{\omega} \left(\frac{\theta}{\theta - 1} \frac{w_t}{Z_t z(\omega)} \right)^{2(1-\theta)} d\omega \tag{A.4}$$

Then, by using the fact that the sum is equal to the product of the average and the total number, the HHI can be calculated by

$$HHI_t = N_{o,t}\left[\frac{1}{1-G(z_t^c)}\int_{z_t^c}^{\infty}\left(\frac{\theta}{\theta-1}\frac{w_t}{Z_t z}\right)^{2(1-\theta)}dG(z)\right] \tag{A.5}$$

and it can be rearranged as

$$HHI_t = N_{o,t}\left(\frac{\theta}{\theta-1}\frac{w_t}{Z_t}\right)^{2(1-\theta)}\left[\frac{1}{1-G(z_t^c)}\int_{z_t^c}^{\infty} z^{2(\theta-1)}dG(z)\right] \tag{A.6}$$

First, the square bracket on the right-hand side of (A.6) can be solved

$$\begin{aligned}
\frac{1}{1-G(z_t^c)}\int_{z_t^c}^{\infty} z^{2(\theta-1)}dG(z) &= \left(\frac{z_t^c}{z_{min}}\right)^{\kappa}\int_{z_t^c}^{\infty} z^{2(\theta-1)}\frac{\kappa z_{min}^{\kappa}}{z^{\kappa+1}}dz \\
&= \kappa(z_t^c)^{\kappa}\int_{z_t^c}^{\infty}\frac{z^{2(\theta-1)}}{z^{\kappa+1}}dz \\
&= \kappa(z_t^c)^{\kappa}\int_{z_t^c}^{\infty} z^{2(\theta-1)-\kappa-1}dz \\
&= \frac{\kappa(z_t^c)^{\kappa}}{2(\theta-1)-\kappa}z^{2(\theta-1)-\kappa}\Big|_{z_t^c}^{\infty}
\end{aligned}$$

and it boils down to the following equation under an additional assumption on the range of $\kappa > 2(\theta-1)$[1]

$$\frac{1}{1-G(z_t^c)}\int_{z_t^c}^{\infty} z^{2(\theta-1)}dG(z) = \frac{\kappa}{\kappa-2(\theta-1)}(z_t^c)^{2(\theta-1)} \tag{A.7}$$

[1] If the shape parameter of Pareto distribution falls in the granular range, $\kappa < 2(\theta-1)$, it goes to infinity. So, this calculation of the Herfindahl index can only be applied to non-granular cases. This caveat stems from the assumption of the infinite upper bound of the Pareto distribution used in the baseline model, which is impossible in real world.

Second, by using the equations (2.3) and (2.6) in the baseline model, the rest of the equation (A.6) can be rearranged

$$
\begin{aligned}
N_{o,t}\left(\frac{\theta}{\theta-1}\frac{w_t}{Z_t}\right)^{2(1-\theta)} &= N_{o,t}\left[\tilde{\rho}^{1-\theta}\tilde{z}_t^{1-\theta}\left(\frac{\theta}{\theta-1}\frac{w_t}{Z_t}\right)^{1-\theta}\right] \\
&= \tilde{z}_t^{1-\theta}\left(\frac{\theta}{\theta-1}\frac{w_t}{Z_t}\right)^{1-\theta} \\
&= (\nu z_t^c)^{1-\theta}\left(\frac{\theta}{\theta-1}\frac{w_t}{Z_t}\right)^{1-\theta}
\end{aligned}
$$

and from the definition of ν, we get the following

$$
N_{o,t}\left(\frac{\theta}{\theta-1}\frac{w_t}{Z_t}\right)^{2(1-\theta)} = \frac{\kappa-(\theta-1)}{\kappa}(z_t^c)^{1-\theta}\left(\frac{\theta}{\theta-1}\frac{w_t}{Z_t}\right)^{1-\theta} \tag{A.8}
$$

Then, by substituting (A.7) and (A.8) into (A.6), the HHI can be rewritten as

$$
\begin{aligned}
HHI_t &= \frac{\kappa-(\theta-1)}{\kappa-2(\theta-1)}\left(\frac{\theta}{\theta-1}\frac{w_t}{Z_t}\right)^{1-\theta}(z_t^c)^{\theta-1} \\
&= \frac{\kappa-(\theta-1)}{\kappa-2(\theta-1)}\left(\frac{\theta}{\theta-1}\frac{1}{Z_t}\right)^{1-\theta}\left(\frac{z_t^c}{w_t}\right)^{\theta-1}
\end{aligned}
$$

and since we know the following from the equation (9) in the Table 2.2,

$$
\frac{\theta f_{X,t}}{Y_t^c} = \left(\frac{\theta}{\theta-1}\frac{1}{Z_t}\right)^{1-\theta}\left(\frac{z_t^c}{w_t}\right)^{\theta-1} \tag{A.9}
$$

the Herfindahl index at time t in the baseline model is given by

$$HHI_t = \frac{\theta(\kappa - \theta + 1)}{\kappa - 2(\theta - 1)} \frac{f_{X,t}}{Y_t^c} \tag{A.10}$$

if $\kappa > 2(\theta - 1)$ holds.

Appendix B

DERIVATION OF THE AGGREGATE VOLATILITY

The aggregate volatility of an economy in the extended model with the idiosyncratic shocks and the discretization at any given time t is defined by

$$\sigma^2_{GDP,t} = \sigma^2 \sum_{j=1}^{\bar{N}} \left(\frac{x_{j,t}}{X_t} \right)^2$$

where $x_{j,t}/X_t$ denotes the market share of the j-th firm. In the presence of idiosyncratic shocks, the expected market share of a product ω in a firm is

$$E_a\left[\frac{x_t(\omega)}{X_t}\right] = E_a\left[\left(\frac{\theta}{\theta-1}\frac{w_t}{Z_t z(\omega) a_t(\omega)}\right)^{1-\theta}\right]$$

and under normalization of the idiosyncratic shocks such that $E_a[a^{\theta-1}] = 1$, the market share of the product ω is given by

$$E_a\left[\frac{x_t(\omega)}{X_t}\right] = \left(\frac{\theta}{\theta-1}\frac{w_t}{Z_t z(\omega)}\right)^{1-\theta} \tag{B.1}$$

Next, to obtain the squared market share of the j-th firm, we need to sum up each product's market share in the firm and square it. Instead, we first square each product's market share and then sum up them, for this way leads to a much simpler result than the other way. Since we need to rely on Jensen's inequality $\left(E_t\left[\frac{x_{j,t}}{X_t}\right]\right)^2 \leq E_t\left[\left(\frac{x_{j,t}}{X_t}\right)^2\right]$ in the process, the result can be interpreted as the upper bound of the squared market share of the firm. The sum of the squared market shares of products in the j-th firm can be calculated by multiplying the average of the squared market share of the products in the firm and the mass of them:

$$E_t\left[\left(\frac{x_{j,t}}{X_t}\right)^2\right] = N_{j,t}\left[\frac{1}{G(z_t^c + ji_t) - G(z_t^c + (j-1)i_t)}\int_{z_t^c+(j-1)i_t}^{z_t^c+ji_t}\left(\frac{\theta}{\theta-1}\frac{w_t}{Z_t z}\right)^{2(1-\theta)} dG(z)\right] \tag{B.2}$$

where $N_{j,t}$ denotes the mass of products in the j-th firm and is defined by $N_{j,t} = G(z_t^c + ji_t) - G(z_t^c + (j-1)i_t)$, which is the portion of the j-th firm in the total mass of products. By solving (B.2), we obtain the following

$$E_t\left[\left(\frac{x_{j,t}}{X_t}\right)^2\right] = \int_{z_t^c+(j-1)i_t}^{z_t^c+ji_t}\left(\frac{\theta}{\theta-1}\frac{w_t}{Z_t z}\right)^{2(1-\theta)} dG(z)$$

$$= \left(\frac{\theta}{\theta-1}\frac{w_t}{Z_t}\right)^{2(1-\theta)}\left[\frac{1}{2(\theta-1)-\kappa}\right]\left[\frac{\kappa(z_t^c)^\kappa}{1-(z_t^c/z_{max})^\kappa}\right]$$
$$\left\{\left[z_t^c + ji_t\right]^{2(\theta-1)-\kappa} - \left[z_t^c + (j-1)i_t\right]^{2(\theta-1)-\kappa}\right\}$$

and summing up all the squared market shares of $\bar{N}$ firms gives us the following:

$$\sum_{j=1}^{\bar{N}} E_t\left[\left(\frac{x_{j,t}}{X_t}\right)^2\right] = \left(\frac{\theta}{\theta-1}\frac{w_t}{Z_t}\right)^{2(1-\theta)}\left[\frac{1}{2(\theta-1)-\kappa}\right]\left[\frac{\kappa(z_t^c)^\kappa}{1-(z_t^c/z_{max})^\kappa}\right]$$
$$\sum_{j=1}^{\bar{N}}\left\{\left[z_t^c + ji_t\right]^{2(\theta-1)-\kappa} - \left[z_t^c + (j-1)i_t\right]^{2(\theta-1)-\kappa}\right\}$$

$$= \left(\frac{\theta}{\theta-1}\frac{w_t}{Z_t}\right)^{2(1-\theta)}\left[\frac{1}{2(\theta-1)-\kappa}\right]\left[\frac{\kappa(z_t^c)^\kappa}{1-(z_t^c/z_{max})^\kappa}\right]$$
$$\left[\left(z_{max}\right)^{2(\theta-1)-\kappa} - \left(z_t^c\right)^{2(\theta-1)-\kappa}\right]$$

Therefore, the upper bound of expected aggregate volatility[1] of the economy is given by

$$\sigma_{GDP}^2 \;\leq\; \sigma^2 \sum_{j=1}^{\bar{N}} E_t\left[\left(\frac{x_{j,t}}{X_t}\right)^2\right] = \sigma^2\left(\frac{\theta}{\theta-1}\frac{w_t}{Z_t}\right)^{2(1-\theta)}\left[\frac{1}{2(\theta-1)-\kappa}\right]\left[\frac{\kappa(z_t^c)^\kappa}{1-(z_t^c/z_{max})^\kappa}\right]$$

$$\left[\left(z_{max}\right)^{2(\theta-1)-\kappa} - \left(z_t^c\right)^{2(\theta-1)-\kappa}\right]$$

[1]Unlike the analytical solution of the Herfindahl index in Appendix A, an additional assumption on the range of κ is not needed to derive the result here. But the signs of the powers of z_{max} and z_t^c flip according to the value of κ, which requires caution in using it.

Appendix C
ELASTICITIES

By log-linearizing the baseline model equations around the steady-state, we obtain the equations in Table 2.3. The 10 equations in the log-linearized system can be boiled down to the following 2 equations:

$$\hat{N}_{t+1} = -\delta(\psi-1)\left(\frac{\theta-2}{\theta-1}+\frac{1}{\kappa}\right)\hat{C}_t+\left(1-\delta+\frac{\delta(\psi-1)}{\kappa}\right)\hat{N}_t-\delta(\psi-1)\left(\frac{1}{\theta-1}-\frac{1}{\kappa}\right)\hat{f}_{X,t}+\delta\psi\hat{Z}_t-\delta\hat{f}_{E,t} \tag{C.1}$$

$$\left[\gamma-\frac{\kappa-(\theta-1)}{\kappa(\theta-1)}\right]\hat{C}_t = \left[\gamma-1+\beta(1-\delta)\frac{(\theta-1)(\kappa+1)-\kappa}{\kappa(\theta-1)}\right]E_t\hat{C}_{t+1}+\left[1-\beta(1-\delta)\frac{\kappa+1}{\kappa}\right]\hat{N}_{t+1}$$

$$+\frac{1}{\kappa}\hat{N}_t-\frac{\kappa-(\theta-1)}{\kappa(\theta-1)}\left(\hat{f}_{X,t}-\beta(1-\delta)\hat{f}_{X,t+1}\right)+\hat{f}_{E,t}-\beta(1-\delta)\hat{f}_{E,t+1} \tag{C.2}$$

where ψ is defined by $\psi = (1-\delta)/\alpha\delta > 0$.

Under the following three assumptions:

$$1)\quad f_{E,t} = \phi_{f_E} f_{E,t-1} \tag{C.3}$$

$$2)\quad f_{X,t} = \phi_{f_X} f_{X,t-1} \tag{C.4}$$

$$3)\ Z_t = \phi_z Z_{t-1} + \epsilon_{Z,t} \tag{C.5}$$

where $\epsilon_{Z,t}$ is i.i.d., normal innovation with zero mean and variance $\sigma^2_{\epsilon_Z}$, the unique solution to the system made by equations (C.1) and (C.2) takes the form:

$$N_{t+1} = \eta_{NN}N_t + \eta_{NZ}Z_t + \eta_{Nf_E}f_{E,t} + \eta_{Nf_X}f_{X,t} \tag{C.6}$$

$$C_t = \eta_{CN}N_t + \eta_{CZ}Z_t + \eta_{Cf_E}f_{E,t} + \eta_{Cf_X}f_{X,t} \tag{C.7}$$

where each η_{xy} represents the elasticity of variable x with respect to variable y.