Essays in Macroeconomics
and Firm Dynamics

Maryam Vaziri

Faculty of Economics
University of Cambridge

This dissertation is submitted for the degree of
Doctor of Philosophy

Queens’ College May 2022
Declaration

This dissertation is the result of my own work and includes nothing which is the outcome of work done in collaboration. It is not substantially the same as any that I have submitted, or, is being concurrently submitted for a degree or diploma or other qualification at the University of Cambridge or any other University or similar institution. I further state that no substantial part of my dissertation has already been submitted, or, is being concurrently submitted for any such degree, diploma or other qualification at the University of Cambridge or any other University or similar institution. It does not exceed the prescribed word limit of 60,000 words.

Maryam Vaziri
May 2022
Acknowledgements

I am deeply grateful to my supervisor Vasco Carvalho for his guidance, support and extensive feedback throughout my PhD. I would also like to express my gratitude to my research advisor, Tiago Cavalcanti, for his invaluable advice, patience and support over the past few years. It was a great privilege to learn from them and I can never thank them enough.

I benefited from many helpful discussions with Charles Brendon, Giancarlo Corsetti, Meredith Crowley, Edo Gallo, Kamiar Mohaddes, and Flavio Toxvaerd during my studies. I also thank my co-authors Sriya Iyer and Chris Rauh, as well as Tiago Cavalcanti for the opportunity to work with them and for introducing me to the field of development economics.

I gratefully acknowledge financial support from the Cambridge Trust, the Cambridge-INET, the Keynes Fund, Queens’ College, the Milgate Fund and Faculty of Economics Trust Funds. I also wish to thank the Omid Trust and especially Navid Pourghazi and Khashayar Ghafarzadeh for their support over the past few years. My thanks go to the IT and administrative staff at the University of Cambridge, in particular to Joanna Gathercole, Silvana Dean, Louise Cross and Craig Peacock.

I would like to thank friends and officemates Alba Patozi, Andrew Hannon, Charles Parry, Christian Roerig, Daria Halatova, Deniz Atalar, Lida Smiktova, Mar Domenech, Margit Reischer, Monica Petrescu, Steph De Mel, Zeina Hasna, and many others for helpful discussions and for an amazing time together. A special thanks to Amir Karimi for his continued support throughout my PhD.

Maryam Vaziri
May 2022
Summary

This thesis contains three chapters and employs empirical and structural tools to study determinants of productivity growth and resource misallocation among firms in the economy.

The first chapter studies the implications of financing constraints on optimal expansion strategies of multiple-product firms and their consequent effect on aggregate productivity level. In particular, this chapter seeks to understand how firms may prioritise expanding their domestic product scope over exporting when they have limited access to financing. To answer this question, I develop a firm dynamics model in which firms are heterogeneous in terms of their productivity and access to financing. Analytically, I find that a firm with sufficiently high levels of productivity but low access to financing overcomes its financing constraints by expanding in the domestic market with lower productivity goods and then exporting. I verify this result by structurally estimating an international trade model that matches the moments of the US economy in the early 2000s. I estimate that removing financing constraints would increase the aggregate productivity level by 3.1%.

The second chapter provides an empirical investigation of the relationship between the enforcement of antitrust law and various macroeconomic outcomes such as productivity growth, firm entry rate, and investment in Research and Development for two cases: the US and Europe. For the US, I proxy antitrust enforcement by the relative share of antitrust budget, and combine it with firm-level and sector-level data. Similarly, for Europe, I use firm-level and sector-level data together with an antitrust index capturing variation of law across countries and over time. Through both exercises, I find that in more concentrated industries stronger antitrust policies are associated with higher productivity growth, higher entry rate but lower investment in Research and Development. This chapter serves as a motivation to the results in chapter 3.

The third chapter develops a structural model to study firms’ strategic and anticompetitive actions, and the consequent role of antitrust law as a macroeconomic policy in generating higher productivity growth. In this chapter, I propose a dynamic general equilibrium model with innovation and oligopolistic product market competition. The oligopolistic competition provides firms with market power, which combined with a dynamic setup, implies that firms may find it optimal to eliminate their competitors through strategic decision making. I then structurally estimate the model to match the recent US experience. Through a quantitative exercise, I find that strengthening antitrust policies improves business dynamism on various fronts: (1) firm entry rate increases, (2) productivity growth improves, (3) labour share of GDP becomes higher, (4) while innovation proxied by the relative share of R&D expenditure falls. The model shows that stronger antitrust policies can improve welfare by up to 16% in consumption equivalent terms.
# Contents

1 International Trade, Financial Constraints and Firm Dynamics 1

1.1 Introduction ................................. 2

1.2 Literature Review ............................ 4

1.3 Model ........................................ 6

1.3.1 Closed Economy ........................... 6

1.3.2 Open Economy ............................. 10

1.3.3 Equilibrium ............................... 14

1.4 Theoretical Implication: Product Sequencing .................... 15

1.5 Dynamic Model ................................ 16

1.6 Calibration ................................... 17

1.6.1 Results .................................... 18

1.7 Counterfactual Scenario and Welfare Analysis .................. 21

1.8 Conclusion .................................. 22


2.1 Introduction .................................. 26

2.2 Literature Review ............................ 27

2.3 Overview of Antitrust Law ........................ 28

2.4 Data .......................................... 30

2.4.1 US ........................................ 30

2.4.2 Europe .................................. 31

2.5 Results ...................................... 32

2.5.1 US: Results ................................ 32

2.5.2 Europe: Results ............................ 34

2.5.3 Robustness ................................ 35

2.6 Conclusion .................................. 36

3 Antitrust Law and Business Dynamism 39

3.1 Introduction .................................. 40

3.2 Literature Review ............................ 43

3.3 Model ........................................ 45

3.3.1 Preferences ............................... 46
### 3.3.2 Firms
- Page 47

### 3.3.3 Antitrust Regulator
- Page 54

### 3.3.4 Equilibrium
- Page 55

### 3.4 Calibration
- Page 55

### 3.5 Quantitative Results
- Page 57
  - 3.5.1 Policy Functions
    - Page 58
  - 3.5.2 Counterfactual Scenario: Strengthening Antitrust Law
    - Page 60
  - 3.5.3 Welfare Implications of Antitrust Law
    - Page 62

### 3.6 Conclusion
- Page 65

---

### A Appendix to Chapter 1
- Page 77
  - A.1 Theoretical Proofs
    - Page 77
  - A.2 Calibration and Numerical Method
    - Page 81

### B Appendix to Chapter 2
- Page 83
  - B.1 Data Sources and Sample Description
    - Page 83
    - B.1.1 US
      - Page 83
    - B.1.2 Europe
      - Page 85
  - B.2 Detailed Specifications and Regression Tables
    - Page 88
    - B.2.1 US
      - Page 88
    - B.2.2 Europe
      - Page 93
  - B.3 Robustness Checks
    - Page 101

### C Appendix to Chapter 3
- Page 105
  - C.1 Model Derivations and Proofs
    - Page 105
  - C.2 Calibration and Numerical Method
    - Page 116
Chapter 1

International Trade, Financial Constraints and Firm Dynamics

Abstract
This chapter investigates the growth trajectory of potential multiple product exporters through developing and structurally estimating a model in which firms are heterogeneous in their productivity and assets. Through analytical derivations, I show that when firms are liquidity constrained, the sequence of product introduction depends on firms’ initial asset level. In particular, liquidity constrained firms with a high productivity and higher initial assets, first enter the foreign market and then increase their domestic product scope. Other firms, with a similar level of productivity but lower initial assets, accumulate assets through increasing their domestic product scope and then export. The model is structurally estimated to match the US data in 1995-2000. The theoretical predictions are verified in the estimated model, and it is shown that financing constraints mainly affect the young firms by delaying their export decision. Further, I estimate that removing financing constraints would increase the aggregate productivity level by 3.1%.
1.1 Introduction

A few firms account for the majority of international trade in each country, usually with a diverse portfolio and exporting to multiple destinations. This raises questions on the process of growth for these firms. Firms are not born superstars and they are certainly not born exporters, such characteristics grow over time. One possible reason for why certain firms do not immediately reach their optimal size is insufficient access to finance. Evidence suggests that financing constraints exist for both exporting and non-exporting firms.\footnote{See for examples of exporting Muûls (2008) for Belgian firms and Manova (2012) using a large panel of countries. For an example of domestic production see Aghion et al. (2010).} These constraints restrict the set of production options that are feasible for the firm and can explain why large multiple product firms take time to break into different markets.

This chapter seeks to understand how multiple product exporters rationalise their production decisions. Are these firms multiple product domestic producers that later start exporting? Or do these firms start exporting their single most productive good and then expand both into the domestic and international markets? This chapter develops a theoretical framework and a structural model and investigates different production paths firms take in becoming diversified exporters.

The framework presented in this chapter builds on Melitz (2003) and Bernard et al. (2006) with heterogeneous firms in terms of their productivity. Firms can produce multiple varieties and each variety is associated with a specific level of productivity. Therefore, the model features both across and within firm heterogeneity on the productivity level. Additionally, firms differ in their access to financing, which together with their productivity level determines their domestic and foreign product scope. In particular, for every new variety the firm adds or exports there are upfront costs to be paid and in order to pay for these costs firms accumulate assets. Exporting is more costly but can generate more profits if the firm has a sufficiently high productivity. Therefore, firms have to decide between two options. They can expand in the domestic market with a new product that has low upfront costs and leads to low profits, or they can enter the foreign market (export) and pay a higher upfront cost but in return earn higher profits. This decision is motivated by firms’ financial constraint and thus being prevented from becoming active in all profitable markets immediately.

Liquidity constraints affect the process of growth of future multiple product exporters and delay the entry of firms with lower initial assets to the export market. These constraints create a trade off for the firm, thus making different orderings of product introduction optimal for firms depending on their initial asset level. In particular, I find that firms with higher initial wealth find it optimal to first export their most productive good then add new varieties, while other firms first build up their assets by increasing their product scope in the domestic market then begin exporting.

Adding financing constraints to a Melitz (2003) type model leads to resource misal-
locations and inefficient entry and exit. Additionally, liquidity constraints explain why we observe firms with similar levels of productivity behaving differently with regards to exporting. Non-exporters with a high level of productivity would like to export, but are prevented from doing so, as they do not have access to sufficient liquidity to cover their costs. This suggests productivity level, alone, is not a sufficient measure of the export status of the firm. The asset level of the firm as a new dimension of heterogeneity, shows different strategies of firms with similar levels of productivity in terms of domestic expansion and exporting capability. Figure 1.1, from Mayer and Ottaviano (2008) shows the overlap in the productivity level of exporters and domestic producers in Belgium. It is evident from the figure that the productivity level alone is not enough to determine whether a firm is an exporter or not.

The first part of the chapter develops a theoretical model and derives the conditions under which firms first expand in the domestic market rather than exporting. In particular, it is possible to show that there is an asset cutoff for every level of productivity, below which firms will find it optimal to expand their domestic product scope prior to exporting.

The second part of the chapter estimates the model structurally, allowing for uncertainty and entry and exit. In this dynamic setting, the setup constrains the number of products per firm to two. Uncertainty is introduced in the form of shocks to the fixed production costs of the firm,\(^2\) thus making exporter firms subject to additional cost shocks. In every time period, firms decide whether to enter in each domestic and foreign market subject to the upfront sunk costs. Firms decide to exit the market when continuing in such markets is no longer profitable. With the possibility of expanding in the domestic market, some firms undertake costly investments to increase their domestic product scope, slowly building up assets, in order to be able to export. Simulations of the firms’ decision confirm the presence of an ordering of product introduction as a function of the firm’s

\(^2\)Similar to Caggese and Cuñat (2013).
wealth. As expected, liquidity constraints create an overlap in the productivity of the exporting firms and domestic producers.

I then use the baseline calibration, and consider a counterfactual scenario to study the costs of financing constraints. In particular, removing financial constraints increases the aggregate productivity by 3.1%. There are additional welfare gains associated with the increase in the total number of varieties available to the consumers. The increase in the total number of varieties, is partially due to higher share of firms producing multiple products, and partially due to a rise in the number of exporting firms.

The chapter is organised as follows. Section 2 provides a brief review of the literature. Section 3 describes the setup of the model. Section 4 discusses the theoretical implications of the model. Section 5 extends the framework to a dynamic setting and Section 6 provides the counterfactual scenario and welfare analysis. Section 7 concludes.

1.2 Literature Review

There is an extensive literature emphasising firm heterogeneity and firm dynamics (Hopenhayn, 1992; Cooley and Quadrini, 2001; Clementi and Hopenhayn, 2006; Clementi and Palazzo, 2016; Carvalho and Grassi, 2019). In the trade literature, seminal work by Melitz (2003) has highlighted the selection of more productive firms into exporting and consequently improving the economy-wide level of productivity through reallocation of resources towards more efficient firms. Empirically, this result has been investigated in many countries: as an example Bernard and Jensen (1999) study the US, Aw et al. (2000) look into Taiwan and Korea, Delgado et al. (2002) find evidence in the context of Spanish firms.

More recent studies have extended the international trade models with heterogeneous firms, to allow for firm-product-level heterogeneity (Iacovone and Javorcik, 2010; Eckel and Neary, 2010; Bernard et al., 2006). The introduction of product scope for firms, generates new dynamics, as now in response to trade liberalisation, there will be resource reallocations not only across firms, but also within firms. The extension of trade models from single-product to multi-product firms is motivated by data showing that multi-product firms dominate the international markets.\footnote{Empirically, Bernard et al. (2007a) using the US data, Andersson et al. (2008) for Sweden, Muiûls (2008) for Belgium, Wales et al. (2018) for the UK and Goldberg et al. (2010) for India emphasise the importance of multi-product firms.} The structure of the model in this chapter follows Melitz (2003) and Bernard et al. (2011). The model allows for heterogeneity across firms and within firms on different products they produce. As it is common in these type of models, firms have to pay sunk costs and fixed costs to enter and operate in the market. With respect to the standard models of international trade, this chapter introduces financial frictions to the model by requiring firms to pay certain costs in advance and before profits are realised. Therefore, this chapter adds another dimension of heterogeneity to existing frameworks and accounts for differences in access to finance.
by firms.

This chapter, therefore, also relates to the literature studying the impact of financing constraints on growth and investment. Early studies by Rajan and Zingales (1996) and Fisman and Love (2007) stress the importance of access to finance for reallocation of resources. More generally, this chapter relates to the literature studying the effect of financial frictions and misallocation (Midrigan and Xu, 2014; Caggese and Perez-Orive, 2017; Buera and Moll, 2015; Buera and Shin, 2017; Galle, 2020; Buera et al., 2021). Financing constraints can force firms to operate at a suboptimal level, limit their investment and through that, slow down the growth of the economy.

More specifically, this chapter contributes to the literature examining the impact of financial constraints on international trade. In particular, papers have studied why firms with similar levels of productivity respond differently to trade liberalisation. Chaney (2016) explains this phenomenon through adding liquidity constraints to the standard Melitz (2003) model. He shows, wealthier firms inheriting large levels of assets, are more likely to export. Empirically, and using a large panel of countries, Manova (2012) confirms that export is lower in sectors more dependent on external finance and in countries where the financial institutions are less developed. Closest to this chapter is Caggese and Cuñat (2013) modifying the Melitz (2003) model to introduce a dynamic setting in which firms accumulate assets to overcome their financing constraints. They show credit constraints impact the firm’s export decision both directly and indirectly through precautionary savings as firms try to avoid a costly bankruptcy. They find substantial productivity losses from the entry decision of firms. I find that these losses will carry on when the model is extended to a multi-product setting.

In the model presented in this chapter, financing constraints show up in form of a sunk cost which has to be paid upfront. Generally, a firm is willing to pay for these high sunk costs only if it expects the high sunk costs will be compensated with future profits. Empirically, the existence of sunk costs for entry into export has been widely investigated. Combining high sunk costs of exporting with financial constraints has an important implication as now there is an opportunity cost: instead of exporting, the firm can invest in other projects. Interacting financing frictions with the firm’s domestic and foreign product scope is the main focus of this chapter.

Another strand of multi-product firm literature highlights the choice of firms’ product mix across destinations. Using French data Mayer et al. (2014) investigate how competition and geography shape a firm’s product mix in a given destination. Specifically, firms skew their product mix towards their best performing products and towards destinations with a bigger market. One important novel element of this chapter is looking at sequence of product introduction and time to export. Similarly, Albornoz et al. (2012) and Albornoz (2021) look at sequential exporting and firm’s decision in entering new des-

---

tinations. Therefore, here I consider another dimension and study the decision of firm between exporting or expanding in the domestic market.

Finally, results of this chapter relate to the strand of literature studying welfare gains of international trade (Arkolakis et al., 2012; Di Giovanni et al., 2014; Melitz and Redding, 2015). In particular, in this chapter I study the gains from international trade through relaxation of financing constraints.

1.3 Model

This section presents a framework with heterogeneous firms in terms of productivity and access to liquidity. Firms, conditional on their productivity, decide over exporting their products, introducing additional product lines in the domestic market or exiting. Firms’ decisions are constrained by their access to financing, as exporting, introducing new products domestically, and keeping their existing product lines operational involves incurring some upfront costs. These upfront costs combined with liquidity constraints lead to inefficiencies as firms are not able to reach their optimal size immediately.

In what follows, first the model is discussed in a closed economy setting and then it is extended to an open economy setting to incorporate the export decisions of the firms. Then, the equilibrium definition is provided.

1.3.1 Closed Economy

Demand- The model presented in this section follows Melitz (2003) with heterogeneous firms in a monopolistic competition setup. There is a continuum of firms producing differentiated varieties that are demanded by households. These varieties are imperfect substitutes and are indexed by $\omega \in \Omega$. Firms themselves are multiple product producers and the varieties each produces is from the same set $\Omega$. Therefore, the specification does not distinguish between varieties that have been produced across firms. Finally, consumers’ preferences over these varieties exhibit constant elasticity of substitution with parameter $\sigma$. The overall demand in this economy can be written as:

$$Q = P^{1-\eta} \quad (1.1)$$

where $\eta$ is the industry price elasticity of demand and $P$ is the CES aggregate price index presented by:

$$P = \left[ \int_{\omega \in \Omega} p(\omega)^{1-\sigma} \right]^{\frac{1}{1-\sigma}} \quad (1.2)$$

where $\sigma > 1$ is the elasticity of substitution. Note that since there is no aggregate uncertainty in the model $P$ will be constant in the equilibrium. The associated quantity with the aggregate price can be written as:
\[ Q = \int_{\omega \in \Omega} q(\omega)^{\frac{\sigma-1}{\sigma}} \, d\omega \tag{1.3} \]

Combining (1.1) and (1.3) and using the aggregate price definition from (1.12) yields the demand for each variety:
\[ q(\omega) = \frac{P^{\sigma-\eta}}{P(\omega)^{\sigma}} \tag{1.4} \]

**Production** - The specification for the production technology follows Melitz (2003) and is similar to the trade literature on heterogeneous multiple-product firms featuring fixed costs and using labour as the only input of production (Bernard et al., 2006; Bernard et al., 2011; Mayer et al., 2014). To enable firms to produce multiple varieties, the specification of Melitz (2003) is extended to augment over the set of varieties the firm produces. Productivity levels differ across and within firms between the varieties that they manufacture.

Prior to entry, potential entrants are uncertain about their productivity level and to learn it, they pay a sunk cost of entry \( S_e \) and get a draw from distribution \( G(\theta) \). Within a firm, there is a variety-specific productivity that can be decomposed into two parts. The first component is called core competency as in Mayer et al. (2014) and is an indication of firms’ efficiency. Alternatively it can be defined as the productivity corresponding to the main variety that the firm produces, where the main variety is the one with the highest level of productivity.\(^5\) The second component of the productivity, is a parameter \( C \in [0,1] \) which generates different levels of efficiency across firms’ products. This assumption is similar to Mayer et al. (2014), as they assume introducing new products pushes the firm away from its core competency and increases the marginal cost of production. Productivity of a variety with core competency \( \theta_c \) and variety-specific productivity \( C^{i-1} \) can be written as:
\[ \theta_{ci} = C^{i-1}\theta_c \quad i \in N \]

where \( i \) is the index showing the number of product lines a given firm owns. It can be observed from the variety-specific productivity that as firm introduces more products, its efficiency level declines at rate \( C \) which is the same across firms and is known in advance.

In the remainder of this chapter, when possible I suppress core competency subscripts for convenience. Given the definitions above, the per period cost of production for a firm in terms of labour can be presented as:
\[ \ell(\theta_c) = \sum_{i \in N} J_i [f_p + \frac{q(\theta_{ci})}{\theta_{ci}}] \tag{1.5} \]

\(^5\)To be precise the core competency is the value drawn from distribution \( G(\theta) \).
with:

\[ \theta_{ci} = C_{i-1} \theta_i \quad i \in N \quad \text{(1.6)} \]

where \( J_i \) is an indicator variable equal to 1 if the firm is active in product market \( i \) and \( f_p \) is the fixed production cost.

The specification above shows the augmented nature of the production technology. Total labour demanded by firm with core competency \( \theta_c \), depends on the number of varieties it produces. As a firm increases its product scope, additional fixed cost \( f_p \) should be paid for each new variety. Variable costs of production are inversely related to the productivity of each variety. It can be observed, from equation (1.6), that as a firm introduces new varieties, its productivity over each variety decreases and therefore the variable costs increase. This condition ensures that each firm produces a finite number of varieties.

**Financial Frictions and Asset Accumulation** - With perfect financial markets, firms with a sufficiently high level of productivity can operate in all profitable markets. This implies, that in a single product setting, the solution would be similar to the Melitz (2003) and in multi-product setting to Bernard et al. (2006) and Bernard et al. (2011). With financial frictions, firms have to pay the sunk and fixed costs of production before the profits are realised. This suggests that if the initial asset holding of the firm is low, the firm may be prevented from expanding its product scope upon entry. In time, sufficiently productive firms, conditional on surviving, accumulate enough wealth to overcome these constraints.

Firms’ initial assets determine the extent to which they can expand into different domestic or international markets. Therefore, after observing their core competency, firms realise the set of varieties they can profitably produce and the set of varieties they can actually afford to produce. Firms then accumulate assets through profits in order to pay for future production costs. The accumulation of wealth enables them to enter into markets that they initially could not afford due to their liquidity constraints. The rate of change of financial wealth is determined as follows:

\[ \dot{a}_t = r(a_t - \sum_{i \in N \setminus \{1\}} D_{i,t}S_i) + \sum_{i \in N} J_i \pi_i^D(\theta_i) \quad \text{(1.7)} \]

Where \( D_{i,t} \) is an indicator variable taking the value one if the firm decides to introduce domestic variety \( i \) in period \( t \) and takes the value zero otherwise. Therefore changes in assets of the firm at time \( t \) is equal to the sum of interest payments on net wealth after the payment of the sunk costs and the stream of profits from the active product lines.

**Firms’ Decision** - After paying the sunk costs of entry \( S_e \) the firm observes the productivity level of each variety. Then, given its liquidity constraints, the firm decides on the product mix, the optimal quantity and the time to introduce each variety. The firm’s
optimisation problem is presented as:

\[ V(\theta_c, a_t) = \int_0^\infty e^{-(1-\delta)(t)} \pi^D(\theta_{c1}) + \sum_{i \in N-\{1\}} \int_{t_i}^\infty e^{-(1-\delta)(t-t_i)} \pi^D(\theta_{ci}) - S_d e^{-(1-\delta)(t_i)} \]  

subject to:

\[ \theta_{ci} = C_{i-1}^{i-1} \theta_c \quad i \in N \]  

\[ a_t \geq \sum_{i \in N} J_{i,t} f_p + \sum_{i \in N-\{1\}} D_{i,t} S_d \]  

\[ J_{i,t} = \max\{D_{i,t}\} \quad \forall t \]  

where \( \delta < 1 \) is the exogenous probability of death. As equation (1.8) shows, the value function \( V^D \) is defined as the net present value of current and future profits. Inequality (1.10) indicates firms’ assets should be higher than their upfront costs. The final equation shows once the firm pays the sunk cost of producing a new variety it will continue its production in the subsequent periods and therefore the model does not allow exiting from a product market. Note that the value function is defined such that \( D_{i,t} = 1 \) if \( t \geq t_i \).

Demand for variety \( i \) of the firm depends on the variety’s price and the aggregate price index \( P \). Given that varieties are substitutable and since all firms are atomistic, a firm’s optimisation problem in each product market implies that the price of a variety is a constant mark-up over the marginal cost:

\[ p(\theta_{ci}) = \frac{w}{\theta_{ci}} \frac{\sigma}{\sigma - 1} \]  

Additionally, since the upfornt costs only include the fixed costs of production and not the variable costs, the financial constraints only impact the number of active lines for a firm but not the quantity produced of each variety. Therefore, the above pricing strategy will hold for all firms and all varieties within a firm.

**Firm-product Profitability-** Demand for a variety depends on the variety’s price relative to the aggregate price \( P \). Given the pricing rule for variety \( i \) of the firm defined as equation (1.12), and normalising the wage \( w = 1 \), the revenue and the profits of the firm over each variety it produces can be presented as:

\[ r(\theta_i) = p(\theta_i) q(\theta_i) = \left( \frac{w}{\theta_i} \frac{\sigma}{\sigma - 1} \right)^{1-\sigma} P^{\sigma-\eta} = Q P^\sigma \left( \frac{\theta_i}{\sigma - 1} \right)^{\sigma-1} = R \left( \frac{P}{\theta_i} \frac{\sigma}{\sigma - 1} \right)^{\sigma-1} \]  

Where \( R \) denotes aggregate expenditure. Similarly, the profits can be written as:

\[ \pi^D(\theta_i) = \frac{r(\theta_i)}{\sigma} - f_p \]  

The profit function presented in equation (1.14) is similar to the specification in Melitz (2003) which leads to a zero profit productivity cutoff for firms. In the setup of this model
the zero profit cutoff is different from the one defined by Melitz (2003), as there are additional sunk costs of setting up a product line. Lemma 1 defines the zero net profit cutoff $\theta^{**}$, as the cutoff that the firm will enter the product line if it draws a value for $\theta_i$ which equal to or greater than $\theta^{**}$.

**Lemma 1:** There exists a zero net profit cutoff $\theta^{**}$ for each variety $i \in \mathbb{N} - \{1\}$, such that the firm will add a new product if the productivity corresponding to that variety is equal or greater than $\theta^{**}$.

\[
\theta_i^{**} = \left( \frac{S_d \int_0^\infty e^{-(1-\delta)t} dt}{f_p} + 1 \right) \frac{1}{\sigma^*} \theta^*
\]

Where $\theta^*$ is the zero profit cutoff productivity as defined by Melitz (2003).

Proof: See appendix.

The sunk cost $S_d$ raises the entry productivity cutoff above $\theta^*$, since now not only the revenues have to cover the fixed cost of production, but the stream of revenues should compensate the firm for the initial sunk cost paid. The two cutoffs coincide when $S_d = 0$.

### 1.3.2 Open Economy

In this section, I extend the closed economy framework described in the previous section to an open economy setting where all trading partners are symmetric in terms of preferences and production technology. I denote export market variables with subscript $x$ and domestic market variables with subscript $d$. In line with the empirical literature, I assume that participating in international trade is costly. There are additional sunk costs, fixed costs and variable costs associated with exporting. The sunk costs of entry into the export market can be interpreted as the cost of initial research required before starting to export. There is a large body of empirical evidence supporting the existence of such high sunk costs for exporting. It is assumed that the sunk cost is incurred for each product that the firm decides to export and is denoted by $S_x$. Further, there are product specific fixed costs, $f_x$ representing product specific costs such as the cost of advertisement. Finally, there are iceberg costs of $\tau > 1$, showing the shipments costs, as it is standard in the literature.

**Production and Firm-product Profitability** - The specification follows Melitz (2003) and as before is augmented to allow for production and export of multiple goods. Since the countries are symmetric, firms face the same elasticity of demand in all countries and export prices are a constant multiple of the domestic prices:

\[
p_x(\theta_{ci}) = \tau p_d(\theta_{ci}) \tag{1.15}
\]
As described above, if a firm exports a variety it has to pay additional fixed cost $f_x$ for each product that it exports. In addition, total quantity produced for varieties that are exported will increase. $q(\theta_i)$ therefore, includes both the quantity supplied to the domestic market $q_d(\theta_i)$ and the quantity exported $q_x(\theta_i)$. Hence, the total labour demand increases for exporter firms by the amount of fixed costs $f_x$ and variable costs $q_x(\theta_i)/\theta_i$, which is implicitly included as an increase in $q(\theta)$. The production technology now can be written as:

$$\ell(\theta_c) = \sum_{i \in N} J_i [f_p + \sum_{J_i^X \subseteq J_i} f_x + \frac{q(\theta_{ci})}{\theta_{ci}}]$$ (1.16)

Where:

$$\theta_{ci} = C_i - 1 \quad i \in N$$ (1.17)

Similar to the closed economy section, $J_i$ is an indicator variable taking the value 1 if the firm is active in production of variety $i$. In a similar vein, $J_i^X$ is an indicator variable taking the value 1 if the firm exports variety $i$.

Additional fixed and sunk costs of exporting imply that it is optimal for a firm to serve the domestic market prior to exporting. Given the characterisation of the production technology (the cost function), therefore, the revenues and costs of production can be proportionally divided between the domestic market and the export market. Thus, a firm deciding whether to export or not, compares the fixed and sunk cost of exporting with its respective revenues only. Given the pricing rule for exports, the firm’s revenue can be written as:

$$r_x(\theta_i) = \tau^{1-\sigma} R(\frac{\sigma}{\sigma-1})^{\sigma-1}$$ (1.18)

The above equation suggests that similar to the domestic market, there exists a productivity cutoff below which the profits generated from exporting a variety are negative and it is not optimal for the firm to export that variety.

**Lemma 2:** There exists a zero net profit cutoff for exporting $\theta^*_x$ for each variety $i \in N$ such that the firm will export the product only if the productivity corresponding to that variety is equal or greater than $\theta^*_x$:

$$\theta^*_x = \left( \frac{S_x}{f_x} \int_0^\infty e^{-(1-\delta)t} dt + 1 \right)^{1-\sigma} \theta^*_x,m$$

Where $\theta^*_x,m$ is the Melitz (2003) exporting cutoff productivity.

Proof: See appendix.

It can be observed that $\theta^*_x$ is strictly greater than $\theta^*_x,m$ as long as $S_x > 0$. This is expected as additional sunk costs imposed on firms should be compensated by the stream of profits in later time periods. This cutoff is independent of the initial level of wealth and provides the lower bound for entry of firms into exporting.

Since all goods are identical in terms of fixed and sunk costs, the zero net profit cutoff
for exporting is the same across all the products the firm manufactures. The intuition underlying the relationship in the export market is similar to the one discussed for the domestic market. An increase in the sunk costs of exporting raises the net cutoff above the exporting cutoff as defined by Melitz (2003). Finally, similar to results in Melitz (2003), opening up to trade, increases the zero profit entry cutoff through a decrease in aggregate price level $P$.

**Firms’ Decision**—Analogous to the closed economy case, firms decide on the time to add each variety in the domestic market $t_i$, prices $p_i$ and quantities $q_i$. Additionally, with opening up to trade, firms decide on the set of products to export and the time to export them $t_i^X$. The decision to export is denoted by $X_{i,t}$ which is a binary variable taking the value 1 if the firm decides to export variety $i$ at time $t$.

Define $V^X$ as the value of a firm that can operate both in home and international markets. Then a liquidity constrained firm decides at any $t$ between expanding in the domestic market or exporting the most productive product that is not already exported. $D_{m} = \max\{D_{i,t} = 1\}_{i=1}^N$ shows the final variety added to the domestic market by time $t$. Similarly, $X_{m} = \max\{X_{m',t} = 1\}_{i=1}^N$ shows the final variety exported by time $t$. Given the above definitions, $X_{m',t}$ is equal to one (i.e., the firm begins exporting a new variety in period $t$) when the following conditions are satisfied for all $t$ and all $m' \leq m$:

$$V^X(\theta_c, a_t)|_{X_{m'}+1,t=1} > V^X(\theta_c, a_t)|_{D_{m+1,t}=1}$$ (1.19)

$$V^X(\theta_c, a_t)|_{X_{m'}+1,t=1} \geq V^X(\theta_c, a_t)|_{X_{m'}+1,t=0}$$ (1.20)

The conditions are written for a liquidity constrained firm under the assumption that the decision to expand or export in not reversible in the subsequent periods. However, the firm can always decide to exit the market entirely if it is not profitable as a whole. Condition (1.19) states that the value of the firm exporting variety $m'+1$ (i.e., the variety with the highest level of productivity that is not already exported) must be greater than the value of adding a new variety in the domestic market. Condition (1.20) states that the value of exporting the new variety must be greater than the value of not exporting it. Similarly, these conditions can be written for a liquidity constrained firm that decides introducing a new variety in the domestic market is optimal. $D_{m+1,t}$ is equal to one if:

$$V^X(\theta_c, a_t)|_{D_{m+1,t}=1} \geq V^X(\theta_c, a_t)|_{X_{m'}+1,t=1}$$ (1.21)

$$V^X(\theta_c, a_t)|_{D_{m+1,t}=1} \geq V^X(\theta_c, a_t)|_{D_{m+1,t}=0}$$ (1.22)

The interpretation of the above conditions is similar to (1.19) and (1.20). Condition (1.21) states that adding a new variety in the domestic market must put the firm on a higher value path compared to exporting an already existing variety. The next condition indicates producing a new variety must generate higher net profits than not producing the variety. Now, $V^X(\theta_c, a_t)$ can be determined as the net present value of future profits.
The value of the firm can be written as:

$$V^X(\theta_c, a_t) = \int_0^\infty e^{-(1-\delta)(t)}\pi^D(\theta_c) + \sum_{i \in N-\{1\}} \left[ \int_{t_i}^\infty e^{-(1-\delta)(t-t_i)}\pi^D(\theta_i) - S_d e^{-(1-\delta)(t_i)} \right]$$

subject to:

Conditions (1.19), (1.20), (1.21), (1.22) and

$$J_{i,t} = \max \{ D_{i,t} \}_{t=0}^T$$

$$J_{i,t}^X = \max \{ X_{i,t} \}_{t=0}^T$$

$$\theta_i = C_i - 1 \theta_c \quad i \in N$$

$$a_t \geq \sum_{i \in N} J_{i,t} f_p + \sum_{i \in N} D_{i,t} S_d + \sum_{i \in N} J_{i,t}^X f_x + \sum_{i \in N} X_{i,t} S_x$$

$$\dot{a}_t = r(a_t - \sum_{i \in N} D_{i,t} S_d - \sum_{i \in N} X_{i,t} S_x) + \sum_{i \in N} J_{i,t}^D(\theta_i) + \sum_{i \in N} J_{i,t}^X \pi^X(\theta_i)$$

Where the value function is the present discounted value of the future profits both from domestic production and exporting. $S_d$ and $S_x$ denote the sunk costs of adding domestic production lines and exporting new products respectively. As before $e^{-(1-\delta)t}$ is the discount factor, where $\delta$ is the exogenous probability of death. $J_{i,t}^X$ is an indicator variable, taking the value one for a firm exporting variety $i$. If a firm pays the sunk cost of exporting at any arbitrary time $t' < t_i^X$ then $X_{i,t'} = 1$ and the firm takes the exporter status for variety $i$. The inequality (1.27) shows that at any point in time the firm should have enough wealth to pay for the upfront costs of production and exporting otherwise it has to exit the market. Condition (1.28) is the asset development equation.

There is a substantial difference between the firm’s decision in a closed economy setting and open economy setting. In a closed economy, the initial asset level of the firm determines the number of products the firm produces in the first time period. Then, as firm accumulates assets it starts adding new varieties as long as they generate positive net profits. The order of adding these new varieties is solely based on the productivity and independent of wealth.

In an open economy, the firm faces a trade off which was not present in a closed economy setting. Now the firm has to decide between adding another line in the domestic market or exporting its most productive variety, given it has a sufficiently high produc-
tivity to do both. This suggests that the optimal decision of multiple-product firms with financial constraints, includes a sequence for introducing new products and depends not only on the productivity level but also the assets of the firm. Conditions (1.19)-(1.22) summarise the decision of the firm and the sequence of product introduction will be further explored in section 1.4.

**Entry Decision**— Firms have to pay a sunk cost to observe their core competency $\theta_c$. After observing $\theta_c$, they decide on the varieties they produce and the markets they serve conditional on having sufficient funds to pay for the sunk costs of entering these markets. Free entry requires the expected value of the entry and learning the core competency be equal to the cost of entry $S_e$:

$$E[V_X(\theta_c,a_0)] = S_e$$  \hspace{1cm} (1.29)

Where the operator $E$ refers to expectation over core competency $\theta_c$. In models without liquidity constraints, the free entry condition provides a unique productivity cutoff above which firms join the market. With financing constraints, however, the expected net present value of profits is a function of firm’s assets. The initial asset level of the firm affects the expected time period in which firms can pay for the sunk costs of entering into the other markets, conditional on having a sufficiently high productivity. This means, the value of observing a certain level of productivity is different among firms with different levels of initial assets. A firm with high initial wealth, immediately pays for the costs of entry into all profitable markets. With a lower level of wealth, the firm cannot afford to become active in all the profitable markets right away. Therefore, the net present value of profits is an increasing function of the initial asset level.

### 1.3.3 Equilibrium

The steady state equilibrium is characterised by an aggregate price $P$, an aggregate quantity $Q$, time invariant distributions of operating and entrant firms over their productivity levels and asset level such that firms maximise their value functions $V^X(\theta_c,a_t)$ defined in (1.23) given conditions (1.24)-(1.28). Existing firms decide to expand in the domestic market only if conditions (1.21) and (1.22) are satisfied. Existing firms decide to export each product according to (1.19) and (1.20). New entrants satisfy condition (1.29).

The mass and distribution of firms over the productivity levels determines the distribution of prices. The CES aggregator then determines the aggregate price level $P$. The presence of the exogenous exit probability $\delta$ ensures that the distribution of wealth across firms does not grow without bounds.
1.4 Theoretical Implication: Product Sequencing

Previous sections briefly discussed the choices financially constrained firms face regarding the introduction of new products. This section explores the decision of the firm in more detail and characterises the firms’ decision as a function of initial wealth. Before deriving this condition, I explain the effect of firms’ asset holding and the option to produce multiple varieties on firms’ production strategies.

First, to isolate the effect of financial constraints, I abstract from a multiple product setting and consider the case in which firms can only manufacture a single product. Financial constraints, as before, come into effect through upfront costs associated with production and exporting. Therefore, if firms’ initial asset levels are low, this will delay their ability to export, and thus generates heterogeneity in the behaviour of firms with the same productivity level. This provides evidence on results observed in Figure 1 showing that firms with similar levels of productivity sometimes export and sometimes not, and justifies the inclusion of wealth as another dimension of heterogeneity.

Enriching the space of products will allow for other mechanisms that further reinforce differences in the behaviour of the firm. Specifically, in a multiple product setting, firms with limited initial assets have to choose between investing in domestic expansion and exporting. This means, for firms the decision to invest in domestic expansion comes at the expense of delaying the export of the existing goods. The strategy of the firm depends on the present discounted value of taking each path. The present value of each path is a function of the productivity level of the firm for each product, its asset level and the sunk costs associated with domestic production and exporting.

To show how the asset level of the firm affects its production strategies, I consider an $n$ good economy. Denote $\{\theta_1, \theta_2, ..., \theta_n\}$ the productivity set for all products of a given firm relating to varieties $\{1, 2, ..., n\}$ respectively. The main result states that there exists a threshold for the asset level below which the firm follows a path of expanding in the domestic market prior to exporting. On the other hand, above this threshold, it is optimal for firms to first export then add the second variety in the domestic market. Therefore, the sequence of product introduction changes depending on the firm being financially constrained or not: firms with a lower access to liquidity add varieties in the domestic market while firms with higher asset levels become unconstrained through exporting. The proposition below characterises the firm’s strategy.

**Proposition** There exists strictly positive productivity levels $\theta^*_x$ and a finite productivity level $\theta_{\text{high}}$ such that:

1. For firms with productivity level $\theta_c \leq \theta^*_x$ it is optimal to only produce for the domestic market.

2. For firms with productivity level $\theta_c \in [\theta^*_x, \theta_{\text{high}}]$ it is always optimal to expand in the
domestic market before starting to export.

3. For firms with productivity level $\theta_c \geq \theta_{\text{high}}$, there exists an asset level $a_{t-1}(\theta_c)$ such that below this level firms will first expand into the domestic market and above which they will overcome their credit constraints through saving and exporting their most productive good prior to increasing their product scope in the domestic market.

Proof: See appendix.

In particular, given the sunk costs and fixed costs of production, the initial asset level of the firm as a function of its productivity level determines the present value of each path and therefore the sequence of product introduction. This means differences in asset levels of firms with similar levels of productivity will make different paths optimal for firms. Some will find it optimal to first expand in the domestic market and then export while others choose to first export then add new varieties in the domestic market. Note that if the firms survive then those with similar levels of productivity end up having the exact same product mix. It is only the sequence of introduction of these goods that differs between them. However, with exogenous probability of death, a fraction of these firms do not live long enough to become unconstrained and active in all profitable markets.

1.5 Dynamic Model

In this section the model is extended to a dynamic setting to be solved numerically. The framework remains as described in the previous section, but a simpler case in which firms can produce and export two varieties is considered. In a two product setting, liquidity constrained firms have to decide between introducing variety two to the domestic market or exporting variety one. Therefore, the main result of the theoretical model, sequence of product introduction with regard to initial wealth, can be illustrated in this setting.

In this setting, the firm’s profit is subject to shock $\epsilon$ that follows a two state symmetric Markov process in which the firm will receive either a positive or negative shock to its costs. The probability of remaining in the same state is equal to $\rho$ and the probability of changing the state is $1 - \rho$. After paying the sunk cost of entry $S_e$ the firm is assigned with the initial shock with equal probability. Therefore, the initial distribution over the value of the shock is uniform. The firm also observes the core competency level which is drawn from an exponential distribution for the entrants and is specified as in Caggese and Cuñat (2013). I assume all entrants are financially constrained however the extent to which they have access to liquidity differs between them.

To model is solved numerically and in discrete time. The discrete time setup and the numerical solution to the model are described in the appendix.\(^6\)

\(^6\)While setting up the model in discrete time is advantageous, the theoretical results as described in section 4 will not be as strong. This has been discussed in details in the appendix.
1.6 Calibration

This section structurally estimates the model to match the moments of data for the sample of US exporter firms between 1995 -2000. Table 1.1 provides the exogenously calibrated variables, their values and their source.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interest rate</td>
<td>$r$</td>
<td>0.04 US interest rate year 2000</td>
</tr>
<tr>
<td>Elasticity of substitution</td>
<td>$\sigma$</td>
<td>4 Costantini and Melitz (2008)</td>
</tr>
<tr>
<td>Industry elasticity of substitution</td>
<td>$\eta$</td>
<td>1.5 Costantini and Melitz (2008)</td>
</tr>
<tr>
<td>Iceberg costs</td>
<td>$\tau$</td>
<td>1.2 Costantini and Melitz (2008)</td>
</tr>
<tr>
<td>Death shock</td>
<td>$\delta$</td>
<td>0.15 Costantini and Melitz (2008)</td>
</tr>
<tr>
<td>Cost shock correlation</td>
<td>$\rho$</td>
<td>0.7 Caggese and Cuñat (2013)</td>
</tr>
</tbody>
</table>

It is assumed that upon paying the sunk cost of entry $S_{e}$ entrants draw their core competency from an exponential distribution with mean $\lambda$ truncated across the productivity (core competency) space. Entrants are all financially constrained and are uniformly distributed across the lower levels of asset grid, such that all entrants remain financially constrained. Similarly the initial value of the cost shock is randomly drawn from a uniform distribution. I assume that for any extra product the firm adds to its portfolio, the productivity of the new product moves one step down on the productivity grid. Furthermore, exporters are subject to additional cost shocks which similar to before follow a two state Markov process indicating that exporting exposes firms to conditions of other markets. The domestic and export shocks are assumed to be independent of each other. The appendix provides more details.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sunk cost of entry</td>
<td>$S_{e}$</td>
</tr>
<tr>
<td>Sunk cost of adding a domestic line</td>
<td>$S_{d}$</td>
</tr>
<tr>
<td>Sunk cost of export</td>
<td>$S_{x}$</td>
</tr>
<tr>
<td>Fixed cost of domestic production</td>
<td>$f_{p}$</td>
</tr>
<tr>
<td>Fixed cost of exporting</td>
<td>$f_{x}$</td>
</tr>
<tr>
<td>Productivity step</td>
<td>$C$</td>
</tr>
<tr>
<td>Parameter of entry distribution</td>
<td>$\lambda$</td>
</tr>
</tbody>
</table>

The model is estimated such that the percentage of exporting firms and multiple product exporters match the empirical moments. To fit the model with empirical data, sunk costs, fixed costs and the demand parameter are simultaneously chosen. Sunk cost and fixed cost of exporting jointly determine the share of exporters and multiple product exporters. Sunk cost of domestic production pins down the share of multiple product firms in the economy and fixed cost of domestic production together with fixed cost of
exporting match share of fixed cost in the economy. Sunk cost of entry and the parameter of entry distribution affect the distribution of incumbents by affecting the entry cutoff and the shape of entrants’ distribution.

### Table 1.3: Moments

<table>
<thead>
<tr>
<th>Data</th>
<th>Simulated moment</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Share of multi product firms</td>
<td>.40</td>
<td>Bernard et al. (2010)</td>
</tr>
<tr>
<td>Share of exporters</td>
<td>.15</td>
<td>Bernard et al. (2011)</td>
</tr>
<tr>
<td>Share of multiple product exporters</td>
<td>.58</td>
<td>Bernard et al. (2011)</td>
</tr>
<tr>
<td>Share of fixed costs</td>
<td>.20</td>
<td>Costantini and Melitz (2008)</td>
</tr>
<tr>
<td>Output share of single product firms</td>
<td>.13</td>
<td>Bernard et al. (2007b)</td>
</tr>
<tr>
<td>Shipment value of exporter to non-exporter</td>
<td>6.48</td>
<td>Bernard et al. (2007b)</td>
</tr>
<tr>
<td>Average productivity of exporter to non-exporter</td>
<td>1.07</td>
<td>Bernard et al. (2007b)</td>
</tr>
</tbody>
</table>

#### 1.6.1 Results

**Exporting, Productivity and Initial Assets**

In the steady state distribution of firms, there is an overlap on the productivity level of exporters and non-exporters suggesting that productivity level is not enough to determine the status of a firm as an exporter. In this regard, Figure 1.2 describes the cutoff of entry into exporting as a function of firm’s initial asset, as well as the expected waiting time for a given firm to be able to start exporting. The very dark blue captures firms that do not export, and thus present the cutoff for exporting as a function of state variables. It can be observe that productivity level alone is not enough in describing the export status.

Firms on the top right hand side of the heat map are high productivity firms with
Figure 1.3: This figure shows the decision of the firm regarding the time to export the existing product or add a new product in the domestic market as a function of the initial wealth.

High assets, and can export immediately. The bottom right section of the heat map has more heterogeneity and points out to firms that are building up their assets to be able to pay for the costs of exporting. For these firms lack of access to finance creates resource misallocation and leads to lower aggregate productivity. The figure also shows that firms higher on the productivity grid outgrow their financing constraints relatively faster, with lighter colours presenting lower waiting times.

Simulations of the Proposition

Figure 1.3 presents the dynamics implied by the Proposition for the firm in a two-product world. It illustrates the ordering decisions of the firm regarding export of the existing variety and expanding in the domestic market with a new variety given the initial asset levels. The first and second statements of the Proposition discuss the cutoffs for entry into the export market and do not have implications for the sequence of product introduction. Therefore, I focus on the third statement of the proposition.

Figure 1.3 shows that the decision regarding the time to expand or export depends on firms’ initial asset level. For very low initial asset levels, the firm does not have access to enough liquidity to enter either of these markets immediately. For example take value 0.1 for initial wealth. The time to introduce variety 2 to the domestic market is $t = 2$ while the time to export variety 1 is $t^e = 3$. While there is a delay in entry to both markets (i.e. the firm cannot enter at time $t = 1$), the time to expand in the domestic market comes before exporting the existing variety 1 for this asset level.

Now, take the value $a = 1.1$. For this value, the firm exports at $t^e = 1$ while the decision to add a new domestic line comes at $t = 2$. Therefore, it can be seen that
Figure 1.4: Average frequency of exporting firms as a function of age

depending on the initial value of wealth the ordering of product introduction changes. The figure is therefore able to capture the non-monotonicity implied in the policy function of the firm. Note that exporting product 2 always comes at the end and therefore is not included in the figure. Finally, for very high initial levels of wealth the firm is able to enter all the markets immediately.

**Firm Dynamics**

Figure 1.4 and Figure 1.5 show the implied dynamics at the firm level. Figure 1.4 plots the probability of being an exporter as a function of age. Similarly, the average frequency of being a multiple product exporter is shown in the same figure. Young firms, on average have a lower probability of being an exporter, as they are liquidity constrained. However, the figure shows by the age of five, firms have outgrown their financing constraints.

Figure 1.5 shows the development of financial assets of firms. Exporters accumulate more wealth since they are more productive in general and they serve multiple markets. It can also be observed that the rate of increase in assets of exporters increases with age for younger firms. This can be explained by lack of access to liquidity. A fraction of young exporters are liquidity constrained and therefore cannot access all the markets that generate profits for them. Through time, these firms outgrow their constraints and their wealth increases at a higher rate.

---

Since the simulations are done in discrete time, there will be some additional dynamics which were not present in a continuous time framework. This has been included in the appendix.
1.7 Counterfactual Scenario and Welfare Analysis

In this section, a counterfactual scenario in which firms do not face financing constraints is considered. The model is analysed under parameter values reported in Table 1.1 and Table 1.2. The aim of this exercise is to understand the inefficiencies and welfare losses due to financing frictions. Table 1.4 reports the results.

<table>
<thead>
<tr>
<th></th>
<th>No financing constraint</th>
<th>Financing constraint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Share of multi product firms</td>
<td>.65</td>
<td>.42</td>
</tr>
<tr>
<td>Share of exporters</td>
<td>.27</td>
<td>.18</td>
</tr>
<tr>
<td>Share of multiple product exporters</td>
<td>.63</td>
<td>.65</td>
</tr>
<tr>
<td>Share of fixed costs</td>
<td>.19</td>
<td>.15</td>
</tr>
<tr>
<td>Output share of single product firms</td>
<td>.11</td>
<td>.25</td>
</tr>
<tr>
<td>Shipment value of exporter to non-exporter</td>
<td>22.62</td>
<td>6.65</td>
</tr>
<tr>
<td>Average productivity of exporter to non-exporter</td>
<td>1.38</td>
<td>1.22</td>
</tr>
</tbody>
</table>

Table 1.4 shows that in response to removing financing constraints, the share of multiple product firms and the share of exporters will increase. Share of multiple product exporters falls, due to having a higher share of single product exporters (in levels both values increase). The number of single product exporters increases, as firms no longer have to rationalise the sequence of product introduction and can immediately enter all profitable markets. As expected, output share of single product firms falls, as now more firms are able to produce multiple products. Further, shipment value of exporters increases with respect to non-exporters as access to financing allows shipping to additional markets.

To understand the welfare implications of relaxing financing constraints, I consider
welfare per worker measured as \( \frac{w}{P} \), wage over aggregate price. As wage is normalised to 1, a decline in aggregate price level leads to welfare improvements.

Relaxing financing constraints can improve welfare through two channels. First, in the absence of liquidity constraints, firms are able to enter all profitable markets immediately, and therefore, there will be more varieties available in total to the consumers. Second, through selection into exporting, similar to the main channel discussed in Melitz (2003), the productivity cutoff of entry increases as now more firms can afford to export. This leads to exit of less efficient firms and improves the aggregate productivity level.

\[
\tilde{\phi} = \frac{1}{M_t} \left[ M_c \tilde{\phi}_c \sigma^{-1} + n M_{c,x} \tau^{-1} \tilde{\phi}_{c,x} \sigma^{-1} + \sum_{i \in N} (M_i \tilde{\phi}_i \sigma^{-1} + n M_{i,x} \tau^{-1} \tilde{\phi}_{i,x} \sigma^{-1}) \right]
\]

Where \( \tilde{\phi} \) is the average productivity in the economy. \( M \) shows the number of firms, with \( M_t \) referring to the total number of firms, \( M_c \) number of firms producing their core product in the domestic market, \( M_{c,x} \) number of firms exporting their core product and \( M_i \) number of firms having their \( i \)-th product line. \( \tilde{\phi}_c \) and \( \tilde{\phi}_i \) refer to average productivity of the core product among all firms and average productivity of the \( i \)-th product line among the firms. \( x \) subscript refers to exporting of each product and \( \tau \) is the iceberg cost.

\( n \) is the number of countries, which for the calibration is set out to 5 as the literature suggests most exporter firms export to at least five destinations. Given the definition in equation above, the aggregate price level can be presented as:

\[
P = M_t^{\frac{1}{\sigma-1}} \frac{1}{\sigma-1} \frac{1}{\tilde{\phi}}
\]

The analysis show that welfare improves by 12.8% as a result of removing financing constraints. This is partially due to productivity improvements, where average productivity increases by 3.1%, but the majority of the welfare improvement is due to the number of available varieties which increase by 30%. The variety effect is sensitive to the number of trading partners, that in this exercise is set to five. Adjusting the number of trading partners to 1, decreases the variety effect from 30% to 21%.

**1.8 Conclusion**

I present a theoretical model in which firms can produce and export multiple products and they face liquidity constraints. Firms accumulate wealth to overcome their financing constraints that affect their ability to pay for fixed operational costs and the one-off sunk costs of entry into any new market. In the process of overcoming their constraints, firms face a choice between increasing the number of varieties they produce in the domestic market and exporting the varieties they already have. Exporting is more costly but it can generate higher profits if the firm has a high enough productivity. Therefore, constrained firms face a trade off between increasing their product scope in the domestic market and
exporting. The model shows that firms with higher initial assets break into export market faster provided they have a sufficiently high level of productivity. This induces a different sequence of product introduction by firms with different level of initial wealth that are otherwise similar.

The results also indicate that in equilibrium, financing frictions lead to misallocation of resources. This occurs because, the lack of entry from firms with lower initial assets is compensated by an increased entry of firms with higher initial wealth but low levels of productivity. As a consequence, there will be substantial welfare losses if a significant number of firms face financial constraints.

Finally, the theoretical framework is applied to a dynamic setting in which firms can produce and export two products. I verify the theoretical predictions using the dynamic model. After the initial entry to the domestic market, firms with high initial asset levels overcome their financing constraints by first exporting the most productive good and then increasing their product scope. While firms with lower initial wealth accumulate assets slowly by introducing a new variety in the domestic market and then starting to export, verifying the existence of an optimal sequence of product introduction based on firms’ assets. Additionally, I show that that for younger firms, liquidity constraints decrease the probability of exporting while this is not the case for older firms. Also, the average asset level of an exporter is much higher than the average asset of a non-exporter. The difference is more significant as the age of the firm increases.

This chapter then studies a counterfactual scenario, in which financing constraints are removed. This leads to an increase in the share of firms producing multiple products and the share of exporter firms. Output share of single product firms falls significantly, as under this scenario, only the least productive firms produce a single product. Further, removing financing constraints lead to 3.1% increase in aggregate productivity and significant efficiency gains.
Chapter 2


Abstract
This chapter provides new evidence on the relationship between antitrust policies and firms’ economic performance. Over the past few decades industry concentration has increased while the enforcement of antitrust has been lax. This chapter studies both the case of the US, where enforcement is proxied by the resources allocated to antitrust, and the case of Europe, where I use an index of competition law available for various countries and over time. Economic performance in the US is measured using firm level data from Compustat and sector-level data obtained from Business Dynamic Statistics and Bureau of Labor Statistics. For Europe, I use data from Orbis and CompNet database. Both exercises show that stronger antitrust policies are associated with higher productivity growth, higher entry rate but lower innovation.
2.1 Introduction

Effective antitrust policies regulate markets and prevent powerful firms from engaging in anticompetitive practices. In turn, protecting the competitiveness of markets fosters growth through facilitating entry of new and more efficient firms. In recent years there has been growing evidence of a decline in the firm entry rate and productivity growth coinciding with an increase in industry concentration and firms’ market power (Akcigit and Ates, 2021).

In this chapter, I empirically investigate the link between firms’ ability to act anticompetitively and the decline in business dynamism. Whether firms can undertake anticompetitive actions or not depends on the market structure and the strength of antitrust policies. In particular, in industries with low levels of concentration, firms have limited power to abuse their position in the market, and therefore there is a much lower need for antitrust enforcement. The opposite holds for industries with high concentration levels. This suggests that antitrust policies are expected to have heterogeneous effects on industries based on their levels of concentration.

To investigate this question, I study antitrust policies and their relation to economic performance in the US and Europe. To this end, I first define a measure for strictness of antitrust for the two scenarios. For the US, I proxy enforcement with the relative share of budget allocated to antitrust, while for Europe, I use an index constructed by legal scholars, which encodes over 700 laws into an index available for a wide range of countries across time. Despite using different measures to capture the strictness of antitrust, I find similar results for these two cases.

To assess economic performance, I use firm-level and sector-level data. For the US, I combine the Compustat database which contains balance sheet information of publicly traded firms with sector-level data on firm entry rate from Business Dynamic Statistics and multi-factor productivity obtained from Bureau of Labor statistics. The appropriation figures are from the Department of Justice website and the period of study is from 1978 to 2018. For Europe, I use firm-level data from Orbis and sector-level data from CompNet database on ten European countries from 1999-2017, though the availability of data differs across various countries.

The main results are based on reduced-form analysis exploiting the variation in antitrust enforcement over time, across countries, and its interaction with the industry concentration level. I find that, as concentration levels increase, strengthening antitrust policies is associated with a higher rate of entry, higher productivity growth, and lower investment in innovation by incumbents. A higher productivity growth, despite a lower innovation rate could be generated by the entry of more efficient firms. This result will be further investigated in the next chapter.

The findings of this chapter highlight the importance of antitrust law and its enforcement for sectors of the economy where concentration levels are high. With the majority

---

1The Comparative Competition Law Database Bradford and Chilton (2018)
of sectors, especially in the US, experiencing increasing trends in concentration and firms’ 
market power, strong antitrust institutions can protect the competitiveness of markets 
through facilitating the entry of more efficient firms and promoting higher growth in the 
economy. Chapter 3 further explores the channels through which antitrust policies can 
deliver this outcome.

The remainder of this chapter is organised as follows. The next section provides a 
brief discussion on the related literature. Section 3 presents an overview of antitrust law 
and its development over time. Section 4 describes the data and section 5 presents the 
empirical specification and robustness checks. Section 6 concludes.

2.2 Literature Review

This chapter is motivated by the literature highlighting the trends in increasing concen-
tration and markups. A series of papers have found evidence of increase in concentration 
specifically in the US but also globally (Gutiérrez, Philippon, et al., 2018; Philippon, 
2019; Grullon et al., 2019; De Loecker et al., 2020; Eeckhout, 2021). These trends suggest 
that there is a shift towards an oligopolistic market structure across many industries.

As firms gain market power, the role of institutions in protecting competition becomes 
more important. In light of trends showing an increase in firms’ market power, another 
set of papers have investigated the evolution of institutions and enforcement of antitrust 
law. Grullon et al. (2019) study the US, and find that there has been a decline in enforce-
ment of antitrust law by the Department of Justice and the Federal Trade Commission, 
thus allowing for approval of mergers between firms with greater market-power and sub-
sequently leading to higher profit margins. In another study focusing on Europe, Koltay 
et al. (2022) find that in recent years merger enforcement has become lax, especially in 
the period after the global financial crisis.

This chapter contributes to the literature that explores the interaction of antitrust in-
stitutions with economic outcomes. The findings of this chapter are inline with Buccirossi 
et al. (2013) who study twelve OECD countries and show that competition policies have 
a positive impact on total factor productivity growth. In another empirical study, Affeldt 
et al. (2021) develop a novel database of concentration levels that are based on the market 
definition used by the European Commission. They find strong evidence that barriers to 
entry are positively related to concentration while past merger enforcement negatively 
correlates with concentration. Besley et al. (2020) explore the impact of antitrust law 
on preserving competition especially in the non-tradable sector across ninety different 
countries. Their findings suggest that a stronger antitrust law significantly lowers profit 
margins in the non-tradable sector. The empirical findings of this chapter complement 
this literature, by studying the response various economic outcomes such as entry rate, 
innovation and productivity growth to different measures of antitrust policy in the US 
and Europe.
2.3 Overview of Antitrust Law

The first US antitrust law, the Sherman Act, was passed in the 1890, with the intention of creating more robust competition. Since then, there have been many developments in the US antitrust law, most notably the passing of the Clayton Act in 1914. The modern practices, however, can be traced back to the discussions of Robert Bork in the late 1970s (Baker, 2019; Sawyer, 2019; Kovacic, 2020). In his book, Bork (1978) proposed consumer welfare as the appropriate standard for evaluating cases of antitrust policy. His arguments in choosing consumer welfare as the appropriate measure shifted the legal practice towards a shorter term analysis of firms’ anticompetitive behaviour, and narrowed the interpretation of antitrust policies (Stucke, 2012; Orbach, 2012; Khan, 2016). As a result, since the early 1980s, the courts have become more lenient towards corporations and the enforcement of antitrust has become lax (Kovacic, 1989). Figure 2.1 illustrates these changes by plotting the total number of investigations initiated under section 1 and section 2 of the Sherman Act. According to the workload statistics, this number has significantly declined since the 1980s under both sections. Figure 2.2 shows

---

2Early drafts indicate that legislators besides promoting a more robust competition also had distributional concerns when preparing the Sherman Act (Baker, 2017; Klobuchar, 2021).

3The Clayton Act supplements the Sherman act by explicitly discussing certain anticompetitive practices in more details. Additionally, it declares certain anticompetitive practices illegal where the existing laws were not sufficiently clear on them or the language was vague. For a detailed discussion on development of antitrust law in the US see Sawyer (2019).

4Many antitrust scholars argue that Bork used the term consumer welfare and efficiency interchangeably. In the sense that consumer welfare did not only refer to the consumers (in terms of price paid), rather considering corporations and monopolies themselves as consumers, arguing higher prices are only a transfer of wealth ((Klobuchar, 2021), pages 134-135).

5Source: Antitrust division, workload statistics 1970-2019. The graphs reflect only the primary type of conduct under investigation at the outset of the investigation. For further information please refer to the workload statistics. Workloads downloaded on August 2021.
the number of investigated cases under section 7 of the Clayton act for merger enforcement.\textsuperscript{6}

As suggested by Figure 2.1 and 2.2 and discussed by Stucke (2012), since the 1980s and the adoption of Bork’s views on antitrust, the influence of antitrust law in the US has declined. Baker (2017) argues that antitrust policies today are not sufficient to deter collusions, anticompetitive mergers, exclusions and vertical agreements. He further argues that with the increase in concentration among US industries, antitrust agencies and policy makers can do more to deter anticompetitive conduct. Other legal scholars share similar concerns on the development and practice on antitrust law. Edlin (2002) discusses in detail the difficult conditions currently required to prove predation in courts and claims that predatory pricing cases are more common than perceived. Crane (2005) shows that despite the difficult conditions required to prove predation, many cases were filed that resulted in settlements.\textsuperscript{7} Shapiro (2019) calls for the restoration of antitrust laws with a focus on stronger merger enforcement and Steinbaum and Stucke (2020) provide alternative measures to the consumer welfare standard.

Finally, in contrast to the US, the main objective of antitrust law in the European Union is integrating and creating a Single Market (Fox, 1997). Despite the differences in their main objective, policies in both the US and the EU are centred around cartel enforcement, monopoly regulations and treatment of mergers and acquisitions (Bartalevich, 2017), and the general trend of antitrust policy has been similar between the two jurisdictions (Kovacic, 2008).

\textsuperscript{6}Source: Antitrust division, workload statistics 1970-2019. In addition to the department of Justice, Competition Enforcement Database provides data on cases pursued by the FTC under 2 general category of merger and non-merger since 1996. During this time span, there is no obvious overall trend in enforcement by the FTC.

\textsuperscript{7}Crane (2005) provides details of federal antitrust lawsuits alleging predatory pricing between 1993-2004. He states there are more unreported federal cases filed as well.
2.4 Data

2.4.1 US

The analysis for the firm level and sectoral outcomes (growth, entry and R&D expenditures) relies on Compustat, the Business Dynamics Statistics (BDS) database and the US Bureau of Labor Statistics (BLS) database. Compustat is a firm-level dataset that contains balance sheet information of all US publicly listed firms. This dataset is used to get information on firms’ R&D expenditures as a measure of investment in innovation and is the source I use to create a measure of concentration for 4-digit and 3-digit NAICS sectors. To get information on firm entry, I use the BDS database, which provides information on firm age for 4-digit and 3-digit NAICS sectors and is used to generate the share of entrant firms at the sectoral level. Finally, the BLS database serves as the source for information on multi-factor productivity of the manufacturing sector aggregated at 4-digit NAICS level. The main period of study for the US is between 1978 to 2018.

The measure of antitrust enforcement for the US is the budget allocated to the Antitrust Division as a share of GDP. The appropriation figures of the Antitrust Division are obtained from the Department of Justice (DoJ) reports. Figure B.2 in the appendix illustrates the changes in enforcement budget over GDP from 1976 to 2021. I consider the enforcement budget to be an appropriate proxy for antitrust policies in the US, as the antitrust law itself has not been subject to any substantial developments since 1976 when the mandatory merger notification was adopted. Therefore, given that the antitrust laws in the US have not changed significantly over the period of study, the resources available for this purpose can capture changes in the stringency of antitrust law over time.

Figure B.2 shows that antitrust enforcement budget as a share of GDP was on average higher between 1976 - 1985 though it started falling in the early 1980s before slightly increasing in the 1990s. Figure B.2 also indicates that the relative budget share started to fall again in the early 2000s reaching historically low levels between 2018-2020. In line with this observation, Grullon et al. (2019) find that antitrust agencies were more lenient since the early 2000s. Historically, the resources allocated to the enforcement of antitrust have been political decisions, reflecting the preferences and the ideology of the elected president with these preferences often going beyond the political affiliation of the president. Klobuchar (2021) provides a detailed historical discussion on the perspective of all US administrations towards the enforcement of antitrust law.

---

8To ensure the results are not driven by business cycles and fluctuations in the GDP, the antitrust budget is divided by GDP trend rather than the realised GDP. GDP trend is estimated by regressing GDP on a linear and quadratic term.
9Using the Comparative Competition Law Dataset developed by Bradford et al. (2019), it can be observed that the Competition Law Index has remained constant since 1976.
10Hart-Scott-Rodino Antitrust Improvements Act of 1976 requires large companies to file notifications with the Federal Trade Commission and the Antitrust division of Department of Justice prior to certain mergers and acquisitions.
2.4.2 Europe

The analysis for the sectoral outcomes for Europe relies on the Orbis database and the CompNet dataset.\textsuperscript{11} Orbis is a cross-country firm level database provided by Bureau van Dijk. It contains information on firms’ characteristics and their balance sheets. The variables of interest are measures of concentration and the share of entrants, which are formed by aggregating firm level data at the 4-digit industry level. The main measure of concentration that I use, is the Herfindahl-Hirschman Index (HHI) which is constructed using sales share of firms at a 4-digit sector level, and entry rates are constructed using information on the date of incorporation. One limitation of Orbis is coverage and representativeness. In order to address such issues, I follow steps of Bajgar et al. (2020). The list of countries and summary statistics are provided in Table B.2 in the appendix.

I use the 7th Vintage of CompNet dataset\textsuperscript{12} which is an unbalanced panel with indicators over various categories based on firm level information, aggregated at a two-digit industry level with 57 sectors in total. The variables of interest for the purposes of this chapter are measures of productivity and concentration. I use the ”all sample” data set from CompNet which includes all firms in the target population. The first available date that the data becomes available is 1999 for Finland, though for most countries the starting date is 2003-2004. The final period of study is 2010, which coincides with the final year that the Competition Law Data, discussed below, is available. Summary statistics are provided in Table B.1 in the appendix.

The main measure used for the intensity of competition policy in Europe is the Competition Law Index, provided by Bradford and Chilton (2018) and Bradford et al. (2019). They introduce two different datasets, the Comparative Competition Law Dataset and the Comparative Competition Enforcement Dataset. First, the Comparative Competition Law Dataset is comprised of longitudinal data for 131 jurisdictions from 1889 to 2010. Their dataset encodes more than 700 competition laws for these jurisdictions to construct an overall index called the Competition Law Index. Second, the Comparative Competition Enforcement Dataset has information on competition agencies’ resources for 100 jurisdictions between 1990 and 2010. As Bradford et al. (2019) explain, their datasets offer the most comprehensive coverage of competition laws with respect to laws, countries and the period of study.

The Competition Law Index (CLI) is constructed such that it remains comparable across time and countries. It takes values between zero and one, where higher values indicate stronger policies.\textsuperscript{13} The frequency of the data is annual, and a distinct index is assigned to each jurisdiction. Bradford and Chilton (2018) construct the CLI by aggregating elements of the ”authority” granted to enforce competition and the ”substance” of the regulations. First, authority refers to the provisions of the agency with the power

\textsuperscript{11}Source: CompNet 2020, User Guide for the 7th Vintage CompNet Dataset

\textsuperscript{12}CompNet 2020, User Guide for the 7th Vintage CompNet Dataset

\textsuperscript{13}These values are constructed using existing competition policies and therefore in case of introduction of new antitrust laws (currently absent from all jurisdictions) the measure might change.
to enforce the law and the remedies that can be imposed in case of violation of the law. Second, substance aggregates information on regulations on three set of policies: merger control, abuse of dominance, and anticompetitive practices. The CLI gives equal weights to authority and substance. Within substance, each category takes an equal weight of one-third.\textsuperscript{14}

### 2.5 Results

In this section, I outline the approach and provide evidence for the main results discussed in the beginning of this section for both the US and Europe.

**Empirical Approach** - This section aims to understand how productivity growth, entry and investments in innovation correspond to changes in antitrust policies and resources. To get a sense of the dynamic relationship of outcome variables with the antitrust measure, I run a sequence of regressions and shift the dependent variable one period forward each time. The estimated coefficients on the variable of interest are then collected, where each estimate captures the response to a change in antitrust policies at horizon $h$. The main specification for the US is outlined below:

$$y_{s,t+h} = \delta_t + \delta_s + \beta_1 \text{budget}_t \times \text{HHI}_{s,t} + \beta_2 \text{HHI}_{s,t} + \beta_3 \text{budget}_t + \epsilon_{s,t}$$

Where $\delta_t$ are year fixed effects and $\delta_s$ are sector fixed effects. Inclusion of time fixed effects implies that coefficient $\beta_3$ cannot be estimated. $y$ is the outcome of interest showing productivity growth, share of entrants or R&D expenditure over sales aggregated at the sector level. In the case of R&D expenditure since data is available at the firm level, the main regression is specified at that level, but I include the sector-level analysis as a robustness check. The intensity of antitrust law is proxied by the enforcement budget as a share of GDP (trend) for the US.

#### 2.5.1 US: Results

**The Relation between Antitrust Policy and Productivity Growth** - The source for productivity data is the BLS, which includes estimates for multifactor productivity at 4-digit NAICS levels for all firms in the manufacturing industry. The concentration measure is the HHI, and the coefficient of interest is $\beta_1$.

A test of my hypothesis is $\beta_1 > 0$, i.e. in sectors with a higher level of concentration, an increase in the antitrust budget as a share of GDP, corresponds to higher productivity growth. Figure 2.3a presents the results and as expected the correlation is positive and

\textsuperscript{14}Figure B.3 shows the development of these laws across European countries from 1995 to 2010. Bradford and Chilton (2018) discuss their methodology in constructing the index extensively.
significant. It can be observed that a 10% increase in the enforcement budget as a share of GDP, evaluated at the sample average of the explanatory variables\(^{15}\) is associated with roughly 0.25 percentage points improvement in the growth rate one period after impact. The peak is reached between year 1 and year 2, before declining and losing significance. Table B.3 relates to results of Figure 2.3a. Productivity growth is the result of interaction between the innovation of incumbents and entry of new and more efficient firms. The response of each channel is discussed below in details.

**The Relation between Antitrust Policy and Entry-** In this specification, I use the BDS data to get the share of entrants \(Ent_{st}\) in sector \(s\) and year \(t\), and Compustat to form the concentration measure. The analysis is run for a 4-digit NAICS level and the concentration measure is the HHI. The goal is to understand how enforcement budget correlates with share of entrants accounting for concentration level. The parameter of interest, therefore, is \(\beta_1\) and a test of my hypothesis is \(\beta_1 > 0\), i.e. the antitrust measure (budget over GDP) matters more for entry as concentration increases.

Figure 2.3b captures the impulse response function of a 10% increase in the enforcement budget as a share of GDP, evaluated at the sample average of the explanatory variables. Figure 2.3b shows the correlation between share of entrants and antitrust policies is positive as expected and reaches its peak after 2 years. More specifically, evaluated contemporaneously, the figure shows that a 10% increase in the enforcement budget as a share of GDP is associated with roughly 7 basis points increase in the share of entrants one year after implementation. Table B.4 in the appendix reports the results. Restricting the sample to years after 1985 leads to a larger response for entry equal to roughly 0.15 percentage points after one year.

**The Relation between Antitrust Policy and R&D Expenditures-** To understand the relationship between antitrust policy and investment in innovation, I use the Compustat data for R&D Expenditures and measure of concentration at a 4-digit NAICS level.

\(^{15}\)The values are 9.87e-06 and 0.40 for the average enforcement budget as a share of GDP and average HHI at a 4-digit NAICS level respectively.
The dependent variable \( RD_{i,t+h} \) shows the expenditures of firm \( i \) in Research and Development as a share of its sales at time \( t + h \). As a robustness check, and to make results comparable to the results of productivity growth and entry, I run another specifications using the weighted average of expenditures on research and development over sales in sector \( s \) and time \( t + h \) as reported in table B.7 and Figure B.7. The specification for innovation is presented below:

\[
y_{i,t+h} = \delta_i + \delta_t + \beta_1 \text{budget}_t \times HHI_{s,t} + \beta_2 HHI_{s,t} + \beta_3 \text{budget}_t + \epsilon_{i,s,t}
\]

Where \( i \) is a firm specific index, as before \( s \) shows sector and \( t \) is year. I include firm and year fixed effects. Similar to previous parts, the concentration measure is the HHI and the parameter of interest is \( \beta_1 \). A test of my hypothesis is \( \beta_1 < 0 \), i.e. in sectors with a higher level of concentration, an increase in the antitrust budget as a share of GDP, corresponds to lower levels of R&D Expenditures. Figure 2.3c shows the results for the specification described above. Results show that a 10% increase in the enforcement budget as a share of GDP, evaluated at the sample average of the explanatory variables is associated with roughly .07 percentage point drop in R&D expenditure over sales after one year. This is equivalent to approximately a 3% drop in ratio of R&D expenditure over sales.

### 2.5.2 Europe: Results

The empirical approach for Europe is similar to the US as in the previous subsection and the main specification is outlined below:

\[
y_{c,s,t+h} = \delta_{c,t} + \delta_{c,s} + \beta_1 \text{CL}_{c,t} \times HHI_{c,s,t} + \beta_2 HHI_{c,s,t} + \beta_3 \text{CL}_{c,t} + \epsilon_{c,s,t}
\]

Where \( c \) shows country, \( s \) sector and \( t \) is year. Country-year \( \delta_{c,t} \) and country-sector \( \delta_{c,s} \) fixed effects are included. The specification is similar to the previous section, however, here, the measure for intensity of competition policy is the competition law index (CLI) as discussed in the data section.

The Relation between Antitrust Policy and Productivity Growth- CompNet provides various measures for total factor productivity corresponding to the dependent variable.\(^{16}\) Figure 2.4a shows the response to a 10% improvement in the index, when all variables are evaluated at their mean.\(^{17}\) The contemporaneous outcome of growth in response to a 10% increase in the index is roughly 0.18 percentage point improvement in the growth rate of productivity. This correlation increases after one year and seems to be persistent at least for up to 8 years.

---

\(^{16}\) There are multiple measure for productivity in the CompNet database. I use all the available measures at sectoral level and present the results in the appendix in Figure B.8 as a robustness check.

\(^{17}\) The average CLI and HHI (2 digit sector) are 0.6 and 0.057 respectively.
The Relation between Antitrust Policy and Entry—In this specification, I use the Orbis database to get the share of entrants $Ent_{c,s,t}$ in country $c$, sector $s$ and year $t$, and to form the concentration measure $HHI_{c,s,t}$. The analysis is done for 4-digit industry levels. The intensity of competition law is measured by the CLI and the parameter of interest is $\beta_1$.

Figure 2.4b represents the results and suggest that a 10% improvement in the index, when all variables are evaluated at their mean,\(^{18}\) is associated with 0.15 percentage point increase in rate of entry upon impact. As in the Orbis database small and young firms are under-represented, this value corresponds to a 4% increase over the sample average. Table B.19 presents the results.

2.5.3 Robustness

In this section I provide a brief discussion on the robustness of the results, focusing on the measure of concentration from other sources, using profit margin as a measure of market power and the role of foreign competition. More details can be found in the appendix.

Concentration Measures from US Census Data—To measure concentration in subsection 2.5.1, I created the HHI from Compustat database. However, as Compustat only includes publicly traded companies, the literature has argued that it may have limitations in measuring the actual concentration value for a given industry (Ali et al., 2008). Instead, literature has suggested using concentration ratios produced from the US Census data. Census concentration ratios are available every 5 years for a subset of industries.\(^{19}\) I use this measure to check robustness and appendix B presents the results in tables B.20, B.21 and B.22. Results are qualitatively robust to using the measures provided by the

---

\(^{18}\) The average CLI and HHI (4 digit sector) are 0.6 and 0.34 respectively.

\(^{19}\) The relevant years for the analysis of this chapter are 2002, 2007, 2012 and 2017 which include data both on manufacturing and non-manufacturing industries. Earlier years only have information on the manufacturing sector.
Census, though the sample size drops to roughly 10% of the number of observations used in the previous subsection due to the limited availability of the Census data. More details are provided in the appendix.

**Alternative Measures for Market Power**—Besides the criticism to using HHI or concentration ratios from Compustat, the literature has questioned the suitability of these measures for antitrust purposes as they are industry-based and different from the definition of the relevant market used by antitrust authorities to assess anticompetitive practices (Affeldt et al., 2021). Since concentration ratios from the US Census data are based on the same industry definitions, similar concerns remain. In particular, for the purposes of antitrust, market definition often depends on the level of substitutability among products competing in a market which may not be well captured by the usual industry classifications (Berry et al., 2019). As the market definitions used by antitrust authorities (and the respective concentration measures) are not publicly available, I use profit ratio as a proxy for market power. While profit ratios do not directly measure the level of substitution between products, they potentially contain information about these values. In particular, if goods are highly substitutable, even with higher levels of concentration the profit ratio is expected to be relatively lower. Figures B.11a, B.11b and B.11c report the results and discuss the measure in more details. It is worth noting that the sample size is roughly 15-20% smaller due to outliers on the measure of profits. Overall, results are qualitatively robust to using profit ratio as a measure of market power though slightly less significant.

**Concentration Measure and Foreign Competition**—Another possible concern is that despite increasing trends in domestic industry concentration, external competition from imports ensures that markets remain competitive. To make sure results are robust to inclusion of external competition I control for imports. First, in case of entry and innovation, I focus on the non-tradable sectors of the economy. For productivity growth, since the analysis is done only for the manufacturing sector, I take a different approach. NBER-CES Manufacturing Industry Database provides information on total industry sales for 6-digit NAICS sectors. I also get data on total imports of each sector from Schott (2008) and adjust the concentration measures by the import share.\(^\text{20}\) I do the analysis using concentration measures from both the Compustat database and the Census data. Results are robust and discussed in details in appendix B.

### 2.6 Conclusion

This chapter empirically investigates the relationship between antitrust policies and various economic outcomes and establishes three novel stylised facts. Given the rising trends in industry concentration and firms’ market power, there has been an increased interest

\(^{20}\)Data is available on Peter Schott’s website.
around the role that antitrust policies could play in limiting firms’ anticompetitive behaviour and ensuring that markets are working efficiently. For example, anticompetitive actions that aim to eliminating efficient and productive entrants from participating in the market would suggest a lower entry rate. To the extent that higher innovation does not compensate for the fall in entry of more productive firms, productivity growth is expected to fall as well.

To explore this, I have studied the US and Europe using firm-level and sector-level data. For the US, given that antitrust policies have not been subject to a significant change in recent years, I take a resource based approach to measure the strength of antitrust enforcement. For Europe, I use country-time variation on existing antitrust policies, and measure the strength of enforcement by an index constructed by legal scholars. The findings suggest that an increase in enforcement of antitrust policies, in more concentrated sectors, is associated with higher entry rates, higher productivity growth but lower investment in innovation by incumbents. These results therefore imply that antitrust policies are particularly important in promoting entry and growth.

This chapter fits into the recent and growing literature debating the need for stronger antitrust enforcement in economies where the share of high concentrated industries has been growing. While the results presented in this chapter cannot be interpreted as the causal impact of antitrust policies, they do highlight the existing trade-offs and the potential role such policies can play in generating a more dynamic economy. In chapter 3, I build on the empirical findings of this chapter, and develop and estimate a structural model to quantify the causal effect of stronger antitrust policies on various macroeconomic outcomes relating to business dynamism.
Chapter 3

Antitrust Law and Business Dynamism

Abstract
In this chapter, I study firms’ strategic and anticompetitive behaviour, and the consequent role of antitrust law as a macroeconomic policy in promoting business dynamism. Over the past few decades, business dynamism has been declining in the US: firm entry has fallen, accompanied by a slowdown in the rate of productivity growth. Additionally, enforcement of antitrust law has been at historically low levels. Building on the results from the previous chapter, I develop and structurally estimate a dynamic general equilibrium model with innovation and oligopolistic product market competition. The dynamic structure of the model allows firms to eliminate competition through strategic decision-making. The model is calibrated to the recent US experience and quantitative exercises show that strengthening antitrust policies results in: (1) a higher firm entry rate, (2) a higher rate of productivity growth, (3) a larger labour share of GDP, and (4) a decline in the innovation rate. Overall, the model indicates that stronger antitrust policies are effective at restoring business dynamism and can deliver up to 16% higher welfare in consumption-equivalent terms. The improvement in welfare is mainly driven by an increase in the welfare of workers, without affecting the capitalists, suggesting that antitrust law has distributional implications, and therefore, has a potential role in reducing inequality.
3.1 Introduction

Over the past few decades, business dynamism has been slowing down, both in the US and globally. Rates of business formation and new firm entry have been falling persistently across a broad range of sectors. Simultaneously, there has been an increase in both market concentration and the profit-share of market leaders, as well as a decline in firms’ investment rates (Akcigit and Ates, 2021). A recent literature has studied these trends and considers various explanations for them, spanning from a demographic change to shifts in the structure of production. Nevertheless, in the continued absence of strong antitrust policies,\(^1\) anticompetitive practices by firms are a potentially important contributor to the observed decline in business dynamism, and one that is relatively understudied.

Enforcement of antitrust law is at historically low levels in the US, with the Department of Justice filing substantially fewer antitrust cases in recent years. For example, the average number of investigations conducted by the Antitrust Division of the Department of Justice in the previous decade is less than 10% of the number of conducted investigations in the 1970s.\(^2\) The fact that this reduction in investigations occurs contemporaneously with an increase in market power suggests that there is an increasingly lax enforcement of antitrust policies.

Little is known about antitrust law as a macroeconomic policy. The common approach in studying the effects of antitrust and firms’ anticompetitive practices, both in the academic literature and in public policy, is to focus on specific actions by individual companies in a well-defined market, and to analyse the implications of such actions for competition in a narrow industry. This approach has provided valuable insights into a wide range of strategic actions that firms undertake, and into their consequent impact on competition. Yet with the increasing trends in market concentration across the majority of US industries, the existence of anticompetitive practices may not be limited to a few sectors, and therefore, will have consequences for the wider economy.

This chapter studies the macroeconomic consequences of firms’ anticompetitive behaviour, and of lax antitrust policies. In this regard, it departs from the common partial equilibrium approach that focuses on a narrow market and develops a general equilibrium model that analyses the implications of lax antitrust policies on macroeconomic outcomes such as productivity growth, firm entry rate, innovation, and labour share of total income. Further, a general equilibrium framework allows us to study the short run effects of antitrust law, the long run trade-offs it generates, and its relation to business dynamism. Additionally, we can compute welfare losses from lax antitrust and of gains from stricter enforcement. In particular, estimates from the model indicate that stronger antitrust policies can generate up to 16% higher welfare in consumption-equivalent terms.

To this end and building on the empirical evidence of chapter 2, I develop a dynamic model with oligopolistic competition and endogenous entry and exit to explain these

---

\(^1\)Throughout this chapter, I will use antitrust policy and competition policy interchangeably.

\(^2\)See figure 2.1 for more details.
mechanisms. The dynamic nature of the model, combined with the incumbents’ market power, gives rise to strategic decisions in which incumbents choose to block the entry of new firms in equilibrium. Such actions have consequences for entry and productivity growth, especially when incumbents target efficient potential entrants.

In the model, incumbents take costly actions to create entry deterrents and increase the costs faced by entrants, thereby discouraging them from joining the market. Prior to entry, entrants and incumbents receive a signal that yields information on entrants’ relative productivity. If entrants are expected to be very efficient, they will be able to capture a larger share of the market, thus posing a more significant challenge to incumbents’ positions. In a dynamic setup, incumbents may find it optimal to respond to the threat of entry by bearing an immediate cost to prevent the entry of new firms. Optimality of these strategic decisions depends on the size of costs and potential benefits and is determined by incumbents’ incentive compatibility constraints.

To increase their lifetime value, besides deterring competitors from entry, incumbents can innovate and improve their productivity over time. An incumbent that invests more in innovation is more likely to be successful in its efforts, and to move up on the productivity ladder. The optimality condition implies that firms invest to the level at which the marginal cost of innovation equals its marginal return. The marginal return depends on the stream of future profits and is therefore correlated with possible market share gains as a firm becomes more productive. The gains from innovation interact with incumbents’ decisions to deter entry of new firms. On the one hand, aggressive strategies increase the lifetime value of the incumbent at all productivity levels. In turn, these higher values encourage incumbents’ innovation efforts. On the other hand, aggressive strategies offer protection against the external competition posed by entrants. This protection lowers incumbents’ incentives to invest in innovation. Both forces are present in the framework of this model, and their relative size differs across firms in the distribution. Thus, the overall effect on innovation in the economy depends on the distribution of firms, which itself is an endogenous object and depends on the calibrated parameters.

In this framework, innovation may be considered a productive approach in increasing profits, while deterring entry to eliminate competition is an aggressive method. The aggressive strategies are modelled in the form of a short term cost, but can have various interpretations, including (but not limited to) aggressive pricing, killer acquisitions, lobbying, and excessive patenting. To regulate the behaviour of firms, the model includes an antitrust authority, which constrains the extent to which firms can engage in aggressive strategies. More specifically, the antitrust authority dictates the maximum amount of firms’ current profit sacrifices on aggressive strategies and creating entry barriers. While this is a simplification of real-world antitrust policies, it reflects the fact that the antitrust authority’s reviews of firms’ anticompetitive practices include an investigation of firms’

---

3The model can equivalently be defined as lowering the value of potential entrants.
The model is structurally estimated to fit the data on productivity growth, entry rate, profit share, innovation, and other facts of business dynamism for the US in 2000-2010. I use the estimated model to analyse counterfactual scenarios in which antitrust law is strengthened until all anticompetitive strategies are ruled out. The model predicts that strengthening antitrust is an effective policy for increasing business dynamism. In particular, counterfactual exercises show that productivity growth can increase by up to 0.8 percentage points, entry rate by up to 8 percentage points and the employment share of entrants by up to 4.4 percentage points. At the same time, profit share of total income and average R&D expenditure can fall by up to 8.1 and 2.9 percentage points. The higher rate of productivity growth, despite the fall in average R&D expenditure under stronger antitrust laws, is a result of higher entry of more efficient firms.

It is worth noting that, in the counterfactual scenarios, the increase in rates of entry and productivity growth is driven by eliminating the dynamic distortions generated by firms’ anticompetitive strategies, and the static distortions in form of high markups remain intact. Therefore, the results suggest that, when concentration levels are high and firms have a greater market power, antitrust law can deliver higher growth even before reducing firms’ markups.

One of the main insights of this chapter is related to the welfare and distributional implications of antitrust policies. I find that strengthening antitrust policies can lead to welfare gains of up to 16% in consumption equivalent terms. This gain is driven primarily by an increase in the rate of productivity growth. Decomposition of welfare gains for workers and capitalists indicates that, while both parties benefit in the long run, workers experience a relatively larger improvement in their welfare. The welfare analysis also indicates that there are short vs long run trade-offs, owing to the reallocation of labour from production to the setting-up of new businesses.

A recent literature has been studying the welfare costs of markups. With oligopolistic competition, and in the presence of firms with high markups, there is a welfare loss due to static distortions associated with moving away from perfect competition and resource misallocation in the market. Edmond et al. (2018) and De Loecker et al. (2021) estimate the cost of these markups to be 7.5% and 9% in consumption equivalent terms. The welfare losses estimated in this chapter are solely based on firms’ anticompetitive strategies, and do not correct for static distortions caused by markups. Altogether, the true cost of firms’ market power is a combination of the two channels, which suggests that the true welfare loss is higher than the values presented by the literature and in this chapter.

The chapter is organised as follows. Section 2 contains a brief review of the literature. Section 3 describes the model set-up. Section 4 includes the baseline calibration, and

---

4This is especially the case in reviewing exclusionary acts under the section 2 of the Sherman Act and is discussed in more details in section 3.4. For mergers and acquisitions, a first round investigation happens based on the value of the deal, and clearing the merger depends mainly on the resulting concentration in response to the M&A.
Section 5 discusses the quantitative results and welfare analysis. Section 6 concludes.

### 3.2 Literature Review

Recent papers have documented trends in falling business dynamism. There has been a decline in the firm entry rate and the growth rate of young firms (Decker et al., 2016; Karahan et al., 2019). Coinciding with lower entry, there is evidence of rising concentration and markups both in the US and globally (Gutiérrez, Philippon, et al., 2018; Grullon et al., 2019; Philippon, 2019; Bajgar et al., 2019; De Loecker et al., 2020; Eeckhout, 2021). Additionally, there has been a decline in capital investment (Gutiérrez and Philippon, 2017; Crouzet and Eberly, 2019), a decline in labour’s share of GDP (Karabarbounis and Neiman, 2014; Barkai, 2016) and an increase in profit share\(^5\) (Eggertsson et al., 2018).

A follow up literature has explained these trends through changes in the fundamentals of the economy such as changes in demographics (Karahan et al., 2019), shifts in production structure towards technologies with more scalability (Autor et al., 2020), and changes in the structure of competition. The proponents of the increase in scalability and intangibles argue that the increase in the concentration is efficient owing to a reallocation of resources towards highly productive "superstar firms". Aghion et al. (2019) and De Ridder (2019) find that shifts towards technologies with increasing returns to scale lead to higher concentration. Others support arguments suggesting that the decline in competition has led to rising barriers to entry (Crouzet and Eberly, 2019; Grullon et al., 2019; Covarrubias et al., 2020). Gutiérrez and Philippon (2019) find that the weakening of competition and the falling entry rate can be explained by increased lobbying and regulation, showing that this trend is most pronounced in industries with high lobbying expenditure. In this chapter, I highlight the role of weak competition, lax enforcement of antitrust law and firms’ anticompetitive practices in eliminating entrants in generating lower dynamism and growth in the economy.

To analyse macroeconomic implications of firms’ anticompetitive behaviour, this chapter builds on a large body of literature studying market power and its consequences in the macroeconomy (Atkeson and Burstein, 2008; Grassi, 2017; Edmond et al., 2018; Baqaee and Farhi, 2020; Burstein et al., 2020; De Loecker et al., 2021). In this regard, the chapter takes a model-based approach and extends an oligopolistic competition and CES demand as in Atkeson and Burstein (2008) to allow for dynamic trade-offs and firms’ strategic decisions. Additionally, the model includes innovation as a source of growth following the endogenous growth literature (Aghion et al., 1997; Aghion et al., 2001; Acemoglu and Akgiit, 2012; Akgiit and Ates, 2019). With respect to this literature, the framework of this chapter allows for endogenous entry of firms, therefore moving from a duopolistic competition to an oligopolistic setup.

\(^5\)For a detailed discussion of trends in falling business dynamism in the US please refer to Akgiit and Ates (2019).
The closest to this chapter is the study by Cavenaile et al. (2021), who also take a structural and general equilibrium approach to antitrust policies. They develop an oligopolistic model with innovation and examine the effect of antitrust policies on Mergers and Acquisitions (M&A) and their consequent welfare implications. Similar to the findings of this chapter, they find considerable welfare gains from strengthening antitrust policies. However, the mechanism through which they get this result is considerably different from mine. Their findings suggest that strong competition policies (captured by a higher threshold of HHI for mergers) will hurt smaller firms, as the increase in the M&A threshold suggests that now there is a lower probability that start-ups would get acquired by another firm. In this regard my chapter is complementary to Cavenaile et al. (2021). I find that strong antitrust policies protect and benefit the highly productive young firms and subsequently increase the competition for the existing market leaders.

These results can be reconciled by examining the nature of the antitrust law and firms‘ anticompetitive actions as well as firms‘ innovation incentives. In markets where entrants‘ productivity is always below the leaders and the main goal of the entrant is to get acquired by an existing market leader, antitrust policies that are solely based on concentration measures would hurt small firms through the channel described by Cavenaile et al. (2021). However, in markets where there is a possibility that the entrants‘ productivity is higher than the incumbents, strong antitrust policies protect young efficient firms, allowing them to grow and even replace the existing market leaders. Compared to Cavenaile et al. (2021) this chapter does not constrain the productivity of entrants with respect to incumbents, and therefore generates different welfare implications. Additionally, the focus of this chapter are strategies that attempt to monopolise the market (rather than M&As which are sometimes efficient), thus pointing to another aspect of antitrust policies in protecting competition.

Antitrust law and its implications have been widely studied in the Industrial Organisation (IO) literature, in a partial equilibrium framework focusing on narrow and well-defined markets. The focus of this area of research has often been on rationalising the existence of aggressive strategies by incumbents and finding evidence of these actions in the data in carefully defined markets. In this chapter I seek to quantify the aggregate losses associated with such aggressive strategies, and therefore, I do not take a stance on the nature of firms‘ anticompetitive practices.\textsuperscript{6} Below I provide a short review of the findings of the IO literature on firms‘ strategic actions in deterring entry.

Studies focusing on strategic entry barriers were pioneered by Bain (1956). Predation is one of the most widely discussed topics with regards to strategic entry barriers and it has been explained by incumbents seeking to establish a reputation (Milgrom and Roberts, 1982; Kreps and Wilson, 1982) or incumbents forcing a financially constrained...

\textsuperscript{6}While the model is set in a generalised framework, in the appendix, I show that the framework of this chapter is better suited for studying strategies such as aggressive pricing, lobbying and killer acquisitions.
entrant out of the market (Telser, 1966; Benoit, 1984; Poitevin, 1989).\textsuperscript{7} Other strategies firms undertake to deter entry and monopolise the market include exclusive dealings, coordinated effects and killer acquisitions.\textsuperscript{8} An exclusive contract limits the access of a competitor to certain suppliers or customers, thereby increasing the costs of competitors and under certain conditions, deterring entry (Segal and Whinston, 2000; Fumagalli and Motta, 2006).\textsuperscript{9} Coordinated effects include tacit or explicit collusion among firms often without a formal contract and are more common when there is multi-market contact - situations in which firms compete with the same competitors across different markets- (Bamberger et al., 2004; Schmitt, 2018). Finally, killer acquisitions occur when incumbents of an industry acquire the start-ups and discontinue their productive innovation lines in order to eliminate future competition (Cunningham et al., 2018; Fumagalli et al., 2020).

The empirical IO literature investigates the existence of such strategic interactions in the data. In particular studying aggressive pricing, exclusive dealings, collusion and killer acquisitions empirically, shows that as predicted by the theory, such actions lead to lower entry rates and a fewer number of competitors in a given industry (Goolsbee and Syverson, 2008; Ellison and Ellison, 2011; Nurski and Verboven, 2016; Aryal et al., 2018; Cunningham et al., 2018; Burgdorf, 2019; Sweeting et al., 2020; Eliason et al., 2020).

All these strategies described by the literature are different in nature. However, a common feature among them is the notion that incumbents have an advantage over the potential entrants or young firms, and would benefit from removing the entrants from the market. The remainder of this chapter builds on the notion that such aggressive strategies exist when firms have high market power. In abstracting from modelling specific forms of aggressive strategies, this chapter is able to study the implication of such actions for the wider economy.

3.3 Model

In this section, I present a dynamic general equilibrium model of oligopolistic competition with step-by-step innovation and entry and exit. The dynamic nature of the model allows for strategies with short term costs, but long term returns such as investment in innovation. Additionally, combining a dynamic setup with oligopolistic competition creates an environment in which firms strategically decide to undertake a costly action today in order to eliminate the competition and increase their value in the future. This chapter restricts

\textsuperscript{7}More recent models of limit and predatory pricing combine the dynamic nature of such frameworks with various informational asymmetries scenarios to study the equilibrium outcome. As an example refer to Toxvaerd (2017) and Kaya (2009).

\textsuperscript{8}Horizontal and vertical mergers and common ownership are other strategies which may be considered anticompetitive, however they have less relevance for deterring entry. For an overview of these topics refer to Morton (2019).

\textsuperscript{9}Theoretical research points out that exclusive contracts can have an opposite effect by promoting investment in the downstream market by removing uncertainty. Therefore, the overall impact of such contracts is ultimately an empirical question.
the analysis to strategic decisions that are directed to entry of new and possibly more efficient firms. To regulate firms’ behaviour and ensure competition is preserved, the model includes an antitrust authority which constraints the extent to which the incumbents can engage in creating strategic entry deterrents.

### 3.3.1 Preferences

The utility of the representative consumer is standard and is given by $U(C_t) = C_t$, where $C_t$ indicates final consumption, which is a composition of the output of a continuum of sectors $Q_{jt}$, $j \in [0, 1]$ as specified below:

$$C_t = \int_0^1 \ln Q_{jt} dj$$  

(3.1)

Within each sector $j$, output is denoted by $Q_{jt}$. Output of each sector itself is composed of $N_j$ distinct goods as in Atkeson and Burstein (2008), using a CES aggregator where $N_j$ is determined endogenously:

$$Q_{jt} = N_j^{\frac{1}{\epsilon}} \left[ \sum_{i=1}^{N_j} q_{ijt}^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{1}{\epsilon-1}}$$  

(3.2)

where $q_{ij}$ denotes quantity produced in sector $j$ by firm $i$ and $\epsilon > 1$ is the elasticity of substitution across firms. The price index of output of sector $j$ is:

$$P_{jt} = N_j^{\frac{1}{\epsilon-1}} \left[ \sum_{i=1}^{N} p_{ijt}^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{1}{\epsilon-1}}$$  

(3.3)

The log-preference assumption of equation (3.1) implies that consumers will optimally allocate a constant proportion of their income to each sector $j$ and this constant share is denoted by $I_t$. Thus prices are defined at each time period and the maximisation problem is subject to $\sum_{i=1}^{N_j} q_{ijt} p_{ijt} = I_t$.

Solving the problem yields the demand for each variety as a function of its price:

$$q_{ijt} = \left( \frac{p_{ijt}}{P_{jt}} \right)^{-\epsilon} \times \frac{I_t}{N_j P_{jt}}$$  

(3.4)

It is worth noting that as there is no disutility of labour, and it is supplied inelastically. I further assume that there is no labour growth over time. Therefore, the total income of the household is equal to the sum of labour income and the profits households receive from firms.

---

10 Similar to Jaimovich and Floetotto (2008) the term $N_j^{\frac{1}{\epsilon}}$ corrects for the variety effect.
3.3.2 Firms

Production Technology- Within each sector, there are a finite number of firms with idiosyncratic productivity levels, producing differentiated goods. Upon paying the sunk cost of entry, firms observe their productivity level and if entry is successful, they get access to an increasing returns to scale technology to produce using labour as the only input. Firms of a given productivity behave symmetrically and they have the option to invest in research and development to improve their productivity. There are fixed costs of production at each time period and the production technology is defined as in Melitz (2003):

\[ l_{ijt} = f + q_{ijt} \times \lambda_{ijt} \]  

(3.5)

Similar to before \( i \) is indexing the type of the firm defined in terms of its productivity level, \( j \) indicates the sector and \( t \) is the time index. \( f \) denotes the fixed cost of production, and \( \lambda = 1/\phi \) is the marginal cost of production defined as the inverse of the productivity of the firm. Firms compete a la Bertrand in the product market.

State Variables- There are three state variables that are relevant for a firm’s decisions. First, the idiosyncratic state of the firm \( \phi \) is given by its productivity level which is initially drawn from a given distribution \( G(\phi) \) when the firm enters, and later can be improved by investing in innovation.

The next state variable is the sectoral state and is composed of two parts: The first part of \( \mu_{jt} \) is a vector of size \( K \), where \( K \) shows the number of distinct productivity levels of firms active in production at time \( t \) in sector \( j \). Each elements of vector \( \mu_{jt} \) presents the number of firms with a given productivity level in sector \( j \) and it can be shown as \( \{\phi_1, \phi_2, ..., \phi_{k-1}, \phi_k, \ldots\} \). I assume that the elements of this set are ordered such that \( \phi_1 < \phi_2 < ..., < \phi_{k-1} < \phi_k < ... \) and \( \phi_k/\phi_{k-1} = \gamma \) for all \( k \in \mathbb{N} \). Therefore, \( \gamma > 1 \) reflects the productivity step and firms with a higher index \( i \) have a higher productivity level. For example, a sectoral state defined as \( [a_1 a_2 a_3 a_4 a_5] \) suggests that \( K = 5 \) and there are 5 types of firms (denoted by their productivities) in sector \( j \). Additionally, it suggests that there are \( a_1 \) firms with productivity level \( \gamma^1 \), \( a_2 \) firms with productivity level \( \gamma^2 \) and so on.

The second part of the sectoral state includes the signal for potential entrants at sector \( j \) denoted by \( \phi^q_{jt} \). The signal varies across time and sectors and is discussed in more details in the next part.

Finally, the aggregate state \( \mu_{agg,t} \) is an aggregation of the sectoral states and it pins down the equilibrium wage in the economy. As the aggregate state combines a continuum of sectors, it implies that despite the idiosyncratic shocks at the sectoral level, there is no uncertainty over the aggregate.

Entry- At every time period, there is a sufficiently large number of potential entrants at
each sector $j$. Prior to entry, potential entrants in each sector receive a sector specific signal of their expected productivity $\phi^q_{jt}$ from distribution $\mathcal{H}(\phi)$, and based on the signal, they can decide to enter or not. If they decide to enter, they have to pay a one-time sunk cost of entry $S$. After paying this cost, they observe their individual productivity level and can decide to whether to produce at time $t+1$ or exit.

More precisely, potential entrants of sector $j$ with signal $\phi^q_{jt}$ will be distributed according to $G(\phi)$ with mean $\phi^q_{jt} + \bar{\phi}_{jt}$, where $\bar{\phi}_{jt}$ is the average productivity of sector $j$ (incumbent firms) at time $t$. Introducing $\bar{\phi}_{jt}$ accounts for productivity growth in the economy and implies there are spillovers from the incumbents to the pool of entrants. Thus as incumbents become more productive, the pool of entrants becomes proportionally more productive too. On the other hand, term $\phi^q_{jt}$ suggests that the expected productivity level of entrants (with respect to the incumbents) changes over time, and in some periods the entrants may be relatively more or less productive on average. Distribution $\mathcal{H}(\phi)$ pins down the frequency of entrants having a higher or lower average productivity with respect to incumbents, while $G(\phi)$ indicates the general shape and other properties of entrants’ distribution.

Therefore, with a high signal, while the potential entrants’ distribution with respect to each other, $G(\phi)$, remains the same, their relative productivity with respect to incumbents is higher and therefore they will have a higher expected value of entry. Note that all entrants of industry $j$ receive the same signal but the signals are different for the prospective entrants across industries. In order to solve for the equilibrium, I assume that entry happens sequentially in each sector and conditional on the signal until the free entry condition is satisfied: \[ E[V_{ent}(\phi, \mu_j, \mu_{agg}) | \phi^q_{jt}] > S \] (3.6)

Sequential entry suggests that the number of successful entrants will depend on the sectoral state and therefore is denoted by $M_j$. Given that there is a continuum of industries, it means that a constant share of industries will always receive signal $\phi^q$ and therefore on aggregate there is no uncertainty regarding the economy-wide level of entry.

Additionally, note that signal $\phi^q_{jt}$ to sector $j$ is observed by the incumbents of that sector as well. This means from the perspective of incumbents at time $t$ there is no uncertainty over the state of the sector and aggregate sectoral productivity with respect to entrants, even before entrants pay the sunk cost. However, from the perspective of entrants there is uncertainty, as for them the individual draw for productivity combined with the sectoral state determines their value. Similar to the incumbents, they know with certainty the state of the sector, but, as they do not yet have information on their idiosyn-

\[11\] Potential entrants are placed in a queue and they know their position in the queue but do not have information on the productivity draw of firms that are in front of them. Therefore, each firm decides to pay conditional on the productivity signal of entry and its relative position. This also implies that if the potential entrant in position $P$ does not find it optimal to enter, all remaining entrants in the queue will not find it optimal either.
cratic state prior to paying $S$, they will base their entry decision on their expectations of profits given the signal $\phi_{jt}^q$.

Finally, in order to endogenise $N$, the number of active firms in each sector, I use the sequential entry assumption and allow firms to enter one by one according to distribution $G$ and taking the sectoral steady state distribution as given. Firms continue to enter until the free entry condition as defined in (3.6) is satisfied. Another interpretation of this assumption is that, at the equilibrium level of $N$ and conditional on having the steady state distribution of firms, new firms will not find entry optimal.

**Incumbents**—The state of firm $i$ at sector $j$ at time $t$ can be described by the idiosyncratic state productivity $\phi_{ijt}$, the sectoral state $\mu_{jt}$ as discussed above and $\mu_{agg,t}$ which shows the aggregate state of the economy. The aggregate state is deterministic, ensures the existence of a balanced growth path and pins down the equilibrium level of wage.

Firms compete under Bertrand and their optimisation problem involves choosing prices, investment in innovation and whether to create strategic entry barriers (deterring strategies are a binary choice). The timing of their decisions is described below. In the beginning of the time period incumbents observe the outcome of their innovations at time $t - 1$ and realise whether it has been successful or not. Successful innovation implies that firms go up one step on the productivity ladder and as a result become more efficient in their production. Next, incumbents and entrants of industry $j$ observe the signal for entry $\phi_{jt}^q$. Upon observing the signal, incumbents commit to prices, amount of strategic entry barriers and investment in innovation. Potential entrants observe the decision of incumbents and can decide to pay the sunk cost of entry in order to enter at time $t + 1$. All firms produce and incumbents can decide to exit and potential entrants (who paid the sunk cost of entry) join the pool of incumbents.

Given the timing, the value function of the incumbents is defined below. Firms’ idiosyncratic state is described by $\tilde{\phi}_{ij}$ which shows the number of steps between firm $i$ and the leader firm in industry $j$ and is a direct mapping from the firm’s productivity $\phi_{ij}$. The sectoral state is denoted by $\mu_j$ and the aggregate state of the economy is shown by $\mu_{agg}$. Therefore, an incumbent firm $i$ in industry $j$ chooses innovation rate, prices and deterring strategies to maximise its value given by:

$$V(\tilde{\phi}_{ij}, \mu_j, \mu_{agg}) = \max_{x, D} \pi^*(\tilde{\phi}_{ij}, \mu_j, \mu_{agg}) - w(\mu_{agg})c(x) - D \times K(\tilde{\phi}_{ij}, \phi_{jt}^q)$$

$$+ \max \left\{ 0, \beta EV(\tilde{\phi}_{ij}', \mu_j', \mu_{agg}') \right\}$$

(3.7)

where $\beta$ is the discount factor and $c(x)$ is the cost innovation paid in units of labour and

---

12Since this is an oligopolistic competition and there are discrete number of firms, the condition will not be satisfied with equality and $N$ is found when adding an additional firm reverses the sign of the condition.
implies a firm spending $c(x)$ on innovation will move up one step on the productivity ladder with probability $h(x)$. $D \in \{0, 1\}$ is a binary variable taking value 1 if the firm engages in creating strategic entry barriers. Thus, the law of motion for the idiosyncratic state can be presented as:

$$E[\tilde{\phi}_{ij}] = \tilde{\phi}_{ij} + (1 - D) \times \phi_{jt} - h(x)$$

which states that the expected future idiosyncratic state of the firm, depends on its current state, entry of new firms and the outcome of innovation. When more efficient firms enter, while the productivity of any given incumbent is not directly affected, its relative position (rank) worsens as the firm is now further away from the market leader, and thus firm loses competitiveness. As it will be discussed in the later sections, this chapter focuses on deterrence strategies that either all incumbents find it optimal to prevent entry or none do. Therefore, considering the decision of each given firm will capture the outcome of the industry. Next, successful innovation directly affects the productivity level of the firm and consequently improves its relative position in its respective industry. Later in this section, I will discuss in details the firm’s decision to deter entry $D$, the costs $K$ associated with it and the firm’s innovation strategy.

Finally note that productivity, innovation and firms’ position on the productivity ladder are distinct in this model. The relationship between productivity and firms’ position is discussed above in detail. In short, the productivity level determines the marginal cost of production but does not provide any details on where the firm stands with respect to the other competitors. The position of the firm on the productivity ladder includes this information and combined with a moment of the distribution such as the mean can get translated into the productivity level. Innovation, in this model, shows the effort of firms to move up the productivity ladder, improve their position and lower their marginal cost.

**Continuation Value**—Firms’ continuation value as defined in equation (3.7) depends on the developments of the sectoral state. The future sectoral state itself, depends on the outcome of entry and the result of innovation by individual firms. As the outcome of innovation is not deterministic, this implies at every time period there will be deviations from the steady state firm distribution over the productivity level. Additionally, as the number of incumbents increases it becomes computationally infeasible to track the realised distribution and the exact probability associated with the event. To overcome this problem, I assume firms have bounded rationality, and they solve their value maximisation problem assuming that future sectoral state $\mu_j'$ is at its steady state value.\(^\text{14}\)

\(^{13}\)The law of motion characterises the evolution of firm’s idiosyncratic state along the equilibrium path.\(^{14}\)The nature of this assumption is similar to the oblivious equilibrium described by Weintraub et al. (2008) with many firms. An alternative assumption is considering dynamic firms’ models with strategic decisions and few firms in each industry. In this respect often the literature considers a duopolistic setup in analysing such strategies. An exception from the duopolistic setup is Cavenaile et al. (2021) in which they consider a setup with maximum 4 incumbents competing in the oligopolistic setup.
Profit Maximisation and Optimal Price- Firms use production technology defined by equation (3.5) and labour as the only input of production to maximise their profits at each time period:

$$
\pi^* (\phi_{ij}, \mu_j, \mu_{agg}) = \max_{p_{ij}, q_{ij}} \left\{ p_{ij} q_{ij} - w(f + g_{ij} \times \lambda_{ij}) \right\}
$$

subject to demand (3.4). Where $\lambda_{ij}$ presents the marginal cost of production and is the inverse of productivity level. Therefore, the static profit maximisation\(^{15}\) yields the pricing rule as in Atkeson and Burstein (2008) and Grassi (2017):

$$
p_{ij} = \left( \frac{\epsilon}{\epsilon - 1} + \frac{s_{ij}}{(\epsilon - 1)(1 - s_{ij})} \right) \times \lambda_{ij} w \tag{3.9}
$$

where $s_{ij}$ is the market share of firm $i$ in sector $j$ and the term in parentheses denotes the firm’s markup which is increasing in the sales share of firm. $s_{ij}$ is defined as:

$$
s_{ij} = \left( \frac{p_{ij}}{P_j} \right)^{1-\epsilon} \times \frac{1}{N_j}
$$

$\epsilon$ is the elasticity of substitution and $P_j$ shows the sectoral price. Similar to before $N_j$ is the total number of firms in sector $j$. All time subscripts have been dropped here.

Optimal Investment in Innovation- Incumbents choose $x$ to improve their productivity and move up the productivity ladder. Moving up on the productivity ladder improves the firm’s relative position in the sector and consequently increases the firms’ market share. Innovation is costly and firms pay $c(x)$ in units of labour to move up one step on the productivity ladder with probability $h(x)$. In the remainder of this chapter, I define the cost of innovation by:

$$
c(x) = b \frac{x^2}{2} \tag{3.10}
$$

The probability of having a successful innovation $h(x)$ is given by:

$$
h(x) = 1 - e^{-x} \tag{3.11}
$$

Therefore, higher investment in innovation leads to a higher probability of climbing up the ladder, but there are decreasing returns to the investment.

Using the cost function defined as (3.10) and the innovation success probability func-

---

\(^{15}\)An alternative way of solving the problem is to include the profits in the value function and decide over the prices in that problem. Under this characterisation prices can be used as a strategy to deter entry of new firms, similar to the limit pricing literature. See for example Fudenberg and Tirole (1983). The aggressive pricing characterisation of the problem, with dynamic profit maximisation and decision over prices is discussed in the appendix. The conditions for the equivalence between the two problems are also discussed. The main characterisation of this chapter allows for wider interpretations beyond limit pricing.
tion (3.11), the optimal amount of innovation can be derived as:

\[ x = W\left( \frac{\beta E[\Delta V]}{w_b} \right) \]  

(3.12)

where \( W(.) \) is the Lambert W-function, defined as the inverse function of \( f(W) = We^W \). \( \Delta V \) is the expected value gain if innovation is successful and \( w \) is wage. Equation (3.12) suggests that the higher the expected value gain in response to successful innovation, the higher the optimal innovation would be. Similarly, higher costs to investment imply a lower level of innovation as the optimal strategy. Derivations of the result are provided in the appendix.

**Aggressive Strategies and Creation of Barriers to Entry-** Firms’ aggressive behaviour aimed at deterring the entry of new and more efficient firms is the mechanism central to this chapter, offering a possible source for the decline in business dynamism. Firms act aggressively in order to eliminate the competition and consequently increase their market share. This is an additional channel, on top of innovation, for firms to improve their position in the market. However, while innovation is considered a productive approach to increasing firms’ market share, creating barriers to entry may affect the sectoral productivity negatively, as some efficient entrants are now eliminated.

Additionally, while aggressive strategies towards entrants are costly in the short run, they increase the incumbents’ value in the long run. It is worth noting that this chapter focuses on aggressive strategies of incumbents towards entrants and does not study the equilibria in which incumbents undertake actions against each other. Formally, firms have to satisfy their incentive compatibility constraint in order to find it optimal to act aggressively towards entrants:

\[
\pi_{D=1}(\tilde{\varphi}_{ij}, \mu_j, \mu_{agg}) + \beta E[V(\tilde{\varphi}_{ij}, \mu_j, \mu_{agg})] \geq \pi_{D=0}(\tilde{\varphi}_{ij}, \mu_j, \mu_{agg}) + \beta E[V(\tilde{\varphi}_{ij}^{''}, \mu_j^{''}, \mu_{agg})] 
\]  

(3.13)

where \( D = 1 \) indicates that firm is creating entry deterrents and \( D = 0 \) shows the opposite. \( \mu_j \) shows the sectoral state, and \( \mu_j' \) and \( \mu_j'' \) show that the development of sectoral state will depend on the incumbents’ aggressive strategies. Overall, this condition states that if the gains of creating strategic entry deterrents compensate the immediate cost, the incentive compatibility constraint would be satisfied and incumbent \( i \) optimally decides to act aggressively by setting \( D = 1 \). Deterrence takes the form of raising entry costs\(^{16}\) in the free entry condition as described by (3.15). Additionally, note that a given firm is willing to pay the cost of entry deterrence only if it can successfully put entrants of sector \( j \) on their participation constraints:

\[
E[V_{ent}(\varphi, \mu_j, \mu_{agg})|\phi_{jt}^f] \leq S + K_{tot,jt}(\phi_{jt}^f) 
\]  

(3.14)

where \( K_{tot,jt} \) presents the total amount of entry barriers created by incumbents at sector

---

\(^{16}\)This is equivalent to assuming that entry deterrence lowers the value of entrants.
and is an aggregation of firm level entry deterents:

\[
K_{\text{tot,jt}}(\phi_{jt}^q) = N_j^{-\frac{1}{\alpha_d}} \left( \sum_{i=1}^{N} K_{ijt}^q(\phi_{jt}^q) \right)^{\frac{1}{\alpha_d}}
\]  

(3.15)

\(N\) denotes the number of incumbents in sector \(j\), \(\alpha_d\) is the elasticity parameter and \(K_{ijt}\) shows the amount of strategic barriers to entry created by firm \(i\) at sector \(j\). Below I describe how individual firms create barriers to entry, \(K_{ijt}\) for new firms.

**Assumption:** To create entry barriers, \(K_{ijt}\), firm \(i\) in sector \(j\) and time \(t\) sacrifices a fraction of its profits according to:

\[
K_{ijt}(\phi_{jt}^q) = \psi(\phi_{jt}^q) \times \pi_{ijt}^*
\]  

(3.16)

where \(\psi(.)\) is a parameter indicating a fraction which depends on the signal of entry at sector \(j\) and time \(t\), and therefore, is common among all incumbents of the sector at every time period, but changes over time based on observations for the signal of entry \(\phi_{jt}^q\).

The assumption states that to deter entry, incumbents forgo a fraction of their profits, therefore, incurring a short term cost. The profit sacrifice, \(K_{ijt}\), then translates into an extra cost imposed on the entrants. Note that this fraction depends on the signal of entry, as the expected value of entry itself would be a function of signal. Higher entry signals, imply higher expected value of entry and therefore, incumbents have to create more entry deterrents in order to successfully prevent entry.

To solve for the optimal value of \(\psi(\phi_{jt}^q)\) required to successfully deter entry, and subsequently understand the value of \(K_{ijt}\), firms use backward induction to find \(K_{\text{tot,jt}}\). This is the amount required to put the potential entrants on their participation constraint. Substituting for \(K_{\text{tot,jt}}\) from equation (3.15), and then substituting for firm level entry deterrents from equation (3.16) yields the optimal value of \(\psi(\phi_{jt}^q)\).

Equation (3.15) states that there are potentially multiple combinations of firm level entry deterrents, \(K_{ijt}\), by firms of sector \(j\) that can put the entrants on their participation constraint. The existence of various combinations implies that there might be multiplicity of equilibria. The assumption above overcomes the multiplicity problem by focusing on the equilibrium that takes the form described by equation (3.16). Further this assumption ensures that the firms’ value remains increasing in their productivity.\(^{17}\)

\(^{17}\)The set of equilibria that impose disproportional costs on firms, may result in non-monotonicity in the value of firms as a function of idiosyncratic productivity level. For example, a deterrence rule which requires the most productive firm to incur a high share of cost of barriers, lowers the value of market leader \(K_{\text{tot,jt}}\) (given its ICC being satisfied), with limited cost on the remaining firms. As long as \(V_1 - V_2 < K_{\text{tot,jt}}\) this creates non-monotonicity in the value function, in turn altering the incentive of firms to innovate, as now there is a penalty in becoming the market leader. This assumption further limits focus to cases without any free riding. So cases where a few firms could create a lot of barriers and other firms free ride are not included under this assumption.

53
3.3.3 Antitrust Regulator

There is a regulator who monitors the actions of incumbents and constrains the extent to which they can engage in aggressive strategies. In the previous sections, firms’ aggressive strategies were modelled as foregoing a fraction of their profits, implying incumbents incur a cost to create barriers to entry for the new firms. The role of the antitrust regulator is to obstruct strategic actions in which incumbents find it optimal and profitable to act aggressively. In this framework, antitrust policy is summarised by the following equation indicating that antitrust policy sets a limit on the level of profit sacrifices by incumbents:

$$\psi(\phi^q) \leq \psi_d$$  \hspace{1cm} (3.17)

The condition states that the incumbents’ profit sacrifices cannot be higher than the antitrust (competition law) parameter $\psi_d$. Note that higher $\psi_d$ implies that firms can sacrifice a larger fraction of their profits and, therefore, they can create more barriers to entry, thus pointing to a more lax antitrust policy. On the other hand, a lower value of $\psi_d$ denotes a more stringent antitrust policy in which aggressive strategies by incumbents are not permitted. In the case where $\psi_d = 0$, the antitrust authority rules out all aggressive strategies, and in the absence of innovation, the problem becomes fully static and equivalent to Atkeson and Burstein (2008).

While this is a reduced-form presentation of antitrust law and abstracts from various complexities of such policies, it is still able to capture the focus of antitrust law on profit margins and profit sacrifices. As it will be discussed in the next section, in cases of monopolisation or attempted monopolisation (Section 2 of the Sherman Act) possible assessments of firms’ anticompetitive conduct include tests examining the extent of profit sacrifices by firms for long term benefits.\(^{18}\)

Finally, while each firm $i$ may individually have the incentive to deter entry of new firms according to (3.13), the antitrust policy sets an upper bound on such aggressive strategies. Consequently, the maximum amount of barriers to entry jointly created by firms of a given sector is:

$$N^{-\frac{1}{1-D}} \left( \sum_{i=1}^{N} K_{\text{max},i}^{\alpha_d} \right)^{\frac{1}{\alpha_d}} \geq EV[\bar{\phi^q}] - S$$ \hspace{1cm} (3.18)

Where $K_{\text{max},i} = \psi_d \times \pi_i^d$ is the maximum amount of deterrent that firm $i$ has the ability to create within the law. The condition therefore pins down the cutoff for signal of entry, $\bar{\phi^q}$, as above a certain entry signal, entrants are expected to have a very high productivity and consequently high values.

\(^{18}\)The guidelines of Department of Justice for these tests, namely the profit sacrifice test and the no economic sense test are discussed in the calibration section.
3.3.4 Equilibrium

The dynamic equilibrium is characterised by a steady state distribution (along a trend) over all sectors. Firms compete in a Bertrand setting maximise their lifetime value as defined in (3.7) with respect to prices, innovation and aggressive strategies subject to demand for their products, as in equation (3.4), the law of motion for the sectoral state, defined in equation (3.8), the antitrust constraint (3.17), and their incentive compatibility constraint (3.13). The maximisation problem is further subject to production technology, cost of innovation, and the probability of successful innovation. The optimal price is defined as equation (3.9), and the optimal innovation is as described in equation (3.12). The grim trigger aggressive strategy is discussed in the appendix. Further, in the equilibrium there is an entry cutoff $\bar{\phi}_{\text{entry}}(\mu_t)$ derived from the free entry condition as in equation (3.14), and a cutoff for exit $\bar{\phi}_{\text{exit}}(\mu_t)$ derived from equation (3.5). Once detrended, the cutoffs become independent of time. Further, households maximise their utility as in equation (3.1) subject to their budget constraint, and there is market clearing for the the goods and the labour market.

3.4 Calibration

In this section, the model is estimated numerically to match the firm-level and sector-level data of the US between 2000 and 2010. The parameters that need to be determined are: $\epsilon, S, f, \psi_{cl}, \beta, L_s, \gamma, \ b, \alpha_d, H_e$ and $G_e$. The description of parameters is provided in Table 3.1. Four of these parameters are exogenously calibrated. The elasticity of substitution is set to 4 as in Costantini and Melitz (2009), $\beta$ the discount factor is set to 0.96 and labour supply is normalised to 1.

Modelling of antitrust authority is motivated by the ”profit-sacrifice” test and the ”no economic sense” test for assessing firms’ anticompetitive conduct by the Department of Justice. These tests investigate if firms’ practices have led to sacrifice of profits in the short run in an exclusionary scheme, only to be recouped in the future. While the wording of these tests considers any deviations from the optimal short run profits anticompetitive, courts under the landmark case of Brooke Group have required showing evidence of a loss. Within the narrow confines of the model, the Brooke Group case provides the most clear-cut measure of profit sacrifices for an exclusionary action to be considered anticompetitive in courts. Therefore, $\psi_{cl}$ the antitrust parameter is set to 1 implying that the profit-sacrifice test does not allow an aggressive strategy leading to a net

\footnote{In total, the department of Justice proposes 5 tests for investigation of exclusionary conduct. Exclusionary conduct relates to actions under section 2 of the Sherman Act. Source: https://www.justice.gov/atr/competition-and-monopoly-single-firm-conduct-under-section-2-sherman-act-chapter-3

\footnote{Brooke Group is a case of predatory pricing and Edlin (2002) argues requirements of the court were influenced by the arguments of Bork.

\footnote{A list of cases that were assessed under the profit-sacrifice test are provided in the Department of Justice publications. The source is as indicated in footnote 19.}
loss, to be consistent with the court rulings. The remaining parameters are structurally estimated using the simulated method of moments approach and their values are reported in Table 3.1.

Table 3.1: Parameters of the theoretical model

<table>
<thead>
<tr>
<th>Internally calibrated</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S$</td>
<td>0.030</td>
<td>Sunk cost of entry</td>
</tr>
<tr>
<td>$f$</td>
<td>0.008</td>
<td>Fixed cost of production</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>1.056</td>
<td>Productivity step</td>
</tr>
<tr>
<td>$H_e$</td>
<td>1.050</td>
<td>Parameter of entry signal distribution $H$ (truncated pareto)</td>
</tr>
<tr>
<td>$b$</td>
<td>0.098</td>
<td>Cost of innovation</td>
</tr>
<tr>
<td>$\alpha_d$</td>
<td>2.001</td>
<td>Deterrent aggregator parameter (elasticity)</td>
</tr>
<tr>
<td>$G_e$</td>
<td>2.570</td>
<td>Parameter of entry distribution $g_{ent}$ (truncated pareto)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Externally calibrated</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$\epsilon$</td>
<td>4</td>
<td>Elasticity of substitution</td>
</tr>
<tr>
<td>$\beta$</td>
<td>0.96</td>
<td>Discount factor</td>
</tr>
<tr>
<td>$\psi_{cl}$</td>
<td>1</td>
<td>Competition law parameter</td>
</tr>
<tr>
<td>$L_s$</td>
<td>1</td>
<td>Labour supply</td>
</tr>
</tbody>
</table>

The estimated moments, their data counterparts and the data source are reported in Table 3.2 and discussed further below. The data for rate of entry of firms is obtained from the Business Dynamics Statistics (BDS), which provides various measures of business dynamics for the economy aggregated at the sectoral level. The BDS data is created from Longitudinal Business Database (LBD) of the US census and thus covering the population of entrant firms. The distribution of entrants in the model is assumed to be pareto (truncated over the productivity space) and the parameter of the distribution is estimated to match the entry rate of firms in the BDS data. Additionally, the BDS database provides information over employment of firms at different age groups, which is used to get the employment share of entrants.

Research and Development expenditure proxies the intensity of innovation in the model. The data counterpart is obtained from the Compustat dataset and is the weighted average of Research and Development expenses over sales for each year. The weights are sales share of firms in their respective 4-digit industries and when averaging over the years,

---

22 The wording of the guideline: “Generally, a profit-sacrifice test asks whether the scrutinized conduct is more profitable in the short run than any other conduct the firm could have engaged in that did not have the same (or greater) exclusionary effects. If the conduct is not more profitable, the firm sacrificed short-run profits and might have been investing in an exclusionary scheme, seeking to secure monopoly power and recoup the foregone profits later.” Source: Antitrust Division of Department of Justice - Chapter 3, General Standards for Exclusionary Conduct. Further, as discussed in section 3 the case of Brooke Group required showing evidence of a loss (along with other factors) for exclusionary behaviour (Edlin, 2002).
Table 3.2: Targeted Moments

<table>
<thead>
<tr>
<th>Moment</th>
<th>Estimated</th>
<th>Data</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entry rate</td>
<td>0.08</td>
<td>0.08</td>
<td>BDS</td>
</tr>
<tr>
<td>Fixed cost over total cost</td>
<td>0.21</td>
<td>0.20</td>
<td>Compustat</td>
</tr>
<tr>
<td>RD Expenditure over total sales</td>
<td>0.040</td>
<td>0.043</td>
<td>Compustat</td>
</tr>
<tr>
<td>Average Markup</td>
<td>1.37</td>
<td>1.45</td>
<td>De Loecker et al., 2020</td>
</tr>
<tr>
<td>Entrants employment share</td>
<td>0.046</td>
<td>0.044</td>
<td>BDS</td>
</tr>
<tr>
<td>Productivity growth</td>
<td>0.012</td>
<td>0.013</td>
<td>BLS</td>
</tr>
<tr>
<td>Profit share of total income</td>
<td>0.13</td>
<td>0.12</td>
<td>Akcigit and Ates, 2021</td>
</tr>
</tbody>
</table>

all years have equal weights.\(^{23}\) The same moment is formed in the model and is used to estimate parameter $b$, denoting marginal cost of innovation. The data moment in Table 3.2 shows the concentration ratio averaged across all 4-digit sectors in year 2010.

The data source for the remaining moments are the values reported in the literature. Average markups are targeted to values in De Loecker et al. (2020). Profit share of GDP is obtained from Akcigit and Ates (2021) and is also similar to values reported in Barkai (2016). The estimate for growth rate of productivity is from the BLS website and is the average of annual growth rate between years 2005-2018.

Table 3.3 reports the untargeted moments of the data. The second column shows the estimated values from the model, and the third column is the data counterparts reported for corporations with more than one hundred employees. The final column provides the source of the data.

The concentration measure is CR4 indicating the sum of sales share of top four firms in each industry and is taken from Akcigit and Ates (2019). Profit over sales of the market leader is obtained from Compustat. The market leaders are the top 5% of firms based on their sales in their respective 4-digit sectors. The moment reported in Table 3.3 is the average ratio of gross profits over sales averaged over all sectors.\(^{24}\) The next two moments are measures of firm size distribution and show the sales’ ratio of 25 and 75 percentile to the median firm. The final moment presented in Table 3.3 is the interquartile range of R&D expenditure where the quartiles are defined based on sales. The information is obtained from Compustat and reported conditional on firms having above one hundred employees.

### 3.5 Quantitative Results

This section uses the calibrated quantitative model to investigate the properties of the equilibrium. I first discuss the firms’ policy functions and then explore the implications of

\(^{23}\) The respective variables in Compustat are xrd and sale.

\(^{24}\) The relevant variables in Compustat are gp and sale.
antitrust law for business dynamism. In particular, I run counterfactual exercises changing the stringency of antitrust law from the baseline lax scenario to cases that put a higher constraint on the extent of anticompetitive practices. In particular, in the limiting case, the antitrust authority is able to prevent all anticompetitive practices, thus providing an upper bound estimate on the effect of strengthening antitrust policies. Next, I show how changes in the stringency of antitrust law affect business dynamism by looking at its impact on the entry rate, productivity growth, the labour share of GDP and the profit share of GDP. In the final subsection, I assess the welfare effects of antitrust law and discuss the possible distributional consequences.

3.5.1 Policy Functions

Figure 3.1 depicts the optimal policy function of the firm in the equilibrium under the benchmark calibration of the previous section. Firms choose prices, investment in innovation and deterrence strategies.

The first panel of Figure 3.1 displays the markups of firm. The relevant idiosyncratic state variable here is the rank of the firm in the distribution or equivalently their distance from the market leader of that industry. Since firms are competing in an oligopolistic setup they internalise the effect of the markup they set on the sector level price as in Atkeson and Burstein (2008) and Grassi (2017). Firms higher on the productivity ladder, have a higher market share and this translates into having higher markups as in equation (3.9). The second panel shows the prices defined over a given productivity space. Unlike the markups, the position of the firm on the productivity ladder is not enough to pin down prices and the marginal cost itself matters. Marginal cost falls over time (through entry and innovation) and prices are accordingly affected.

The third panel of Figure 3.1 plots the expected innovation decision of incumbents. Incumbents closer to the market leader invest more in innovation compared to those that are lagged behind. Below, in subsection 7.2, I discuss in more details how innovation

---

25Decision over innovation happens after the signal for entry is observed, therefore it is also a function of entry signal. To simplify the presentation, the graph shows the expected value of innovation over all signals.
incentives of incumbents interact with aggressive strategies. The fourth panel of Figure 3.1 shows incumbents’ aggressive strategies in response to given signals for entry. The x-axis depicts the signal for entry and is an indication of the relative productivity of entrants with respect to incumbent. For example, value 2 on the x-axis suggests that entrants attach a non-zero probability to receiving signals which are (at most) two steps above the leader of the industry. Therefore, higher signals for the productivity of the entrant increase the expected value of entrants. The y-axis shows whether firms decide to act aggressively towards entrants in response to the entry signal. Aggressive strategies take values $\{0, 1\}$, where 1 indicates firms deciding to deter entry and 0 suggests that firms do not find it optimal to react. If incumbents decide to act aggressively, they have to forego a fraction of their profits as equation (3.16).

As in can be observed from Figure 3.1 aggressive strategies happen in response to signal 2 and 3 while incumbents do not react to other entry signals. Choosing $D = 0$ can happen for two distinct reasons. First, if there is a low draw for the entrants, incumbents do not perceive entrants to be a threat and will optimally decide not to react. Second, if entrants have a very high draw for their productivity signal, to prevent entry, incumbents have to part with a larger share of their profits in order to create sufficient amount of barriers. However, sacrificing such a large fraction may either be too costly for the incumbent itself, such that it does not satisfy the incentive compatibility constraint, or not allowed given the antitrust policy, therefore not satisfying the antitrust condition as 3.17.
Table 3.4: Counterfactual analysis: Moments

<table>
<thead>
<tr>
<th></th>
<th>Baseline estimation</th>
<th>Counterfactual: $\psi_d = 0.6$</th>
<th>Counterfactual: $\psi_d = 0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entry rate</td>
<td>0.08</td>
<td>0.13</td>
<td>0.16</td>
</tr>
<tr>
<td>Fixed cost over total cost</td>
<td>0.21</td>
<td>0.25</td>
<td>0.27</td>
</tr>
<tr>
<td>RD Expenditure over sales</td>
<td>0.039</td>
<td>0.015</td>
<td>0.01</td>
</tr>
<tr>
<td>Average Markup</td>
<td>1.37</td>
<td>1.36</td>
<td>1.35</td>
</tr>
<tr>
<td>Entrants employment share</td>
<td>0.046</td>
<td>0.08</td>
<td>0.09</td>
</tr>
<tr>
<td>Productivity growth</td>
<td>0.012</td>
<td>0.017</td>
<td>0.02</td>
</tr>
<tr>
<td>Profit share of total income</td>
<td>0.13</td>
<td>0.09</td>
<td>0.049</td>
</tr>
</tbody>
</table>

3.5.2 Counterfactual Scenario: Strengthening Antitrust Law

In this section, using the parameter values from the baseline calibration, I vary the antitrust policy parameter to reflect stricter antitrust policy regimes. Recall that under the baseline scenario, the "profit-sacrifice test" of the antitrust authority required firms to make a loss for the conduct to be considered anticompetitive. In the counterfactual scenarios, I consider an intermediate case, and an extreme case in which any profit sacrifice and deviation from the short run profits is considered anticompetitive and illegal. Table 3.4 presents the results of the counterfactual scenarios, with the second column including the baseline calibration under lax policies, the third column showing the intermediate case, and the final column reporting the results under very strict antitrust policies.

In both counterfactual exercises firms’ ability to engage in strategic and aggressive actions decreases as the antitrust authority takes a tougher stance on the profit-sacrifice test. In response to antitrust law becoming stronger, entry rate increases from 8 percent to 13 and 16 percent under the intermediate and extreme case respectively.

Next, it can be observed that the measure of innovation captured by the weighted average of R&D expenditure over sales falls from 3.9 percentage points under the baseline scenario to 1.5 and 1 percentage points. To offer a breakdown of the contribution of each firm to the aggregate measure of innovation, the first panel of Figure 3.2 plots the expected innovation of firms as a function of their position on the productivity ladder. It can be observed that firms do not act uniformly in response to strengthening of antitrust policies, as some increase their investment in innovations while others do the opposite.

In particular, in determining the response of incumbents’ investment in innovation to the changes in antitrust policy, there are two opposing forces at play. First, under lax policies, incumbents are able to act more strategically and aggressively, in turn increasing their lifetime value. Higher lifetime value encourages incumbents to increase their investment in innovation. Second, more aggressive strategies under lax policies protect

---

26Incumbents decide on investment in innovation after observing the signal for entry, this graphs takes the expected value of innovation under all signals.
incumbents against external competition from entrants, thus lowering incumbents’ incentive to innovate. These two forces are similar to the Arrow replacement effect and the Schumpeter effect discussed by the literature.27

As illustrated in the first panel of Figure 3.2 the dominating force in determining innovation is different among incumbents, and some incumbents increase their innovation efforts while others do the opposite. Further, based on the innovation decision of incumbents alone on the first panel of Figure 3.2 it is not clear that the aggregate innovation would decline in response to strengthening antitrust policies. The aggregate innovation measure, therefore, depends on the share of incumbents increasing their innovation in equilibrium. The second panel of Figure 3.2 illustrates the firms’ distribution under each antitrust regime and shows that there are fewer high innovation incumbents under strong antitrust policies. The endogenous distribution of firms in the equilibrium is one contributing factor for the lower aggregate innovation under stronger antitrust policies. In fact, if the firms’ distribution under lax antitrust is applied to the innovation policy function under intermediate antitrust, the measure of aggregate innovation becomes 4.2 percentage point, more than the estimated value under the baseline calibration. Further, in this setup it would not be possible to discuss the inverted U shape relationship of concentration and innovation of Aghion et al. (2001), as concentration remains high under all antitrust regimes.

Another outcome of interest is the response of productivity growth to changes in antitrust law. As shown in Table 3.4, productivity growth increases from 1.2 percentage points in the baseline model to 1.7 and 2 percentage points in the intermediate and extreme case respectively. The results in the final column of Table 3.4 require the antitrust authority to detect all aggressive strategies and profit sacrifices, and thus should be interpreted as an upper bound on the effect of antitrust law. Note that productivity growth itself, is a combination of innovation efforts of incumbents and the contribution of net entry. Therefore, while innovation falls with stronger antitrust policies, net entry is able to drive a higher growth rate because entrants may be more productive than incumbents.

In addition to higher entry rate and productivity growth, Table 3.4 suggests that stronger antitrust policies lead to a more dynamic economy along other dimensions. It can be observed that the share of employment of young firms (entrants) increases in response to limiting the extent of aggressive strategies, while the profit share of total income falls. Since the only factor of production in the model is labour, the results point to a higher share of labour in national income. It is worth noting that markups remain relatively high under the strict antitrust law case. Therefore, antitrust policies can be used to promote business dynamism by limiting firms’ anticompetitive conduct, even before

27The Arrow replacement effect argues that more competition fosters innovation, and the Schumpeter effect argues that high monopolistic profits incentivise more innovation. In this model, similar to the replacement effect, higher entry creates more competition, not by lowering concentration levels, but by increasing turnover, replacing market leaders and pushing less productive firms out of the market. Similar to the Schumpeter effect, less competition from lower entry, increases lifetime value of the firms (by increasing their probability of survival), thus encouraging more innovation.
implementing policies directly aimed at lowering firms’ markups.

### 3.5.3 Welfare Implications of Antitrust Law

This section presents the welfare costs of lax antitrust policies and its distributional implications. Total welfare is measured in terms of present value of consumption where $U(C_t) = C_t$, and is then decomposed into the welfare of worker and the welfare of capitalist. To decompose, I assume workers take home the wage part of the total income, while capitalists consume the earnings from capital and profits. Since the model features only one factor of production (labour), I adjust the wage income by factor $\alpha = 2/3$ to correct for the share of capital. Welfare of worker is defined as:

$$V_w = \sum_{t=0}^{\infty} \beta^t \frac{\alpha w P_t}{P_t}$$

where $w$ is the wage and $P_t$ is the aggregate price at time $t$. Welfare of capitalist is defined as

$$V_c = \sum_{t=0}^{\infty} \beta^t \frac{(1 - \alpha)w + \pi}{P_t}$$

with $\pi$ denoting profits.

Table 3.5 shows the welfare gains in response to strengthening antitrust policies. In Panel A a shift from the baseline model to the case with no anticompetitive conduct, leads to 16% improvement in total welfare. As Panel A rules out all aggressive strategies, the numbers should be taken as an upper bound on the effect of antitrust policies. The remaining parts of the panel indicate that workers benefit more from strengthening antitrust policies with their lifetime value of consumption increasing by 28%. Capitalists, on the other hand, remain unaffected. In Panel B there is a strengthening of antitrust law to an intermediate level and firm are still able to act strategically though to a lesser extent compared to the baseline scenario. The gains are smaller compared to the previous exercise with total welfare increasing by 6%.

The increase in welfare under both cases is due to higher growth under more stringent antitrust policies. The distributional differences can be explained by the increase in wage and fall in profit rates as competition policies become stronger.

Table 3.5 contains the welfare results, and the response of consumption decomposed for the workers and capitalists and Figure 3.3 plots the response of consumption over time. In particular, these functions depict relative changes in consumption under a strict(er)
Table 3.5: The Change in Relative Welfare in Response to Strengthening Antitrust Policies

<table>
<thead>
<tr>
<th></th>
<th>Welfare</th>
<th>Consumption (immediate)</th>
<th>Consumption (after 50 years)</th>
<th>Break even year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Panel A</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>0.16</td>
<td>-0.15</td>
<td>0.25</td>
<td>23</td>
</tr>
<tr>
<td>Workers</td>
<td>0.28</td>
<td>-0.06</td>
<td>0.37</td>
<td>10</td>
</tr>
<tr>
<td>Capitalists</td>
<td>0.00</td>
<td>-0.27</td>
<td>0.07</td>
<td>41</td>
</tr>
<tr>
<td><strong>Panel B</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>0.06</td>
<td>-0.12</td>
<td>0.12</td>
<td>28</td>
</tr>
<tr>
<td>Workers</td>
<td>0.12</td>
<td>-0.06</td>
<td>0.19</td>
<td>16</td>
</tr>
<tr>
<td>Capitalists</td>
<td>-0.03</td>
<td>-0.20</td>
<td>0.02</td>
<td>46</td>
</tr>
</tbody>
</table>

Panel A indicates change in welfare in consumption equivalent terms as a result of moving from the baseline model to the case where no anticompetitive practices are allowed. Panel B indicates an intermediate level, with strengthening antitrust policies relative to the baseline model.

antitrust regime relative to consumption under the benchmark case:

\[ C_T = \frac{C_{\text{strict}}}{C_{\text{lax}}} \]

Additionally Figure 3.3 plots changes in consumption of workers and capitalists as antitrust regime changes. More specifically these functions are presented as:

\[ C_w = \frac{C_{w,\text{strict}}}{C_{w,\text{lax}}}, \quad C_c = \frac{C_{c,\text{strict}}}{C_{c,\text{lax}}} \]

where \( C \) shows consumption, subscript \( w \) and \( c \) indicates workers and capitalists respectively. Given the above definitions, any value greater than one presents an improvement in consumption. As it can be observed from Figure 3.3 there is an immediate drop in all three measures in response to strengthening antitrust policies, indicating a short- and medium- run decline in consumption. This trend, however, is reversed in the long run, showing significant improvements in total consumption and the consumption of worker.

The initial drop in consumption in response to strengthening antitrust policies is due to reallocation of labour from production to the setting up of new firms. Recall from section 3.3 that labour is supplied inelastically and is used for setting up a new firm, innovation, and production. Under lax antitrust law, aggressive strategies mean entry rate is lower, and thus the fraction of labour allocated to setting up a new firm is instead used for production and innovation. Despite the higher rate of productivity growth, in the short run, the reallocation of labour leads to a fall in total output.

Similar reasoning exists for \( C_w \), but now the higher rate of growth is combined with higher wage, thus leading to a weaker immediate decline and higher rate of consumption.
Panel A indicates change in consumption as a result of moving from the baseline model to the case where no anticompetitive practices are allowed. Panel B indicates an intermediate level, with strengthening antitrust policies relative to the baseline model.

Figure 3.3: Consumption

Panel A indicates change in consumption as a result of moving from the baseline model to the case where no anticompetitive practices are allowed. Panel B indicates an intermediate level, with strengthening antitrust policies relative to the baseline model.

growth. As for capitalists, the immediate drop in their share of total income is large enough to require a much longer horizon for consumption to return to its previous levels. Figure C.1 depicts development of consumption in a longer horizon.

The results of this section suggest that when analysing the effect of antitrust policies, besides the dynamic considerations of consumer welfare standards, there are distributional and general equilibrium effects, captured by wages and prices, that should be considered. While the overall improvements to welfare are due to increase in the rate of productivity growth, strengthening antitrust policies would have unequal effect on workers vs. capital owners.

A Short Discussion on Inequality- The relationship between market power, antitrust law and inequality has been widely discussed in the past few years (Baker and Salop, 2015; Stiglitz, 2017; Zingales, 2017). In the context of this chapter, higher market power leads to more barriers to entry, thereby increasing the value of incumbents at the expense of (potential) entrants. Further, greater barriers to entry lead to the concentration of profits in the hands of a few firms, reducing the share of the population that can enjoy such high gains. In this section, I provide some rough calculations, to illustrate the effectiveness of stronger antitrust policies in addressing inequality.

The measure of inequality used for the analysis is P90-P10 ratio, indicating the relative real income of the 90th percentile to the 10th percentile of wealth distribution. Based on Cagetti and De Nardi (2006) and Lee (2019) roughly 10% of population in the US are entrepreneurs and 90% are dependent on wage income. To get an estimate of the P90-P10 ratio, I assume that the bottom 90% of the wealth distribution are all workers and the source of their income is from wage, while the top 10% are all entrepreneurs. I then calculate the present discounted value of consumption of workers and capitalists.
under the three antitrust regimes and correct for their relative shares in the population to get consumption per worker and consumption per capitalist. The value of consumption per worker under the benchmark case is normalised to one, and the results are reported in Table 3.6.

Under the benchmark case, P90-P10 ratio is 6.69, indicating that the capitalists which under the simple approximation are equivalent to the 90th percentile, consume roughly 6.7 times more than the workers.\textsuperscript{28} The actual value estimated by the OECD for the US population is 6.2.\textsuperscript{29} The estimated value from the model, therefore, appears to be sufficiently close to its data counterpart.

These simple calculations show that strengthening antitrust policies to an intermediate and a very strict case lowers the measure of inequality by 14% and 22% respectively. In both cases the effect on the consumption per capitalist seems to be marginal (or nonexistent) and the improvement in the inequality measure happens through an increase in consumption per worker.

Table 3.6: The effect of antitrust law on inequality

<table>
<thead>
<tr>
<th></th>
<th>Benchmark</th>
<th>Intermediate</th>
<th>Strict</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\psi_{cl} = 1$</td>
<td>1</td>
<td>1.12</td>
<td>1.28</td>
</tr>
<tr>
<td>Consumption per worker</td>
<td>6.69</td>
<td>6.45</td>
<td>6.69</td>
</tr>
<tr>
<td>Consumption per capitalist</td>
<td>6.69</td>
<td>5.76</td>
<td>5.23</td>
</tr>
</tbody>
</table>

The objective of this exercise is to illustrate that antitrust policies, whether lax or strong, can have implications for inequality in the economy. Otherwise, it would be premature to draw conclusions solely based on the estimates of this section.

3.6 Conclusion

A recent literature has documented a decline in business dynamism in the past few decades. At the same time enforcement of antitrust in the US has been at historically low levels. This chapter develops a structural model and studies the role of antitrust law as a macroeconomic policy in improving business dynamism and its impact on welfare.

The chapter develops a dynamic general equilibrium model with oligopolistic competition in each sector, in which firms can invest in innovation and act anticompetitively towards entrants in order to increase their lifetime value. The model features an antitrust authority monitoring the decision of firms and constraining the extent to which firms can eliminate their competitors. The model is structurally estimated to match the US

\textsuperscript{28}A more conservative estimate, assuming 14% of population are entrepreneurs is provided in Table C.2 in the appendix. 14% is the highest share of entrepreneurs in the US based on Lee (2019).

\textsuperscript{29}See https://data.oecd.org/inequality/income-inequality.htm
data on various dimensions of business dynamism such as entry rate, markups, share of young firms in employment, among other moments between 2000-2010. In this regard, the framework takes a different approach from the literature that focused on analysing firms’ anticompetitive behaviour and antitrust law in partial equilibrium and narrow markets, and instead investigates the macroeconomic and distributional implications of firms’ strategic behaviour.

Using the estimated model, the chapter considers counterfactual scenarios in which antitrust law becomes stronger. The results point out to a significant increase in the rate of productivity growth through higher entry in response to a tightening of antitrust policies. In particular, under the strictest case of antitrust with no tolerance for aggressive strategies, productivity growth increases by 0.8 percentage points relative to the benchmark calibration. Further, there is an increase in the labour share of total income and employment share of young firms (entrants). It is worth noting that the change in antitrust policies in this framework and under the baseline calibration has a limited impact on firms’ market power. Therefore, there is scope for antitrust policies in generating a more dynamic economy even when high concentration and high market power are inherent to the structure of the market.

An important insight of this chapter is to study the welfare implications of stronger antitrust policies. Given the model specification, an antitrust law that is able to rule out all anticompetitive practices improves welfare by 16%, where welfare is defined in terms of net present value of consumption. This number should be interpreted as an upper bound to the effectiveness of antitrust policies as it relies on the ability of the antitrust authority to rule out all anticompetitive practices. Further, this chapter takes a first look at the distributional implications of strengthening antitrust policies and finds that those dependent on labour income benefit relatively more from strengthening antitrust law. The literature has been debating the effect of monopolies on income inequality and their interaction with antitrust law (Baker and Salop, 2015; Stiglitz, 2017; Zingales, 2017). The findings of this chapter suggest that antitrust policies will have a distributional impact and can potentially be used in addressing inequality. More studies with frameworks suited in answering such questions are required to shed light on the role of antitrust in reducing inequality.
Bibliography


Bain, J. (1956). “Barriers to entry”. In.


— (2020). “Coverage and representativeness of Orbis data”. In.


De Ridder, M. (2019). “Market power and innovation in the intangible economy”. In.


Fumagalli, C., M. Motta, and E. Tarantino (2020). “Shelving or developing? The acquisition of potential competitors under financial constraints”. In.


Appendix A

Appendix to Chapter 1

A.1 Theoretical Proofs

Proof of Lemma 1

To derive the zero net profit cutoff, first define the zero-profit cutoff \( \theta^* \), the productivity level at which the per period profits of the firm are equal to zero. Then:

\[
\begin{align*}
    r(\theta^*) &= \sigma f_p \quad \forall \theta_i
\end{align*}
\]

This characterisation is as in Melitz (2003), and simplifies the revenue of any firm from a given variety associated with productivity level \( \theta \) to:

\[
\begin{align*}
    r(\theta) &= \left( \frac{\theta}{\theta^*} \right)^{\sigma-1} \sigma f_p
\end{align*}
\]

And profits can be written as:

\[
\begin{align*}
    \pi^D(\theta) &= \left( \left( \frac{\theta}{\theta^*} \right)^{\sigma-1} - 1 \right) f_p
\end{align*}
\]

For any additional variety the firm adds in the domestic market, there is a one-off sunk cost \( S_d \) to be paid. Hence, a firm with the zero-profit cutoff productivity level for one of its varieties, generates negative net profits. The presence of this sunk cost implies a zero net profit cutoff productivity level above \( \theta^* \) that makes the firm indifferent between adding a new product line and not entering that market. To derive this cutoff, define \( \theta^{**} \) as the productivity cutoff above which net present value of profits from variety i are positive and define \( \Delta = \int_0^\infty e^{(1-\delta)t} dt \) to get:

\[
\begin{align*}
    \Pi^D &= \int_0^\infty \pi_i e^{-(1-\delta)t} dt - S_d \\
    \left( \left( \frac{\theta}{\theta^*} \right)^{\sigma-1} - 1 \right) \frac{f}{\Delta} - S_d &= 0
\end{align*}
\]
Above holds at $\theta = \theta^{**}$.

Therefore:

$$\theta^{**} = \left( \frac{S_d \Delta}{f} + 1 \right)^{\frac{1}{\sigma - 1}} \theta^*$$

Note that if $\theta^{**} \leq \theta^*(a_0)$ then the entry cutoff for new varieties will coincide with $\theta^*(a_0)$. Where $\theta^*(a_0)$ is the value of entry for liquidity constrained firms.

**Proof of Lemma 2**

To derive the zero net profit cutoff for exporting, as before define the zero-profit cutoff $\theta^*_{x,m}$, the productivity level at which the profits of the firm are equal to zero at a given point in time. This is exactly the same as the productivity cutoff defined in the Melitz (2003) model and leads to a similar exporting cutoff:

$$r_x(\theta^*_{x,m}) = \sigma f_x$$

(A.4)

$$\theta^*_{x,m} = \tau \left[ (\frac{f_x}{f_p}) \right]^{\frac{1}{\sigma - 1}} \theta^*$$

(A.5)

The setup presented in chapter 1, however has additional sunk costs associated with exporting. Therefore, the actual cutoff above which firms start exporting has a different characterisation from Melitz (2003). In presence of sunk cost $S_x$, the productivity cutoff is presented by the level at which net present value of exporting is zero. Since $S_x > 0$, it must be that $\theta^*_x$ is higher than the $\theta^*_{x,m}$. $\theta_x$ can be written as a function of the Melitz (2003) export cutoff $\theta^*_{x,m}$.

Consider the zero net profit condition for exporting and as before and define $\Delta = \int_0^\infty e^{(1-\delta)t} dt$ to get:

$$\left( \frac{\theta}{\theta^*_{x,m}} \right)^{\sigma - 1} - 1 \frac{f_x}{\Delta} - S_x = 0$$

Above holds at $\theta = \theta^*_x$.

Therefore:

$$\theta^*_x = \left( \frac{S_x \Delta}{f_x} + 1 \right)^{\frac{1}{\sigma - 1}} \theta^*_{x,m}$$

**Proof of Proposition**

To prove the proposition, I start from a two good case and then generalise. First, suppose that the firm is constrained with initial asset level $a_0 < a_u$ where $a_u$ shows the asset level for which the firm will be unconstrained. Also suppose that the economy is at its steady state such that the aggregate price is known to all firms.

As before, we continue to rank products based on their productivity, such that the first variety that the firm produces is the most productive one. The productivity of the second variety is a fraction of the first and so on. Therefore, we have:
\[ \pi_1^D > \pi_2^D > \ldots > \pi_n^D \]

Where \( \pi_i^D \) shows the profit from the domestic market for good \( i \).

In a two good world, if a firm is liquidity constrained it means that it cannot expand to all the domestic and export markets that are considered profitable.
Define:
\[
\begin{align*}
\pi_1^D &= \left( \theta_c \right)^{\sigma - 1} \frac{RP^{\sigma - 1}}{\sigma} - f_p \\
\pi_2^D &= \left( \theta_2 \right)^{\sigma - 1} \frac{RP^{\sigma - 1}}{\sigma} - f_p \\
\pi_1^X &= \left( 1 - \sigma \right) \left( \theta_c \right)^{\sigma - 1} \frac{RP^{\sigma - 1}}{\sigma} - f_x \\
\pi_2^X &= \left( 1 - \sigma \right) \left( \theta_2 \right)^{\sigma - 1} \frac{RP^{\sigma - 1}}{\sigma} - f_x
\end{align*}
\]

Also define \( \Pi_i^D = \int_0^\infty \pi_i^D e^{-(1-\delta)t} dt - S_d \) and \( \Pi_i^X = \int_0^\infty \pi_i^X e^{-(1-\delta)t} dt - S_x \) as the net discounted value of profits. The subscripts indicate the variety and the superscripts indicate the market the firms serves.

**Case 1:** \( \theta_x \) shows the cutoff for entry into the export market. It is the productivity level below which it is not profitable for the firm to export. This cutoff is independent of the asset level of the firm. Note that because of the sunk cost of exporting, the cutoff is slightly different from Melitz (2003). \( \theta_x^* \) and \( \theta_{x,m}^* \) are defined as in section chapter 1:
\[
\theta_x^* = \left( \frac{S_x \delta}{f_x} + 1 \right)^{\frac{1}{\sigma - 1}} \theta_{x,m}^*
\]
showing the productivity cutoff below which firms will not export.

**Case 2:** this case occurs when profits from selling variety 2 in the domestic market are higher than exporting good 1.
\[
\pi_2^D \geq \pi_1^X
\]
\[
\left( \frac{\theta_2}{\theta_x^*} \right)^{\sigma - 1} - 1 \right) \frac{f_p}{f_x} \geq \eta_x \left( \left( \frac{\theta_2}{\theta_{x,m}^*} \right)^{\sigma - 1} - 1 \right) \frac{f_p}{f_x}
\]
Where \( \theta_{x,m}^* = \tau \left( \frac{f_x}{f_p} \right)^{\frac{1}{\sigma - 1}} \theta^* \). Substituting for \( \theta_{x,m}^* \) and noting \( \theta_2 = c \theta_c \) we get the cutoff \( \theta_{high}^* \) for which firms always prefer to add a new domestic product before starting to export. Substituting in gives cutoff \( \theta_{high}^* \) as:
\[
\theta_{high}^* = \left( \frac{f_x - f_p}{f_p \left( \frac{S_x}{\theta_x^*} - c^{\sigma - 1} \right)} \right)^{\frac{1}{\sigma - 1}} \theta^*
\]
Note that this condition requires \( \frac{n_x}{\tau} \geq c \). Otherwise the value of expanding in the domestic market will always generate higher profits.

**Case 3:** this scenario in a two product world shows situations in which the productivity
level of the firm is such that an additional good in the domestic market and exporting are both profitable. Given the productivity of the firm, however, the profits generated by exporting the most productive good are higher than those from adding the second good in the domestic market:

$$\Pi^X_1 \geq \Pi^D_2$$

Since the firm is credit constrained \(a_0 < a_u\) the option to export and expand is not available immediately. The firm can take two different paths: 1) Introduce good 2 in the domestic market then export. 2) Export good 1 and then introduce good 2 in the domestic market. Profits generated from path 1 (therefore from production of good 2 in the domestic market) are smaller compared to the profits of exporting, but can be generated at an earlier date as the sunk cost of expanding in the domestic market is smaller than the sunk cost of exporting and the firm can afford to pay this cost at a closer date. To show the existence of an asset cutoff affecting the firm’s sequence of product introduction, consider the present discounted value of paths described above. Once the firm becomes unconstrained it starts exporting good 2. Therefore, the path that gets the firm to the asset level which allows it to pay for the sunk cost of exporting good 2 must have a higher present value. Since this term exists in the present value of both paths, it can be ignored from the calculations without affecting the final result. Similarly, profits from selling good 1 in the domestic market are common among both paths and so it can be excluded form the PV in both cases. Below I only include the parts that are important for the sake of comparison.

$$PV(1) = \Pi^D_2 e^{-(1-\delta)t_1} + \Pi^X_1 e^{-(1-\delta)(t_1+t_2)}$$

$$PV(2) = \Pi^X_1 e^{-(1-\delta)t_4} + \Pi^D_2 e^{-(1-\delta)(t_4+t_5)}$$

Where:

\[
t_1 = \max\left\{ 0, \frac{S_d + 2f_p - a_0}{\pi^D_1} \right\}, \quad t_2 = \begin{cases} \frac{S_X + 2f_p + f_x - a_0}{\pi^D_1 + \pi^D_2} & \text{if } t_1 = 0 \\ \frac{S_d + 2f_p + f_x - a_0}{\pi^D_1 + \pi^D_2} & \text{ow} \end{cases}
\]

\[
t_4 = \max\left\{ 0, \frac{S_X + f_p + f_x - a_0}{\pi^D_1} \right\}, \quad t_5 = \begin{cases} \frac{S_d + 2f_p + f_x - a_0}{\pi^D_1 + \pi^D_2} & \text{if } t_1 = 0 \\ \frac{S_d + 2f_p + f_x}{\pi^D_1 + \pi^D_2} & \text{ow} \end{cases}
\]

First suppose \(t_1 \neq 0\) and \(t_4 \neq 0\). Then:

$$PV(1) = \Pi^D_2 e^{-(1-\delta)\frac{S_d + 2f_p - a_0}{\pi^D_1}} + \Pi^X_1 e^{-(1-\delta)(\frac{S_d + 2f_p + f_x - a_0}{\pi^D_1 + \pi^D_2} + \frac{S_X + f_p + f_x - a_0}{\pi^D_1})}$$

$$PV(2) = \Pi^X_1 e^{-(1-\delta)\frac{S_X + f_p + f_x - a_0}{\pi^D_1}} + \Pi^D_2 e^{-(1-\delta)(\frac{S_d + 2f_p + f_x - a_0}{\pi^D_1 + \pi^D_2} + \frac{S_d + 2f_p + f_x}{\pi^D_1 + \pi^D_2})}$$

The equation capturing the firm being indifferent between the two path can be written
as:

\[ PV(1) = PV(2) \quad (A.6) \]

Note that as \( a_0 \) decreases \( t_4 \) increases much above \( t_1 \) (assuming \( S_x > S_d \)). The value of \( PV(2) \) decreases relative to \( PV(1) \) and therefore the first path is preferred. Similarly as \( a_0 \) increases \( t_4 \) and \( t_1 \) both decrease. As \( a_0 \) reaches \( S_x \), the value of \( t_4 \) and \( t_1 \) get closer to each other. However, \( \Pi_X > \Pi_D \), which means \( PV(2) > PV(1) \). Now to show the uniqueness of such \( a_0 \) above (below) which path 2 (1) is preferred, it suffices to show that both \( PV(1) \) and \( PV(2) \) are monotonic increasing in \( a_0 \) and second derivative does not change sign:

\[
\frac{\partial PV(1)}{\partial a_0} = \frac{1}{\pi_1^D} \Pi_2^D (1 - \delta)e^{-(1-\delta)t_1} + \frac{1}{\pi_1^X} \Pi_1^X (1 - \delta)e^{-(1-\delta)(t_1+t_2)} > 0
\]

It can be seen that all terms in the FOC are positive and therefore the FOC is increasing in \( a_0 \). And the second derivative:

\[
\frac{\partial^2 PV(1)}{\partial a_0^2} = (\frac{1}{\pi_1^D})^2 \Pi_2^D (1 - \delta)^2e^{-(1-\delta)t_1} + (\frac{1}{\pi_1^X})^2 \Pi_1^X (1 - \delta)^{t_1+t_2}e^{-(1-\delta)(t_1+t_2)} > 0
\]

It can similarly be shown for \( PV(2) \) and other cases regarding \( t_1 \) and \( t_4 \). Also, because of the curvature of the present value functions, there will be another intersection between the two functions which would realise as \( a_0 \) reaches \( a_0^* \). Note that only if \( t_4 = 0 \) since the profits from exporting are higher than profits from adding good 2 in the domestic market, an ordering dependent on the asset level will not exist.

Finally, the above result for the two product world can be generalised an n-product setting with similar reasoning. For any additional product that the firm wants to introduce the value of two paths should be compared. What is of interest here, is the point at which the firm becomes an exporter. Since export will always start with the most productive good, assuming the firm is already producing \( i \) varieties for the domestic market, the paths that should be compared are 1) Introducing \( I_1 \) or 2) Introducing \( D_{i+1} \). Therefore, first the comparison is between \( I_1 \) and \( D_2 \) which is the similar to before. The second round, if \( D_2 \) is chosen, is between \( I_1 \) and \( D_3 \). As the profit of \( D_2 \) is common in both present value functions, with the same reasoning as in Case 3, it can be excluded from the \( PV \) expression. This additional profit will only be present in the exponents of discount factor which is an indicator of the time it would take for the firm to introduce that good. The rest of the proof is exactly similar to the two-good world.

### A.2 Calibration and Numerical Method

In order to obtain the solution to the problem a number of firms are simulated. Each firm has three attributes: productivity level, initial asset level and initial cost shock. Core competency is defined over 12 grids with the lower bound value normalised to 1.
The value of asset is between \( f_p \) and \( \bar{a} \), where \( \bar{a} \) is high enough such that firms are not financially constrained. The cost shock is a two state symmetric Markov process and its value is chosen such that it is never the main driver of the profits. The initial draw for the productivity level is from an exponential distribution. The draw for asset level is a uniform distribution and the initial cost shock can take either one of the two values with equal probability.

To solve, first, I make an initial guess for the aggregate price level \( P \). Using the guess, the problem of the firm is solved, value functions are calculated with backward induction and the policy functions are derived. Then the free entry condition is applied to determine the active firms. Given the above, the stationary distribution of firms is calculated and the aggregate price \( P \) is updated. The procedure is repeated until the aggregate price converges to its equilibrium level.

**Discrete time setup**

Firm’s problem:

\[
V^X(\theta, c, a_t, \epsilon_t) = \max_{p,q,X_i,D_i} E_t \sum_i J_{i,t} \pi_i^D(\theta_i) - \sum_i D_{i,t} S_d + \sum_i J_{i,t}^{X_i} X_{i,t} \pi_i^{X_i}(\theta_i) - \sum_i X_{i,t} S_{x} + (1 - \delta) E_t [V^X(\theta, c, a_{t+1}, \epsilon_{t+1})]
\]

Subject to:

\[
J_{i,t} = \max \{ J_{i,t-1}, D_{i,t} \} \\
J_{i,t}^{X_i} = \max \{ J_{i,t-1}^{X_i}, X_{i,t} \} \\
\theta_i = c^{i-\theta_c} \quad i \in N \\
\]

\[
a_t \geq \sum_i J_{i,t} f_p + \sum_i D_{i,t} S_d + \sum_{J \in J} J_{i,t}^{X_i} f_{x} + \sum_i D_{i,t} S_d \\
a_t = r(a_{t-1} - \sum_i D_{i,t-1} S_d - \sum_i X_{i,t-1} S_x) + \sum_i J_{i,t} \pi_i^D(\theta_i) \sum_i J_{i,t}^{X_i} \pi_i^{X_i}(\theta_i)
\]

Where \( r \) is the interest rate and now there is an \( \epsilon \) shock to the profits of the firm. The other terms are defined similar to the setting described in previous section. One issue to note is that in discrete time the uniqueness result is not guaranteed. As an example, it is possible that firms with a very high level of productivity become unconstrained after one period and enter all the profitable markets. While in continuous time, the continuity in the rate of asset growth ensures the existence of a sequence.
Appendix B

Appendix to Chapter 2

In this appendix, I provide description of the data, regression tables and robustness checks used in chapter 2. The organisation is as follows. Section B.1 provides information about the data used for the US and Europe.

B.1 Data Sources and Sample Description

This section discusses data sources used in chapter 2 for the US and Europe.

B.1.1 US

The main data sources used for the US are Compustat database, Business Dynamic Statistics, Bureau of Labour Statistics, data from the US Census website, and the DoJ website. In the main analysis where I use Compustat, I exclude firms with negative sales, cost of goods sold and total assets from the calculations. I exclude unclassified sectors, utilities, finance and real estates. As mentioned in the data section of chapter 2, the sample for the U.S is from 1978-2018 (inclusive) for the explanatory variables where data on these years is available. While looking into the dynamic responses, where possible I use future values of dependent variables to get better estimates. Share of entrants and growth rates for manufacturing are trimmed at top/bottom 5%. For R&D expenditure I do both a firm-level regression and a sector-level regression in which firm-level R&D expenditure share is aggregated to a 4-digit sector level weighted by firms’ sale share. In all analysis, standard errors are clustered at sector-year level unless otherwise stated.

Turnover of Market Leaders

To investigate turnover rate, using Compustat data, I rank firms in each 4-digit NAICS sector based on their sales share. Figure B.1 shows the average number of years a given firm has been among the top 8 firms over the next 10 years. Therefore if a given firm is always ranked above 8, the value recorded for years at the top will be zero. This means

1The analysis is robust to other cutoffs. Top 8 firms capture concentration ratio CR8.
results reported in Figure B.1 will depend on the composition of firms, as an increase in the number of publicly traded firms would affect the average. To correct for the size of the market, I consider only the sample of firms that have been among the top 8 firms of their respective sector for at least one year and report the results in Figure B.1. Both figures point to an increase in the average number of years firms remain in the leading position since the 1990s, and thus they show lower turnover among top firms.

![Figure B.1: Turnover rates](image)

**Antitrust Enforcement Budget USA**

The measure of strictness of antitrust for the US is the relative share of enforcement budget allocated to the Antitrust Division of the Department of Justice (DoJ) is obtained from the DoJ website as discussed in chapter 2. The budget is then divided by GDP trend to become a stationary variable. I consider GDP trend rather than GDP to ensure cyclicalities that exist in GDP are not driving the result.

![Figure B.2: Antitrust Enforcement Budget over GDP Trend](image)
B.1.2 Europe

The main sources of data for Europe are the Comparative Competition Law database, CompNet database and Orbis. More details are provided below.

**Competition Law Index**- This part contains information on development of the Competition Law index across European countries, as well as maps visualising the budget available for each country.

![Development of Competition Law Index over Time](image1)

Figure B.3: Source: Comparative Competition Law Dataset

Figures B.4 and B.5 and B.6 depict the Competition Law Index for year 2010 for the world and for Europe respectively. Figure B.6 shows the Enforcement budget for Europe in 2010, the final year the data is provided.

![Competition Law Index](image2)

Figure B.4: Competition Law Index for all countries in 2010
I use the 7th vintage of CompNet database. Countries included are listed in table B.1. The TFP variables used are:

- **PE21_lntfp_red_in_ols_S_mn**: Logarithm of the total factor productivity, derived from OLS estimation of revenue-based Cobb-Douglas production function with intangibles
- **PE23_lntfp_red_ols_S_mn**: Logarithm of the total factor productivity, derived from
OLS estimation of revenue-based Cobb-Douglas production function

- PE25_lntfp_rcd_wd_S_mn: Logarithm of the total factor productivity, derived from Wooldridge estimation of revenue-based Cobb-Douglas production function

- PE27_lntfp_rtl_ols_S_mn: Logarithm of the total factor productivity, derived from OLS estimation of revenue-based translog production function

- PE29_lntfp_rtl_vi_ols_S_mn: Logarithm of the total factor productivity, derived from OLS estimation of revenue-based translog production function with variable inputs

- PE31_lntfp_rtl_vi_wd_S_mn: Logarithm of the total factor productivity, derived from Wooldridge estimation of revenue-based translog production function with variable inputs

- PE33_lntfp_rtl_wd_S_mn: Logarithm of the total factor productivity, derived from Wooldridge estimation of revenue-based translog production function

- PE35_lntfp_vcd_ols_S_mn: Logarithm of the total factor productivity, derived from OLS estimation of value-added based Cobb-Douglas production function

- PE37_lntfp_vcd_wd_S_mn: Logarithm of the total factor productivity, derived from Wooldridge estimation of value-added based Cobb-Douglas production function. All estimations are at the sectoral level

Measure of concentration used is:

- CV07_hhi_rev_sam_S_tot: Hirschman-Herfindahl index of market concentration at the sector level based on the firm sample

- CV03_hhi_rev_pop_S_tot: Hirschman-Herfindahl index of market concentration at the sector level based on the firm population

For robustness check I also use the second measure, but I decide the former variable for the main analysis as it has better coverage. Results are robust to dropping one country at a time, and trimming the growth variable at top/bottom 5%. The Competition Law Index is available only up to 2010, however the growth variables are available until 2018. I use the values beyond 2010 for the dynamic responses when available.

**Orbis** - List of countries and years of coverage are included in table B.2. Share of entrants are trimmed at top/bottom 5%. Industries where sale information is missing for more than 60% of firms are excluded. Results are robust to making this cutoff stricter. Results are robust to dropping one country at a time. Robust standard errors are used. Analysis in done from 2000-2016, where available future values of entrants are used when iterating forward to understand the dynamic responses. Note that the competition law index is available only until 2010 and therefore the averages presented in table B.2 reflect this
Table B.1: Summary Statistics: CompNet

<table>
<thead>
<tr>
<th>Country</th>
<th>Coverage</th>
<th>Average HHI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>2003-2017</td>
<td>.10</td>
</tr>
<tr>
<td>Denmark</td>
<td>2000-2016</td>
<td>.07</td>
</tr>
<tr>
<td>Finland</td>
<td>1999-2017</td>
<td>.08</td>
</tr>
<tr>
<td>France</td>
<td>2004-2016</td>
<td>.03</td>
</tr>
<tr>
<td>Germany</td>
<td>2001-2017</td>
<td>.06</td>
</tr>
<tr>
<td>Italy</td>
<td>2006-2016</td>
<td>.04</td>
</tr>
<tr>
<td>Netherlands</td>
<td>2007-2017</td>
<td>.08</td>
</tr>
<tr>
<td>Portugal</td>
<td>2004-2017</td>
<td>.06</td>
</tr>
<tr>
<td>Spain</td>
<td>2008-2017</td>
<td>.06</td>
</tr>
<tr>
<td>Sweden</td>
<td>2003-2016</td>
<td>.07</td>
</tr>
</tbody>
</table>

period. As literature has discussed Orbis has better coverage of large firms and small and young firms are under-represented. For the analysis of this chapter, the results remain valid as long as they are not driven by changes in the coverage. This is ensured by following Bajgar et al. (2020) and Kalemli-Ozcan et al. (2015).

Table B.2: Summary Statistics: Orbis and CLI

<table>
<thead>
<tr>
<th>Country</th>
<th>Coverage</th>
<th>Average HHI</th>
<th>Average share of entrant</th>
<th>Average CL index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>2000-2016</td>
<td>.38</td>
<td>.059</td>
<td>.70</td>
</tr>
<tr>
<td>Belgium</td>
<td>2000-2016</td>
<td>.31</td>
<td>.021</td>
<td>.61</td>
</tr>
<tr>
<td>Finland</td>
<td>2000-2016</td>
<td>.31</td>
<td>.040</td>
<td>.62</td>
</tr>
<tr>
<td>France</td>
<td>2000-2016</td>
<td>.20</td>
<td>.023</td>
<td>.72</td>
</tr>
<tr>
<td>Germany</td>
<td>2000-2016</td>
<td>.32</td>
<td>.041</td>
<td>.70</td>
</tr>
<tr>
<td>Greece</td>
<td>2000-2016</td>
<td>.32</td>
<td>.046</td>
<td>.54</td>
</tr>
<tr>
<td>Italy</td>
<td>2000-2016</td>
<td>.18</td>
<td>.046</td>
<td>.65</td>
</tr>
<tr>
<td>Netherlands</td>
<td>2000-2016</td>
<td>.47</td>
<td>.064</td>
<td>.23</td>
</tr>
<tr>
<td>Portugal</td>
<td>2000-2016</td>
<td>.25</td>
<td>.062</td>
<td>.59</td>
</tr>
<tr>
<td>Spain</td>
<td>2000-2016</td>
<td>.16</td>
<td>.035</td>
<td>.66</td>
</tr>
<tr>
<td>Sweden</td>
<td>2000-2016</td>
<td>.29</td>
<td>.023</td>
<td>.57</td>
</tr>
</tbody>
</table>

B.2 Detailed Specifications and Regression Tables

Similar to before, I discuss the case of the US and Europe.

B.2.1 US

This section provides more details on the specification used in chapter 2 for the US. For productivity growth the regression is defined as below:
\[ \frac{mfp_{s,t+h} - mfp_{s,t+h-1}}{mfp_{s,t+h-1}} = \delta_t + \delta_s + \beta_1\text{budget}_t \times HHI_{s,t} + \beta_2 HHI_{s,t} + \beta_3 \text{budget}_t + \epsilon_{s,t} \] (B.1)

\( mfp_{s,t+h} \) shows multifactor productivity in sector \( s \) and time \( t + h \). Data comes from BLS for the manufacturing sector at 4-digit industry level from 1987-2018.

For Entry data comes from the BDS database for all industries at a 4-digit level between 1978-2018. Data from BDS are also available for 3-digit industry level. The results are robust to using both values.

\[ \text{Ent}_{s,t+h} = \delta_t + \delta_s + \beta_1 \text{budget}_t \times HHI_{s,t} + \beta_2 HHI_{s,t} + \beta_3 \text{budget}_t + \epsilon_{s,t} \] (B.2)

Measure of investment in innovation is relative share of R&D expenditure to the sales of the firm. The analysis is done at two levels. The main specification uses firm level values for the relative share of R&D expenditure in the analysis and the standard errors are clustered at firm and year level. The main analysis is written as:

\[ RD_{i,t+h} = \delta_t + \delta_i + \beta_1 \text{budget}_t \times HHI_{i,t} + \beta_2 HHI_{i,t} + \beta_3 \text{budget}_t + \epsilon_{i,t} \] (B.3)

**Result Tables: US**

Table B.3: Growth Rates

<table>
<thead>
<tr>
<th>Productivity Growth - Manufacturing - USA</th>
<th>(0)</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HHI \times \text{budget}</td>
<td>3416.78</td>
<td>6717.44**</td>
<td>7144.04**</td>
<td>5111.25*</td>
<td>5283.95*</td>
<td>2553.77</td>
</tr>
<tr>
<td>(2799.19)</td>
<td>(2897.01)</td>
<td>(3061.17)</td>
<td>(3057.28)</td>
<td>(3039.12)</td>
<td>(2866.20)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>budget</th>
<th>-0.03</th>
<th>-0.07**</th>
<th>-0.07**</th>
<th>-0.05*</th>
<th>-0.06*</th>
<th>-0.03</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0.03)</td>
<td>(0.03)</td>
<td>(0.03)</td>
<td>(0.03)</td>
<td>(0.03)</td>
<td>(0.03)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>cons</th>
<th>0.01***</th>
<th>0.01***</th>
<th>0.00***</th>
<th>0.01***</th>
<th>0.01***</th>
<th>0.01***</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Industry FE</th>
<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sector-Year FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>( N )</td>
<td>2165</td>
<td>2177</td>
<td>2180</td>
<td>2184</td>
<td>2198</td>
<td>2201</td>
</tr>
</tbody>
</table>

Standard errors in parentheses.* \( p < 0.10 \), ** \( p < 0.05 \), *** \( p < 0.01 \)

HHI is the Herfindahl index, budget is share of budget in GDP trend.

Column \( h \) is the response of dependent variable at \( t + h \).
Table B.4: Entry - USA

<table>
<thead>
<tr>
<th>Share of Entrants</th>
<th>(0)</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HHI × budget</td>
<td>1377.80</td>
<td>1566.18</td>
<td>1824.03</td>
<td>1150.05</td>
<td>1282.75</td>
<td>667.27</td>
</tr>
<tr>
<td></td>
<td>(776.81)</td>
<td>(708.25)</td>
<td>(719.19)</td>
<td>(654.64)</td>
<td>(676.52)</td>
<td>(634.59)</td>
</tr>
<tr>
<td>budget</td>
<td>-0.00</td>
<td>-0.01</td>
<td>-0.01</td>
<td>-0.00</td>
<td>-0.01</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
</tr>
<tr>
<td>cons</td>
<td>0.09***</td>
<td>0.09***</td>
<td>0.09***</td>
<td>0.09***</td>
<td>0.09***</td>
<td>0.08***</td>
</tr>
<tr>
<td></td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>Industry FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Sector-Year FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>N</td>
<td>7765</td>
<td>7748</td>
<td>7727</td>
<td>7545</td>
<td>7363</td>
<td>7175</td>
</tr>
</tbody>
</table>

Standard errors in parentheses. ∗ p < 0.10,  ∗∗ p < 0.05,  ∗∗∗ p < 0.01
HHI is the Herfindahl index, budget is share of budget in GDP trend.
Column h is the response of dependent variable at t + h.

Table B.5: Entry - USA - Sample from 1985 to 2018

<table>
<thead>
<tr>
<th>Share of Entrants</th>
<th>(0)</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HHI × budget</td>
<td>2530.00</td>
<td>3589.13</td>
<td>2019.86</td>
<td>2056.22</td>
<td>2188.99</td>
<td>1505.60</td>
</tr>
<tr>
<td></td>
<td>(1002.38)</td>
<td>(1223.16)</td>
<td>(1126.07)</td>
<td>(1078.96)</td>
<td>(1057.87)</td>
<td>(1081.37)</td>
</tr>
<tr>
<td>budget</td>
<td>-0.02</td>
<td>-0.03</td>
<td>-0.02</td>
<td>-0.02</td>
<td>-0.02</td>
<td>-0.01</td>
</tr>
<tr>
<td></td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
</tr>
<tr>
<td>cons</td>
<td>0.08***</td>
<td>0.08***</td>
<td>0.08***</td>
<td>0.08***</td>
<td>0.08***</td>
<td>0.08***</td>
</tr>
<tr>
<td></td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>Industry FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Sector-Year FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>N</td>
<td>6558</td>
<td>6384</td>
<td>6210</td>
<td>6028</td>
<td>5846</td>
<td>5658</td>
</tr>
</tbody>
</table>

Standard errors in parentheses. ∗ p < 0.10,  ∗∗ p < 0.05,  ∗∗∗ p < 0.01
HHI is the Herfindahl index, budget is share of budget in GDP trend.
Column h is the response of dependent variable at t + h.
Table B.6: R&D Expenditure - All Firms

<table>
<thead>
<tr>
<th></th>
<th>(0)</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HHI × budget</td>
<td>-740.04</td>
<td>-1639.76</td>
<td>-1339.31</td>
<td>-1041.84</td>
<td>-426.58</td>
</tr>
<tr>
<td></td>
<td>(643.70)</td>
<td>(623.68)</td>
<td>(648.02)</td>
<td>(632.28)</td>
<td>(630.58)</td>
</tr>
<tr>
<td>budget</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HHI</td>
<td>0.01</td>
<td>0.02**</td>
<td>0.02*</td>
<td>0.01</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
</tr>
<tr>
<td>cons</td>
<td>0.07***</td>
<td>0.07***</td>
<td>0.07***</td>
<td>0.07***</td>
<td>0.07***</td>
</tr>
<tr>
<td></td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>Firm FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Year FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>N</td>
<td>117952</td>
<td>109919</td>
<td>102435</td>
<td>95014</td>
<td>86840</td>
</tr>
</tbody>
</table>

Standard errors in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01
HHI is the Herfindahl index, budget is share of budget in GDP trend.
Column h is the response of dependent variable at $t + h$.

Table B.7: R&D Expenditure - All Firms Aggregated to NAICS-4 Level

<table>
<thead>
<tr>
<th></th>
<th>(0)</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HHI × budget</td>
<td>-3793.48</td>
<td>-3074.07</td>
<td>-2635.67</td>
<td>-840.97</td>
<td>-283.56</td>
</tr>
<tr>
<td></td>
<td>(1386.20)</td>
<td>(1458.37)</td>
<td>(1628.61)</td>
<td>(1481.78)</td>
<td>(1496.27)</td>
</tr>
<tr>
<td>budget</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HHI</td>
<td>0.06***</td>
<td>0.05**</td>
<td>0.04*</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.02)</td>
</tr>
<tr>
<td>cons</td>
<td>0.02***</td>
<td>0.02***</td>
<td>0.02***</td>
<td>0.02***</td>
<td>0.02***</td>
</tr>
<tr>
<td></td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>Industry FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Sector-Year FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>N</td>
<td>8507</td>
<td>8425</td>
<td>8206</td>
<td>7993</td>
<td>7775</td>
</tr>
</tbody>
</table>

Standard errors in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01
HHI is the Herfindahl index, budget is share of budget in GDP trend.
Column h is the response of dependent variable at $t + h$.  

91
Table B.8: R&D Expenditure - All Firms

<table>
<thead>
<tr>
<th></th>
<th>(0)</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HHI × budget</td>
<td>-5698.91***</td>
<td>-4765.04**</td>
<td>-4149.63*</td>
<td>-2076.16</td>
<td>-1253.83</td>
</tr>
<tr>
<td></td>
<td>(1476.44)</td>
<td>(1560.50)</td>
<td>(1704.40)</td>
<td>(1573.27)</td>
<td>(1557.96)</td>
</tr>
<tr>
<td>budget</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HHI</td>
<td>0.08***</td>
<td>0.07***</td>
<td>0.06**</td>
<td>0.03*</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.02)</td>
</tr>
<tr>
<td>cons</td>
<td>0.02***</td>
<td>0.02***</td>
<td>0.02***</td>
<td>0.02***</td>
<td>0.02***</td>
</tr>
<tr>
<td></td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>Industry FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Sector-Year FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>N</td>
<td>8101</td>
<td>8019</td>
<td>7805</td>
<td>7600</td>
<td>7384</td>
</tr>
</tbody>
</table>

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

HHI is the Herfindahl index, budget is share of budget in GDP trend.

Column h is the response of dependent variable at t + h.

To make results comparable to other regressions, I also aggregate the measure of innovation to 4-digit sector level. For the aggregation I use two robustness checks. 1) A weighted average of R&D expenditure to the sales weighted by each firms’ sale share. 2) Average of R&D expenditure to the sales of market leaders:

\[
RD_{s,t+h} = \delta_{t} + \delta_{s} + \beta_{1} budget_{t} \times HHI_{s,t} + \beta_{2} HHI_{s,t} + \beta_{3} budget_{t} + \epsilon_{s,t} \quad (B.4)
\]

Figure B.7: Average industry R&D expenditure share response
B.2.2 Europe

The specification for productivity growth for Europe uses information from the CompNet data base:

\[ y_{c,s,t+h} - y_{c,s,t-1} = \delta_{c,t} + \delta_{c,s} + \beta_1 CL_{c,t} \times HHI_{c,s,t} + \beta_2 HHI_{c,s,t} + \beta_3 CL_{c,t} + \epsilon_{c,s,t} \] (B.5)

Variables are defined in the first part of this appendix. Tables B.9 to B.17 respond to the results of this section. Figure B.8 corresponds to a 10% improvement in the index, when all variables are evaluated at their mean.\(^2\) The contemporaneous outcome of growth in response to a 10% increase in the index is roughly 0.2 to 0.4 percentage point improvement in the growth rate of productivity, depending on the specification for the production technology. In most specifications, this correlation increases after one year and becomes relatively stable from year three. This relationship seems to be persistent at least for up to 5 years.

Data for entry is obtained from the Orbis database:

\[ Ent_{c,s,t+h} = \delta_{c,t} + \delta_{c,s} + \beta_1 CL_{c,t} \times HHI_{c,s,t} + \beta_2 HHI_{c,s,t} + \beta_3 CL_{c,t} + \epsilon_{c,s,t} \] (B.6)

The main results use the HHI index, however as robustness check, sales share of top 8 firms is used as another measure of concentration. Results remain robust.

Result Tables: EU

This section includes the regression tables for the analysis of Europe. CompNet database provides nine different measure of productivity based on assuming different production functions and estimating them. I use all measures available and investigate the implications of improving the measure of antitrust (competition policy). Next, to investigate the response of entry, I use the Orbis database and tables B.18 and B.19 refer to these results.

The result presented here are different from the analysis on the US, where the correlation while positive and significant, was temporary. To investigate whether this more persistent correlation is due to differences between Europe and the US or differences between budget and law, I run the same regression for Europe while including the interaction between concentration and budget as a share of GDP. The results are shown in Figure B.9 and Figure B.10, presenting the coefficient on the interaction of concentration with law and budget respectively. It seems that budget is associated with a smaller and temporary correlation while results with respect to the antitrust law remain similar to Figure B.8. The results suggest that improvements in competition law are associated with larger and more persistent improvements in productivity growth, while increasing resources exhibits a temporarily improvement. This result, however, requires further investigation.

\(^2\)The average CLI and HHI are 0.6 and 0.057 respectively.
### Table B.9: Growth (1)

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
<th>(9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HHI × CLI</td>
<td>0.38***</td>
<td>0.70***</td>
<td>0.61**</td>
<td>1.05***</td>
<td>1.18***</td>
<td>1.25***</td>
<td>1.42***</td>
<td>1.17**</td>
<td>0.80***</td>
</tr>
<tr>
<td></td>
<td>(0.06)</td>
<td>(0.13)</td>
<td>(0.24)</td>
<td>(0.23)</td>
<td>(0.13)</td>
<td>(0.14)</td>
<td>(0.18)</td>
<td>(0.37)</td>
<td>(0.23)</td>
</tr>
<tr>
<td>CLI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HHI</td>
<td>-0.12***</td>
<td>-0.31***</td>
<td>-0.21***</td>
<td>-0.58***</td>
<td>-0.64***</td>
<td>-0.73***</td>
<td>-0.70***</td>
<td>-0.56***</td>
<td>-0.35***</td>
</tr>
<tr>
<td></td>
<td>(0.03)</td>
<td>(0.08)</td>
<td>(0.06)</td>
<td>(0.08)</td>
<td>(0.14)</td>
<td>(0.15)</td>
<td>(0.12)</td>
<td>(0.30)</td>
<td>(0.12)</td>
</tr>
<tr>
<td>cons</td>
<td>-0.01***</td>
<td>-0.00</td>
<td>-0.00</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01***</td>
<td>0.01</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
</tr>
<tr>
<td>Country year FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Country sector FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Obs</td>
<td>2096</td>
<td>2092</td>
<td>2091</td>
<td>2089</td>
<td>2088</td>
<td>2087</td>
<td>2090</td>
<td>1882</td>
<td>1511</td>
</tr>
</tbody>
</table>
| Standard errors in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01

HHI is the Herfindahl index, CLI is the competition law index. Column h is the response of dependent variable at \(t+h\).

### Table B.10: Growth (2)

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
<th>(9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HHI × CLI</td>
<td>0.62***</td>
<td>1.00***</td>
<td>0.99**</td>
<td>1.26***</td>
<td>1.19***</td>
<td>1.32***</td>
<td>1.02***</td>
<td>0.98***</td>
<td>0.73***</td>
</tr>
<tr>
<td></td>
<td>(0.22)</td>
<td>(0.24)</td>
<td>(0.22)</td>
<td>(0.16)</td>
<td>(0.20)</td>
<td>(0.15)</td>
<td>(0.23)</td>
<td>(0.25)</td>
<td>(0.11)</td>
</tr>
<tr>
<td>CLI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HHI</td>
<td>-0.20</td>
<td>-0.40*</td>
<td>-0.51***</td>
<td>-0.67***</td>
<td>-0.64***</td>
<td>-0.75***</td>
<td>-0.62***</td>
<td>-0.56***</td>
<td>-0.48***</td>
</tr>
<tr>
<td></td>
<td>(0.18)</td>
<td>(0.18)</td>
<td>(0.10)</td>
<td>(0.10)</td>
<td>(0.11)</td>
<td>(0.13)</td>
<td>(0.15)</td>
<td>(0.11)</td>
<td>(0.11)</td>
</tr>
<tr>
<td>cons</td>
<td>-0.01</td>
<td>-0.01</td>
<td>0.00</td>
<td>0.01</td>
<td>0.01</td>
<td>0.02**</td>
<td>0.02</td>
<td>0.02**</td>
<td>0.02**</td>
</tr>
<tr>
<td></td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
</tr>
<tr>
<td>Country year FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Country sector FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Obs</td>
<td>2794</td>
<td>2792</td>
<td>2791</td>
<td>2786</td>
<td>2787</td>
<td>2785</td>
<td>2784</td>
<td>2540</td>
<td>2054</td>
</tr>
</tbody>
</table>
| Standard errors in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01

HHI is the Herfindahl index, CLI is the competition law index. Column h is the response of dependent variable at \(t+h\).

### Table B.11: Growth (3)

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
<th>(9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HHI × CLI</td>
<td>0.53**</td>
<td>0.80**</td>
<td>0.37***</td>
<td>0.94***</td>
<td>0.77***</td>
<td>1.27***</td>
<td>0.70***</td>
<td>0.76***</td>
<td>0.47***</td>
</tr>
<tr>
<td></td>
<td>(0.18)</td>
<td>(0.33)</td>
<td>(0.09)</td>
<td>(0.21)</td>
<td>(0.14)</td>
<td>(0.13)</td>
<td>(0.18)</td>
<td>(0.11)</td>
<td></td>
</tr>
<tr>
<td>CLI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HHI</td>
<td>-0.25</td>
<td>-0.37</td>
<td>-0.33*</td>
<td>-0.69***</td>
<td>-0.65***</td>
<td>-0.97***</td>
<td>-0.72***</td>
<td>-0.75***</td>
<td>-0.56***</td>
</tr>
<tr>
<td></td>
<td>(0.14)</td>
<td>(0.28)</td>
<td>(0.15)</td>
<td>(0.17)</td>
<td>(0.10)</td>
<td>(0.10)</td>
<td>(0.10)</td>
<td>(0.12)</td>
<td>(0.06)</td>
</tr>
<tr>
<td>cons</td>
<td>-0.01</td>
<td>-0.01</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00*</td>
<td>0.01**</td>
<td>0.01</td>
<td>0.01*</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>(0.00)</td>
<td>(0.01)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>Country year FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Country sector FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
| Standard errors in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01

HHI is the Herfindahl index, CLI is the competition law index. Column h is the response of dependent variable at \(t+h\).
Table B.12: Growth (4)

Log of the TFP, from OLS estimation of revenue-based translog production function

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
<th>(9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HHI × CLI</td>
<td>0.60***</td>
<td>1.12***</td>
<td>0.87***</td>
<td>1.41***</td>
<td>1.32***</td>
<td>1.49***</td>
<td>1.20***</td>
<td>1.83***</td>
<td>0.83***</td>
</tr>
<tr>
<td></td>
<td>(0.13)</td>
<td>(0.18)</td>
<td>(0.28)</td>
<td>(0.21)</td>
<td>(0.27)</td>
<td>(0.17)</td>
<td>(0.21)</td>
<td>(0.19)</td>
<td>(0.08)</td>
</tr>
</tbody>
</table>

|        |        |        |        |        |        |        |        |        |        |
| HHI    | -0.27** | -0.44*** | -0.44** | -0.75*** | -0.76*** | -0.91*** | -0.81*** | -0.80*** | -0.67*** |
|        | (0.09) | (0.13) | (0.15) | (0.09) | (0.14) | (0.09) | (0.11) | (0.09) | (0.09) |
| cons   | -0.01 | -0.01 | -0.00 | 0.00 | 0.00 | 0.01 | 0.01*** | 0.01** | 0.02*** |
|        | (0.00) | (0.01) | (0.01) | (0.01) | (0.01) | (0.00) | (0.01) | (0.01) | (0.01) |

Country year FE: Yes, Yes, Yes, Yes, Yes, Yes, Yes, Yes, Yes
Country sector FE: Yes, Yes, Yes, Yes, Yes, Yes, Yes, Yes, Yes
Obs: 2788, 2785, 2782, 2774, 2775, 2773, 2771, 2524, 2034

Standard errors in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01
HHI is the Herfindahl index, CLI is the competition law index. Column h is the response of dependent variable at t + h.

Table B.13: Growth (5)

Log of the TFP, OLS estimation of revenue-based translog production function with variable inputs

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
<th>(9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HHI × CLI</td>
<td>0.27***</td>
<td>0.75***</td>
<td>0.38</td>
<td>1.30</td>
<td>1.30***</td>
<td>1.27***</td>
<td>0.99***</td>
<td>0.78***</td>
<td>0.85***</td>
</tr>
<tr>
<td></td>
<td>(0.05)</td>
<td>(0.10)</td>
<td>(0.20)</td>
<td>(0.17)</td>
<td>(0.20)</td>
<td>(0.15)</td>
<td>(0.12)</td>
<td>(0.14)</td>
<td>(0.04)</td>
</tr>
</tbody>
</table>

|        |        |        |        |        |        |        |        |        |        |
| HHI    | -0.20*** | -0.40*** | -0.15* | -0.66*** | -0.66*** | -0.53*** | -0.39*** | -0.58*** |
|        | (0.03) | (0.07) | (0.08) | (0.11) | (0.13) | (0.09) | (0.08) | (0.09) | (0.07) |
| cons   | 0.00 | -0.01 | -0.01 | -0.01 | -0.01 | -0.01 | -0.01 | -0.01 | 0.00 |
|        | (0.00) | (0.01) | (0.01) | (0.01) | (0.01) | (0.00) | (0.00) | (0.00) | (0.01) |

Country year FE: Yes, Yes, Yes, Yes, Yes, Yes, Yes, Yes, Yes
Country sector FE: Yes, Yes, Yes, Yes, Yes, Yes, Yes, Yes, Yes
Obs: 2786, 2784, 2784, 2780, 2779, 2776, 2776, 2535, 2048

Standard errors in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01
HHI is the Herfindahl index, CLI is the competition law index. Column h is the response of dependent variable at t + h.

Table B.14: Growth (6)

Log of the TFP, Wooldridge estimation of revenue-based translog production function with variable inputs

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
<th>(9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HHI × CLI</td>
<td>0.33***</td>
<td>0.83***</td>
<td>0.39</td>
<td>1.30***</td>
<td>1.49***</td>
<td>1.57***</td>
<td>1.20***</td>
<td>1.30***</td>
<td>1.23***</td>
</tr>
<tr>
<td></td>
<td>(0.04)</td>
<td>(0.15)</td>
<td>(0.36)</td>
<td>(0.24)</td>
<td>(0.23)</td>
<td>(0.23)</td>
<td>(0.26)</td>
<td>(0.29)</td>
<td>(0.31)</td>
</tr>
</tbody>
</table>

|        |        |        |        |        |        |        |        |        |        |
| HHI    | -0.25*** | -0.49*** | -0.22 | -0.74*** | -0.83*** | -0.82*** | -0.67*** | -0.69*** | -0.75*** |
|        | (0.04) | (0.10) | (0.14) | (0.09) | (0.10) | (0.08) | (0.10) | (0.09) | (0.07) |
| cons   | 0.00 | -0.00 | -0.00 | -0.00 | -0.00 | -0.00 | -0.00 | -0.00 | 0.00 |
|        | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.01) |

Country year FE: Yes, Yes, Yes, Yes, Yes, Yes, Yes, Yes, Yes
Country sector FE: Yes, Yes, Yes, Yes, Yes, Yes, Yes, Yes, Yes
Obs: 2732, 2784, 2784, 2780, 2779, 2776, 2776, 2535, 2002

Standard errors in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01
HHI is the Herfindahl index, CLI is the competition law index. Column h is the response of dependent variable at t + h.
### Table B.15: Growth (7)

Log of the TFP, Wooldridge estimation of revenue-based translog production function

<table>
<thead>
<tr>
<th>HHI × CLI</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
<th>(9)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.93</td>
<td>1.23***</td>
<td>-0.16</td>
<td>0.87**</td>
<td>-0.17</td>
<td>0.54</td>
<td>1.29</td>
<td>1.35**</td>
<td>-0.02</td>
</tr>
<tr>
<td></td>
<td>(0.56)</td>
<td>(0.33)</td>
<td>(0.22)</td>
<td>(0.37)</td>
<td>(0.21)</td>
<td>(0.62)</td>
<td>(0.77)</td>
<td>(0.48)</td>
<td>(0.31)</td>
</tr>
</tbody>
</table>

**CLI**

<table>
<thead>
<tr>
<th>HHI</th>
<th>-0.34</th>
<th>0.08</th>
<th>0.51</th>
<th>-0.56***</th>
<th>-0.26***</th>
<th>-0.37</th>
<th>-0.93*</th>
<th>-0.90</th>
<th>-0.20</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(0.32)</td>
<td>(0.28)</td>
<td>(0.31)</td>
<td>(0.13)</td>
<td>(0.07)</td>
<td>(0.23)</td>
<td>(0.46)</td>
<td>(0.61)</td>
<td>(0.28)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>cons</th>
<th>-0.00</th>
<th>-0.03**</th>
<th>0.01</th>
<th>0.03***</th>
<th>0.03*</th>
<th>0.03</th>
<th>0.03</th>
<th>0.03</th>
<th>0.03</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.00)</td>
<td>(0.01)</td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.02)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Country year FE</th>
<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Country sector FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Obs</td>
<td>2399</td>
<td>2397</td>
<td>2392</td>
<td>2388</td>
<td>2382</td>
<td>2387</td>
<td>2383</td>
<td>2153</td>
<td>1732</td>
</tr>
</tbody>
</table>

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

HHI is the Herfindahl index, CLI is the competition law index. Column h is the response of dependent variable at \( t + h \).

### Table B.16: Growth (8)

Log of the TFP, OLS estimation of value-added based Cobb-Douglas production function

<table>
<thead>
<tr>
<th>HHI × CLI</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
<th>(9)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.24</td>
<td>0.39***</td>
<td>0.71**</td>
<td>1.22***</td>
<td>1.25**</td>
<td>1.82</td>
<td>2.55**</td>
<td>1.17****</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.11)</td>
<td>(0.25)</td>
<td>(0.28)</td>
<td>(0.29)</td>
<td>(0.33)</td>
<td>(0.31)</td>
<td>(0.30)</td>
<td>(0.33)</td>
<td>(0.26)</td>
</tr>
</tbody>
</table>

**CLI**

<table>
<thead>
<tr>
<th>HHI</th>
<th>-0.04</th>
<th>-0.35**</th>
<th>-0.20</th>
<th>-0.51***</th>
<th>-0.57***</th>
<th>-0.97***</th>
<th>-1.03***</th>
<th>-1.46***</th>
<th>-0.74***</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(0.08)</td>
<td>(0.12)</td>
<td>(0.19)</td>
<td>(0.13)</td>
<td>(0.17)</td>
<td>(0.17)</td>
<td>(0.15)</td>
<td>(0.17)</td>
<td>(0.15)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>cons</th>
<th>-0.00</th>
<th>-0.00</th>
<th>0.00</th>
<th>0.01</th>
<th>0.02</th>
<th>0.03***</th>
<th>0.03*</th>
<th>0.03**</th>
<th>0.04**</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Country year FE</th>
<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Country sector FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Obs</td>
<td>2819</td>
<td>2817</td>
<td>2817</td>
<td>2812</td>
<td>2812</td>
<td>2809</td>
<td>2810</td>
<td>2569</td>
<td>2081</td>
</tr>
</tbody>
</table>

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

HHI is the Herfindahl index, CLI is the competition law index. Column h is the response of dependent variable at \( t + h \).

### Table B.17: Growth (9)

Log of the TFP, Wooldridge estimation of value-added based Cobb-Douglas production function

<table>
<thead>
<tr>
<th>HHI × CLI</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
<th>(9)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.24</td>
<td>0.85***</td>
<td>0.69***</td>
<td>0.96***</td>
<td>1.15***</td>
<td>1.63***</td>
<td>1.64***</td>
<td>1.50***</td>
<td>2.46***</td>
</tr>
<tr>
<td></td>
<td>(0.30)</td>
<td>(0.24)</td>
<td>(0.21)</td>
<td>(0.28)</td>
<td>(0.27)</td>
<td>(0.34)</td>
<td>(0.37)</td>
<td>(0.37)</td>
<td>(0.16)</td>
</tr>
</tbody>
</table>

**CLI**

<table>
<thead>
<tr>
<th>hhi</th>
<th>-0.09</th>
<th>-0.47***</th>
<th>-0.40*</th>
<th>-0.46***</th>
<th>-0.62***</th>
<th>-1.05***</th>
<th>-1.08***</th>
<th>-1.63***</th>
<th>-0.83***</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(0.23)</td>
<td>(0.14)</td>
<td>(0.20)</td>
<td>(0.05)</td>
<td>(0.17)</td>
<td>(0.14)</td>
<td>(0.13)</td>
<td>(0.14)</td>
<td>(0.04)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>cons</th>
<th>-0.00</th>
<th>0.01**</th>
<th>0.02*</th>
<th>0.02</th>
<th>0.03***</th>
<th>0.04***</th>
<th>0.04***</th>
<th>0.04***</th>
<th>0.04***</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(0.01)</td>
<td>(0.00)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.00)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Country year FE</th>
<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Country sector FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Obs</td>
<td>2769</td>
<td>2767</td>
<td>2766</td>
<td>2759</td>
<td>2758</td>
<td>2755</td>
<td>2754</td>
<td>2513</td>
<td>2028</td>
</tr>
</tbody>
</table>

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

HHI is the Herfindahl index, CLI is the competition law index. Column h is the response of dependent variable at \( t + h \).
Table B.18: Entry - Orbis

<table>
<thead>
<tr>
<th></th>
<th>(0)</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CR × CLI</td>
<td>0.08***</td>
<td>0.06***</td>
<td>0.05***</td>
<td>0.06***</td>
<td>0.06***</td>
<td>0.0493***</td>
</tr>
<tr>
<td></td>
<td>(0.01)</td>
<td>(0.0071)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.0066)</td>
</tr>
</tbody>
</table>

CLI

|                |         |         |         |         |         |         |
| Cr             | -0.06*** | -0.04*** | -0.03*** | -0.03*** | -0.03*** | -0.03*** |
|                | (0.00)  | (0.00)  | (0.00)  | (0.00)  | (0.00)  | (0.00)  |

| cons           | 0.02*** | 0.02*** | 0.02*** | 0.02*** | 0.02*** | 0.02*** |
|                | (0.00)  | (0.00)  | (0.00)  | (0.00)  | (0.00)  | (0.00)  |

Country-year FE  | Yes  | Yes  | Yes  | Yes  | Yes  | Yes  |
Country-sector FE | Yes  | Yes  | Yes  | Yes  | Yes  | Yes  |
Obs              | 75464 | 75160 | 75132 | 75205 | 75267 | 75323 |

Standard errors in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01
HHI is the Herfindahl index, CLI is the competition law index.
Column h is the response of dependent variable at \( t + h \).

Table B.19: Entry - Orbis

<table>
<thead>
<tr>
<th></th>
<th>(0)</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HHI × CLI</td>
<td>0.07***</td>
<td>0.04***</td>
<td>0.03**</td>
<td>0.03**</td>
<td>0.02*</td>
<td>-0.01</td>
</tr>
<tr>
<td></td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
</tr>
</tbody>
</table>

CLI

|                |         |         |         |         |         |         |
| HHI            | -0.05*** | -0.03*** | -0.02**  | -0.02**  | -0.02** | 0.00  |
|                | (0.01)  | (0.01)  | (0.01)  | (0.01)  | (0.01)  | (0.01)  |

| cons           | 0.02*** | 0.02*** | 0.03*** | 0.03*** | 0.03*** | 0.03*** |
|                | (0.00)  | (0.00)  | (0.00)  | (0.00)  | (0.00)  | (0.00)  |

Country-year FE  | Yes  | Yes  | Yes  | Yes  | Yes  | Yes  |
Country-sector FE | Yes  | Yes  | Yes  | Yes  | Yes  | Yes  |
Obs              | 44207 | 44235 | 44233 | 44224 | 44183 | 44134 |

Standard errors in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01
HHI is the Herfindahl index, CLI is the competition law index.
Column h is the response of dependent variable at \( t + h \).
Growth rates calculated for: (1) Logarithm of the total factor productivity, derived from OLS estimation of revenue-based Cobb-Douglas production function with intangibles (2) Logarithm of the total factor productivity, derived from OLS estimation of revenue-based Cobb-Douglas production function (3) Logarithm of the total factor productivity, derived from Wooldridge estimation of revenue-based Cobb-Douglas production function (4) Logarithm of the total factor productivity, derived from OLS estimation of revenue-based Cobb-Douglas production function (5) Logarithm of the total factor productivity, derived from Wooldridge estimation of revenue-based Cobb-Douglas production function (6) Logarithm of the total factor productivity, derived from OLS estimation of revenue-based translog production function with variable inputs (7) Logarithm of the total factor productivity, derived from Wooldridge estimation of revenue-based translog production function with variable inputs (8) Logarithm of the total factor productivity, derived from OLS estimation of value-added based Cobb-Douglas production function (9) Logarithm of the total factor productivity, derived from Wooldridge estimation of value-added based Cobb-Douglas production function. All estimations are at the sectoral level.

Shaded areas are 90% confidence intervals.
Growth rates calculated for: (1) Logarithm of the total factor productivity, derived from OLS estimation of revenue-based Cobb-Douglas production function with intangibles (2) Logarithm of the total factor productivity, derived from OLS estimation of revenue-based Cobb-Douglas production function (3) Logarithm of the total factor productivity, derived from Wooldridge estimation of revenue-based Cobb-Douglas production function (4) Logarithm of the total factor productivity, derived from OLS estimation of revenue-based translog production function (5) Logarithm of the total factor productivity, derived from Wooldridge estimation of revenue-based translog production function with variable inputs (6) Logarithm of the total factor productivity, derived from Wooldridge estimation of revenue-based translog production function with variable inputs (7) Logarithm of the total factor productivity, derived from Wooldridge estimation of revenue-based translog production function (8) Logarithm of the total factor productivity, derived from OLS estimation of value-added based Cobb-Douglas production function (9) Logarithm of the total factor productivity, derived from Wooldridge estimation of value-added based Cobb-Douglas production function. All estimations are at the sectoral level.

Shaded areas are 90% confidence intervals.
Figure B.10: Enforcement Budget as a Share of GDP and Growth.

Growth rates calculated for: (1) Logarithm of the total factor productivity, derived from OLS estimation of revenue-based Cobb-Douglas production function with intangibles (2) Logarithm of the total factor productivity, derived from OLS estimation of revenue-based Cobb-Douglas production function (3) Logarithm of the total factor productivity, derived from Wooldridge estimation of revenue-based Cobb-Douglas production function (4) Logarithm of the total factor productivity, derived from OLS estimation of revenue-based translog production function (5) Logarithm of the total factor productivity, derived from OLS estimation of revenue-based translog production function with variable inputs (6) Logarithm of the total factor productivity, derived from Wooldridge estimation of revenue-based translog production function with variable inputs (7) Logarithm of the total factor productivity, derived from Wooldridge estimation of revenue-based translog production function (8) Logarithm of the total factor productivity, derived from OLS estimation of value-added based Cobb-Douglas production function (9) Logarithm of the total factor productivity, derived from Wooldridge estimation of value-added based Cobb-Douglas production function. All estimations are at the sectoral level.

Shaded areas are 90% confidence intervals.
B.3 Robustness Checks

This section discusses the robustness checks of chapter 2. Tables B.20, B.21 and B.22 show the results using the concentration ratio of top 4 firms from the US Census data. Results look similar when using concentration ratios based on top 8, 20, and 50 firms. Census data is provided every 5 years and includes information on both manufacturing and non-manufacturing sectors. I use the concentration ratios provided for 4-digit NAICS industries to match the entry rates and productivity rates provided by BDS and BLS databases. For R&D expenditure share the analysis is done at firm level. I trim the data at 5% for outliers, but the results are robust to trimming at 1% as well. Column 2 of tables B.20, B.21 and B.22 focuses on sectors with higher concentration levels (dropping the bottom 30% concentration ratios) such that the minimum level of CR4 is now 0.14 and the average value of CR4 increases from 0.27 to 0.35.

In the second robustness check I use an alternative measure to capture firms market power. This measure is based on firms’ profits and is from Compustat database. The relevant variable is oiadp or operating income after depreciation as in Covarrubias et al. (2020). I create profit ratio by dividing this variable by firms’ sale. To correct for outliers I drop all values of profit ratio that are above 1 or below -1. Next, I drop sectors in which less than 3 firms remain- this is to control for the sectors that had a high number of outliers or originally contained very few firms. I then find the median profit ratio for each sector at each year and drop the bottom/top 1%. I use that as the measure of market power. Results are similar when using a weighted average of profit ratio as well. For R&D expenditure ratio, since the analysis is done at the firm level, I drop values above 1 or below -1 and trim the data at 1%. Due to high number of outliers on oiadp variable, the sample size becomes 15-20% smaller compared to the main regressions of the chapter. For the sector level regressions standard errors are clustered at sector and year level and for the firm level regression the clustering is at firm and year level.

![Graphs](image.png)

(a) Productivity Growth  (b) Share of Entrants  (c) R&D Expenditure

Figure B.11: Dynamic responses - profit margin as the measure of market power
Shaded areas are 90% confidence intervals.

In another robustness check, I investigate implications of external competition coming from imports. For entry and R&D since data is available for the entire economy, I restrict
Table B.20: Growth Rate

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L.CR4 × L.budget</td>
<td>11529.47*</td>
<td>11964.36***</td>
</tr>
<tr>
<td></td>
<td>(4609.65)</td>
<td>(1531.32)</td>
</tr>
<tr>
<td>L.budget</td>
<td>-0.14*</td>
<td>-0.16***</td>
</tr>
<tr>
<td></td>
<td>(0.05)</td>
<td>(0.02)</td>
</tr>
<tr>
<td>cons</td>
<td>0.01**</td>
<td>0.02***</td>
</tr>
<tr>
<td></td>
<td>(0.00)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>Industry FE</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Year FE</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>N</td>
<td>276</td>
<td>220</td>
</tr>
</tbody>
</table>

Standard errors in parentheses
* p < 0.10, ** p < 0.05, *** p < 0.01
Column (1) is on all values of concentration.
Column (2) on high concentration industries: trimming bottom 30%.

Table B.21: Entry Rate

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L.CR4 × L.budget</td>
<td>4542.93*</td>
<td>9046.85**</td>
</tr>
<tr>
<td></td>
<td>(1768.60)</td>
<td>(1868.00)</td>
</tr>
<tr>
<td>L.CR4</td>
<td>-0.03</td>
<td>-0.08**</td>
</tr>
<tr>
<td></td>
<td>(0.02)</td>
<td>(0.02)</td>
</tr>
<tr>
<td>L.budget</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

cons 0.07***
(0.00)

Industry FE Yes Yes Year FE Yes Yes N 725 513

Standard errors in parentheses
* p < 0.10, ** p < 0.05, *** p < 0.01
Column (1) is on all values of concentration.
Column (2) on high concentration industries: trimming bottom 30%.

analysis to the non-tradable sector as this would eliminate the impact of foreign competition. As in Besley et al. (2020), tradable sectors that are excluded from the analysis are agriculture, mining and manufacturing. The outcome is presented in figure B.12b and
### Table B.22: R&D Expenditure

<table>
<thead>
<tr>
<th>R&amp;D Expenditure - Robustness Checks</th>
<th>(1)</th>
<th>(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L.CR4 × L.budget</td>
<td>-7171.14**</td>
<td>-7488.46*</td>
</tr>
<tr>
<td></td>
<td>(3402.44)</td>
<td>(4440.31)</td>
</tr>
<tr>
<td>L.budget</td>
<td>0.08**</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td>(0.04)</td>
<td>(0.05)</td>
</tr>
<tr>
<td>cons</td>
<td>0.09***</td>
<td>0.10***</td>
</tr>
<tr>
<td></td>
<td>(0.00)</td>
<td>(0.01)</td>
</tr>
<tr>
<td>Firm FE</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Year FE</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>N</td>
<td>5950</td>
<td>4175</td>
</tr>
</tbody>
</table>

Standard errors in parentheses
* \( p < 0.10 \),  ** \( p < 0.05 \),  *** \( p < 0.01 \)

Column (1) is on all values of concentration.
Column (2) on high concentration industries: trimming bottom 30%.

B.12c. For productivity growth since the data is only available for the manufacturing sector which is highly exposed to imports competition, I adjust the measure of concentration as follows. NBER-CES provides data on manufacturing sector and in particular variable vship capturing total value of shipment, provides information on total sales of each industry at 6-digit level. I aggregate this variable to 4-digit industry level to match the measure of productivity. Further, I get the value for total imports from Schott (2008) between 1989-2011. I use gen_val_yr variable capturing total value of imports and aggregate it to 4-digit industry level. The correction term is defined by \( \frac{\text{totalshipment}}{\text{totalshipment} + \text{imports}} \) similar to Covarrubias et al. (2020). The average value of import share in the manufacturing industry is 0.26 and the corrected value of concentration is 0.23 (correction term × concentration). I do a similar analysis using the census data and results remain robust.

![Figure B.12: Dynamic responses - adjusted for foreign competition](image)

Shaded areas are 90% confidence intervals.
Appendix C

Appendix to Chapter 3

C.1 Model Derivations and Proofs

This part of the appendix includes discussions on the full set of aggressive equilibria of the model described in chapter 3, the equilibrium used throughout the analysis and other derivations including the optimal investment choice of incumbents.

Describing the Full Set of Aggressive Equilibria

The model presented in chapter 3 has multiple equilibria with respect to deterrence strategies. In the next subsection I will discuss the equilibrium that is the focus of this chapter, and here I provide a description on the full set of equilibria.

First, define the firm’s incentive compatibility constraint (ICC) as:

\[ V_i|D=1 > V_i|D=0 \]

To observe a firm behaving aggressively, the firm’s ICC must be satisfied, which states that the value of firm \( i \) under deterrence strategies \( D = 1 \) should be higher than otherwise \( (D = 0) \). Call \( \Delta V_i \) the maximum amount firm \( i \) is willing to give up in an aggressive strategy to prevent entry. Then total amount of deterrent that a given sector has the ability to create is:

\[ K_{tot,max} = \frac{1}{N} \left( \sum_{i=1}^{N} \Delta V_i^{\alpha_d} \right)^{\frac{1}{\alpha_d}} \]

Recall from equation (3.15) that the amount of deterrent required to prevent entry is \( K_{tot} \). If

\[ K_{tot,max} > K_{tot} \]

The model has multiple equilibria as the total amount of deterrence firms have the ability and the incentive to create exceeds the amount that is required. Below I describe the set of equilibria in this model and later I will focus on only a subset of this set.
As it will be discussed the minmax strategy is when no firm engages in deterrence activities, as long as no single firm alone has the ability to create sufficient amount of barriers to keep entrants out. Therefore, I will breakdown the description into two cases:

**Case 1**: No single firm alone has the ability and resources to create sufficient entry deterrence:

Formally, the above statement requires that \( \zeta_{i,max} > 1 \) for all \( i \), where \( \zeta_{i,max} \) can be solved for from:

\[
K_{tot} = \frac{1}{N} (\zeta_{i,max} \Delta V_i)
\]

where \( K_{tot} \) is defined as (3.15) and can be found using backward induction as discussed in the model section of the chapter.

Given \( \zeta_{i,max} > 1 \) for all \( i \), the set of equilibria is any \( \zeta = (\zeta_1, \zeta_2, ..., \zeta_N) \) such that \( \zeta_i \leq 1 \), \( \forall i \) such that:

\[
K_{tot} = \frac{1}{N} \left( \sum_{i=1}^{N} (\zeta_i \Delta V_i)^{\alpha_d} \right)^{\frac{1}{\alpha d}}
\]

**Case 2**: There is at least one firm that has the ability and resources to create sufficient entry deterrence all by itself. Formally, this requires \( \zeta_{i,max} \leq 1 \) for some \( i \). The set of equilibria then will be \( \zeta = (\zeta_1, \zeta_2, ..., \zeta_N) \) such that \( \zeta_i = \zeta_{i,max} \) for the firm with \( \zeta_{i,max} \leq 1 \) and \( \zeta_{-i} = 0 \).

The full set of equilibria will be the combination of those described under case 1 and case 2. To avoid computational complications due to the multiplicity of equilibria in this chapter I will only consider the equilibrium that are defined under case 1 and take the form described below.

Define \( a_i \) such that \( \Delta V_i = a_i \pi \). Substitute for \( \Delta V_i \) in the above equation to get:

\[
\sum_{i=1}^{N} \zeta_i a_i \pi = K_{tot}
\]

Define \( o_i \) \( \forall i \):

\[
\begin{cases} 
fr_{gent}, & \text{if } \zeta a_i \geq fr_{gent} \\
0, & \text{otherwise}
\end{cases}
\]

Chapter 3 focuses on equilibrium structures that have the above structure.

**Equilibrium Concept for Deterrence Strategies:**

In this section I show that aggressive strategies in response to certain entry signals are Nash and can be achieved under the game described in the model section. I also discuss that these strategies create higher values for the firm compared to the alternative of not
acting aggressively.

As discussed in the previous section of the appendix, the model has multiple equilibria. I restrict the analysis to cases in which incumbents sacrifice a fraction $fr$ of their profits to create deterrents. I will show this strategy by $D1$. The alternative strategy is when firms do not create deterrents and this strategy is denoted by $D0$.

This game has 2 pure Nash equilibria. First, take firm $i$ and suppose $-i$ are playing $D0$. The definition of SPE implies that a strategy profile $s^* = (s_1^*, s_2^*, ..., s_N^*)$ is a SPE for all $i$ and all histories $h$

$$V(\phi_{ij}, \mu_j, \mu_{agg}|s^*, h) > V(\phi_{ij}, \mu_j', \mu_{agg}|s_i, s_{-i}^*, h) \quad \forall s_i$$

Therefore if $s_{-i}^* = D0$, then the best response of $i$ is to play $D0$ as well. Deviating from it leads to a sacrifice of profits $fr\pi_i^*$ without any gain. Therefore playing $D0$ at every stage will be equilibrium. In fact playing $D0$ will be the minmax profile. The minmax is dependent on no single firm being able to unilaterally block the entry of firms. This assumption is checked in equilibrium.

The second equilibrium of the model is playing $D1$ in response to certain entry signals and $D0$ to others. Now let $s_{-i}^* = D1$. Then playing $D1$ delivers a higher payoff according to the incentive compatibility constraint (3.13):

$$\pi_{aggressive}(\phi_{ij}, \mu_j, \mu_{agg}) + \beta E[V(\phi_{ij}, \mu_j', \mu_{agg})] \geq \pi_{static}(\phi_{ij}, \mu_j, \mu_{agg}) + \beta E[V(\phi_{ij}, \mu_j'', \mu_{agg})]$$

Deviating from $D1$ to $D0$ lowers the value of the firm and therefore is not a profitable deviation. As a result $D1$ in response to certain entry signals is also Nash.

SPE can be written as:

- $s_1^*$ plays $D1$ in response to entry signals $\phi^a \in \{\phi_{ent}, \phi_{ent, agr}\}$ and $D0$ in response to other signals as long as there been no deviations from this strategy in the past.
- $s_i^*$ plays $D0$ otherwise.

Where $\phi_{ent}$ is the productivity cutoff for entry, below which entrants will not find it optimal to enter and $\phi_{ent, agr}$ is the productivity cutoff for entry above which incumbents find it too costly to take action to deter potential entrants from joining the market. Finally, denote $v_i$ the minmax payoff of firm $i$. Folk theorem states that in any repeated game any vector of payoff with $u_i \geq v_i$ can be achieved as the average payoff of some SPE if the discount factor is sufficiently large. Since the payoff of playing $D1$ in response to entry signals specified above delivers a higher value than playing $D0$, this means these strategies can be sustained as an equilibrium of the model. Throughout the chapter, the states describing the history of aggressive strategies have been dropped in the interest of space, and the analysis is done along the equilibrium path.
Mapping of Various Aggressive Strategies to the Model Setup

In this section I will discuss how different forms of anticompetitive behaviour can be mapped into the model setup. In particular I will focus on aggressive (predatory) pricing and mergers and killer acquisitions.

1) Aggressive (predatory) pricing:

I show that there exists $\alpha_d$ such that aggressive pricing strategies can map into the framework presented in the theory section. First knowing the signal for entry, the necessary sectoral price to deter entry can be calculated using the free entry condition of potential entrants. I will show this sectoral price by $P_{\text{pred}}$:

$$E[V_{\text{ent}}] > S$$

$$E[\pi_{\text{ent}}] + \beta E[\pi_{\text{ent}}] > S$$

Where $CV_{\text{ent}}$ shows the continuation value of entrant. I assume that potential entrants, knowing incumbents will price aggressively, give their best response to the aggressive sectoral price. For a given firm $i$ predatory price $p_{\text{ent},t,\text{pred}}$ is the best response of entrant to the aggressive sectoral price and is according to:

$$p_{\text{ent}} = \frac{\epsilon}{\epsilon - 1}$$

Which indicates that entrant would act as a price taker, knowing it cannot affect the sectoral price.

Now using the entry condition and making use of the pricing strategy:

$$p_{\text{ent}}q_{\text{ent}} - w(f + q_{\text{ent}}\lambda_{\text{ent}}) + \beta E[CV] = S$$

$$E[q_{\text{ent}}(p_{\text{ent}} - \lambda_{\text{ent}})] = S - \beta E[CV] + wf$$

Substituting the pricing strategy as above gives:

$$E[q_{\text{ent}} \frac{1}{\epsilon - 1} w\lambda_{\text{ent}}] = S - \beta E[CV] + wf$$

Where $q_{\text{ent}}$ satisfies (3.4). Using this equation we have:

$$\left(\frac{p_{\text{ent}}}{P_{\text{Pred}}}\right)^{-\epsilon} \frac{I_t}{N_t P_{\text{Pred}}} \frac{1}{\epsilon - 1} w\lambda_{\text{ent}} = S - \beta E[CV] + wf$$

Isolating $P_{\text{pred}}$ on one side gives:

$$P_{\text{pred}}^{\epsilon - 1} = \frac{N_t}{I_t} \frac{1}{w\lambda_{\text{ent}}} (\frac{\epsilon}{\epsilon - 1}) w\lambda_{\text{ent}} (S - \beta E[CV] + wf)$$
This equation shows that when sunk costs and fixed costs of entry are high, less predatory behaviour is needed to keep potential entrants out. In other words, even higher sectoral prices can keep entrants out. Knowing the predatory sectoral price, the next step is to pin down pricing strategy of incumbent firms. Since the focus of this chapter is on equilibria that the aggressive strategy leads to giving up a fraction of profits, the incumbents strategy can be figured out by having:

\[ p_{i,t} - w(f + q_{i,t}\lambda_i) = (1 - fr_{pred})\pi_i^* \]

Where \( q_{i,t} \) satisfies (3.4) and \( \pi_i^* \) is the profit relating to (3.9). \( fr_{pred} \) is the fraction of profits firms will sacrifice and needs to be solved. From equation above

\[ q_{i,t}(p_{i,t} - w\lambda_i) = (1 - fr_{pred})\pi_i^* +wf \]

Call \( p_{i,t} - w\lambda_i = \mu_{pred,i,t}w\lambda_i \) where \( \mu_{pred,t} \) is the markup and might be below one in cases of below marginal cost predatory pricing.

\[ ((1 + \mu_{pred,i,t})w\lambda_i)^{-\epsilon}P_{pred}^{x-1}\mu_{pred,i,t}w\lambda_i = \frac{N_t}{I_t}[(1 - fr_{pred})\pi_i^* +wf] \]

\[ (1 + \mu_{pred,i,t})^{-\epsilon}\mu_{pred,i,t} = \frac{N_t}{I_t}[(1 - fr_{pred})\pi_i^* +wf]P_{pred}^{1-\epsilon}(w\lambda_i)^{\epsilon-1} \]

This relation holds for all incumbents and provides N equations. The unknown variables are \( \mu_{pred,i,t} \) for all \( i \) (therefore N unknowns) and \( fr_{pred} \). Therefore one extra equation is needed. This extra equation is the definition for aggregate sectoral price as (3.3). Together, these equations would allow to solve for all \( \mu_{pred,i,t} \) and \( fr_{pred} \) at time \( t \).

Now to see how the case of predatory pricing maps to the setup of this chapter, find \( K_{tot} \) required to deter entry from the entry condition of firms.

\[ EV_{ent} = S + K_{tot} \]

Then using (3.16) and (3.15) \( K_i = fr_{pred}\pi^*_i \) can be calculated. Using \( K_{tot} \) calculated above, there exists some \( \alpha_d \) such that:

\[ K_{tot} = \frac{1}{N} \left( \sum_{i=1}^{N} (fr_{pred}\pi^*_i)^{\alpha_d} \right)^{\frac{1}{\alpha_d}} \]

Thus mapping aggressive pricing into the setup of this chapter.

2) Mergers and killer acquisitions

The model with its current interpretation is not easily applicable to the case of mergers and acquisitions since in the model aggressive strategies affect some aggregate variable
in the sector and mergers are directed at specific firms. Therefore, to do so, I suggest an alternative way of interpreting variables. I show that acquisitions require a weaker condition compared to the aggressive strategy presented in the model section. Therefore, the aggressive strategies of incumbents can include mergers and killer acquisitions as these strategies require a higher sacrifice of profits.

To map the setup of the model to the case of mergers and acquisitions, I assume that firms previously denoted as potential entrants have entered however they are small such that \( s_i \rightarrow 0 \). I also assume there is uncertainty about their productivity but their expectation over their productivity is \( \phi^q \) which previously was modelled as the signal for entry. To expand such that \( s_i >> 0 \) they have to pay a one-time expansion cost of \( S \). At this stage they might get acquired by incumbents with a high market power. The participation constraint of the firms getting acquired implies:

\[
EV - S \leq Val_{acq}
\]

Where \( EV \) denotes the expected value of entrants after their expansion and \( Val_{acq} \) is the acquisition offer.

Comparing this with (3.18) it is clear that for acquisition to takes place \( Val_{acq} = K_{tot} \). However, previously \( K_{tot} \) was an aggregate object affecting the entire sector while now it is equal to the amount necessary to acquire a given firm. Recall that all entrants (or here all small firms) have the same signal. Therefore, the total amount necessary to acquire all small firms is equal to \( MV\alpha_{acq} \) or equally \( MK_{tot} \). I show that total amount of profit sacrifices under the main setup of the model is higher that \( MK_{tot} \), therefore, mergers and acquisitions are included under that setup.

Total amount required to acquire all firms:

\[
Req = MK_{tot} = \frac{M}{N} \left( \sum_{i=1}^{N} (fr\pi_i^*)^{\alpha_d} \right)^{\frac{1}{\alpha_d}} \leq \left( \sum_{i=1}^{N} (fr\pi_i^*)^{\alpha_d} \right)^{\frac{1}{\alpha_d}}
\]

Where the inequality holds as long as \( M \leq N \).

Total amount of profit sacrifices according to the model is:

\[
Sacr = fr \sum_{i=1}^{N} (\pi_i^*)
\]

To show that acquisitions are less costly it is necessary to show \( Req \leq Sacr \).

Define \( a_i = fr\pi_i^* \) and note that \( a_i \geq 0 \) for all \( i \). We need to show

\[
\sum_{i=1}^{N} a_i^{\alpha_d} \leq \left( \sum_{i=1}^{N} a_i \right)^{\alpha_d}
\]

Let \( \bar{a} = \sum_{i=1}^{N} a_i \). Assume at least one \( a_i > 0 \) then \( \bar{a} > 0 \). This is not a strong assumption
as it is requiring at least one firm to be making profit sacrifices. This holds in the main setup if firms are to succeed in deterring entry.

∀i let \( a_{rel,i} = \frac{a_i}{\bar{a}} \). Thus we have \( 0 \leq a_{rel,i} \leq 1 \). So:

\[
(a_{rel,i})^{\alpha_d} \leq a_{rel,i}
\]

\[
\sum_{i=1}^{N} (a_{rel,i})^{\alpha_d} \leq \sum_{i=1}^{N} a_{rel,i}
\]

Also note that, \( \sum_{i=1}^{N} a_{rel,i} = \sum_{i=1}^{N} \frac{a_i}{\bar{a}} = 1 \).

Then:

\[
\sum_{i=1}^{N} a_i^{\alpha_d} = \bar{a}^{\alpha_d} \sum_{i=1}^{N} a_{rel,i}^{\alpha_d} \leq \bar{a}^{\alpha_d} \sum_{i=1}^{N} a_{rel,i} = \bar{a}^{\alpha_d}
\]

Using the definition of \( \bar{a} \) we have:

\[
\sum_{i=1}^{N} a_i^{\alpha_d} \leq (\sum_{i=1}^{N} a_i)^{\alpha_d}
\]

Which is the required condition and holds as long as \( \alpha_d > 1 \).

While here it is possible to provide an interpretation of mergers and acquisitions and show that in general it is less costly than the alternatives, the analysis depend on the assumption that prior to getting acquired one firm was much smaller. This may not be the case in many sectors and therefore more costly strategies will be required. The model presented here is not able to directly analyse those cases. However we can think those cases are implicit in the model as the general setup required more costly action compared to the case analysed above.

**Result**: Sales share of a given firm \( i \) increases when the number of firms falls from \( K \) to \( K - 1 \) as long as\(^1\):

\[
\hat{s}_{i,K} + \hat{s}_{i,K-1} < \frac{\epsilon}{\epsilon - 1}
\]

Where \( \hat{s}_i \) is sales share of firm \( i \) under monopolistic competition.

**Proof**:

The setup of this model does not admit an analytical solution. To be able to analyse changes in sales share of firms with number of incumbents in each sector, I use an approximation derived in Grassi (2017). Grassi (2017) approximates sales share of firms in an oligopolistic setup with sales share of firms under monopolistic competition \( \hat{s}_i \). I will drop the firm subscript \( i \) from this point on. The subscript \( K \) shows the number of incumbents.

\(^1\)This is a sufficient (but not necessary) condition
\[ s_K - s_{K-1} \approx \hat{s}_K - (1 - \frac{1}{\epsilon})\hat{s}_K^2 - \hat{s}_{K-1} + (1 - \frac{1}{\epsilon})\hat{s}_{K-1}^2 \]
\[ = \hat{s}_K - \hat{s}_{K-1} - (1 - \frac{1}{\epsilon})(\hat{s}_K - \hat{s}_{K-1}) \]
\[ = (\hat{s}_K - \hat{s}_{K-1})(1 - (1 - \frac{1}{\epsilon})(\hat{s}_K + \hat{s}_{K-1})) \]

I will consider 2 cases now: When the \( K \)th firm has a higher productivity level compared to the average productivity level of firms in the market and second, when its productivity level was below the average.

First, consider the case with the \( K \)th firm has a productivity level above the average. This means:
\[ P_K > P_{K-1} \]
Where \( P_K \) shows the aggregate price under monopolistic competition with \( K \) incumbents. Therefore, in the relation derived above:
\[ (\hat{s}_K - \hat{s}_{K-1}) = \left( \frac{\epsilon}{\epsilon - 1} \right)^{1-\epsilon} \frac{1}{P_K} - \left( \frac{\epsilon}{\epsilon - 1} \right)^{1-\epsilon} \frac{1}{P_{K-1}} \]
\[ = \left( \frac{\epsilon}{\epsilon - 1} \lambda_i \right)^{1-\epsilon} \left( \frac{P_{K-1}^{\epsilon-1}}{K} - \frac{P_{K-1}^{\epsilon-1}}{K-1} \right) < 0 \]

For the second term we have:
\[ (1 - (1 - \frac{1}{\epsilon})(\hat{s}_K + \hat{s}_{K-1})) > 0 \]
\[ 1 > \frac{\epsilon - 1}{\epsilon} (\hat{s}_K + \hat{s}_{K-1}) \]
\[ \frac{\epsilon}{\epsilon - 1} > (\hat{s}_K + \hat{s}_{K-1}) \]

Therefore, given \((\hat{s}_K + \hat{s}_{K-1}) < \frac{\epsilon}{\epsilon - 1}\), \( s_K < s_{K-1} \) for all firms.

Now suppose moving from \( K \) to \( K - 1 \), the \( K \)th firm has a lower productivity level such that:
\[ P_K > P_{K-1} \]
Then:
\[ (\hat{s}_K - \hat{s}_{K-1}) = \left( \frac{\epsilon}{\epsilon - 1} \right)^{1-\epsilon} \frac{1}{P_{K-1}} - \left( \frac{\epsilon}{\epsilon - 1} \right)^{1-\epsilon} \frac{1}{P_{K-1}} \]
\[ = \left( \frac{\epsilon}{\epsilon - 1} \lambda_i \right)^{1-\epsilon} \left( \frac{P_{K-1}^{\epsilon-1}}{K} - \frac{P_{K-1}^{\epsilon-1}}{K-1} \right) \]

Here, we cannot directly conclude that \( \frac{P_{K-1}^{\epsilon-1}}{K} < \frac{P_{K-1}^{\epsilon-1}}{K-1} \). If this is the case, then we will have similar results to the case where \( P_K < P_{K-1} \).

To show \( \frac{P_{K-1}^{\epsilon-1}}{K} < \frac{P_{K-1}^{\epsilon-1}}{K-1} \), I use contradiction. Thus suppose \( \frac{P_{K-1}^{\epsilon-1}}{K} > \frac{P_{K-1}^{\epsilon-1}}{K-1} \). Then:
\[ \hat{s}_K - \hat{s}_{K-1} > 0 \]

\(^2\text{This is not a strong requirement as under the monopolistic competition and for the approximation to remain valid } \hat{s} \to 0 \)
Also from before, as long as \((\hat{s}_K + \hat{s}_{K-1}) < \frac{\epsilon}{\epsilon - 1}\) the second term is positive. These two facts combined give:

\[ s_K - s_{K-1} > 0 \]

This holds for all firms (as none of the derivations were dependent on the productivity of each individual firm). Therefore, sales share of all firms drop when there are \(K - 1\) firms in the market. Since \(s_K \geq 0\) for all firms and \(\sum_K s_i = 1\) we have arrived at a contradiction and it must be that \(\frac{P_K^{K-1}}{K} < \frac{P_{K-1}^{K-1}}{K-1}\). Therefore:

\[ s_K < s_{K-1} \]

Next step is to show that profits of incumbents is increasing in sales share. Denote profits of high concentration, \(K - 1\) number of firms with \(\pi'\) and profits of high number of firms, low concentration with \(\pi\). The goal is to show that:

\[ \Delta \pi = \pi' - \pi > 0 \]

Then:

\[
\pi'_i - \pi_i = p_i' q_i - w(f + q_i' \lambda_i) - [p_i q_i - w(f + q_i \lambda_i)]
\]

\[
= q_i' \frac{1}{(\epsilon - 1)(1 - s')} - q_i (\epsilon - 1)(1 - s)
\]

\[
= \frac{I w \lambda_i}{\epsilon - 1} \frac{p_i^{\epsilon - 1} P^{\epsilon - 1}}{(1 - s')N'} - \frac{p_i^{\epsilon - 1} P^{\epsilon - 1}}{(1 - s)N}
\]

To show profits increase, the term in brackets should be positive. Use the definition for sales share to substitute in the above equation:

\[ s_i = \frac{1}{N}(p_i \bar{P})^{1-\epsilon} \]

This gives:

\[
\pi'_i - \pi_i = \frac{I w \lambda_i}{\epsilon - 1} \frac{s'}{(1 - s')p_i'} - \frac{s}{(1 - s)p_i}
\]

\[
= \frac{I w \lambda_i}{\epsilon - 1} \frac{s'}{(1 - s') (\epsilon - 1)} (\epsilon - 1) - \frac{s}{(1 - s) (\epsilon - 1)} (\epsilon - 1)
\]

\[
= I \frac{s'}{\epsilon - 1} \frac{w \lambda_i}{\epsilon - 1} \left[ \frac{s'}{\epsilon(1 - s') + s'} - \frac{s}{\epsilon(1 - s) + s} \right]
\]

Which uses \(p_i = \frac{\epsilon(1-s)+s}{(1-s)(\epsilon-1)} w \lambda_i\). I need to show that the term in brackets is positive. Note that the nominator \(s' > s\) and the denominator \(\epsilon(1 - s') + s' < \epsilon(1 - s) + s\). Therefore
the term in brackets is positive and we have shown that

$$\pi'_i - \pi_i > 0 \ \forall i$$

Therefore profit of all incumbent firms increases. So,

$$N'\frac{N}{\alpha d} \left( \sum_{i=1}^{N'} (fr\pi_i')^{\alpha d} \right) \frac{1}{\alpha d} \geq N\frac{N}{\alpha d} \left( \sum_{i=1}^{N} (fr\pi_i)^{\alpha d} \right) \frac{1}{\alpha d}$$

**Result 2:** The change in sales share of a given firm \(i\) when the number of firms falls from \(K\) to \(K - 1\) is increasing in the productivity of the firm iff:

$$\frac{d(s_{i,K-1} - s_{i,K})}{d\phi_i} > 0 \iff \hat{s}_{i,K} + \hat{s}_{i,K-1} < \frac{1}{2} \frac{\epsilon}{\epsilon - 1}$$

Where similar to before \(\hat{s}_i\) is sales share of firm \(i\) under monopolistic competition.

**Derivation:**

Note \(\frac{d(s_{i,K-1} - s_{i,K})}{d\phi_i} > 0\) is equivalent to showing \(\frac{d(s_{i,K-1} - s_{i,K})}{d\phi_i} < 0\). Using the approximation by Grassi (2018) and dropping the firm subscript \(i\):

$$\frac{d(s_{K-1} - s_K)}{d\lambda} = \frac{d\hat{s}_{K-1}}{d\lambda} - \frac{d\hat{s}_K}{d\lambda} - 2(1 - \frac{1}{\epsilon}) \left[ \frac{d\hat{s}_{K-1}}{d\lambda} \hat{s}_{K-1} - \frac{d\hat{s}_K}{d\lambda} \hat{s}_K \right]$$

Where:

$$\frac{d\hat{s}_{K-1}}{d\lambda} - \frac{d\hat{s}_K}{d\lambda} = \left( \frac{\epsilon}{\epsilon - 1} \right)^{1-\epsilon} (1 - \epsilon) \lambda^{-\epsilon} \left( \frac{P_{K-1}^{-1}}{K - 1} - \frac{P_K^{-1}}{K} \right)$$

and,

$$\frac{d\hat{s}_{K-1}}{d\lambda} \hat{s}_{K-1} - \frac{d\hat{s}_K}{d\lambda} \hat{s}_K =$$

$$\left( \frac{\epsilon}{\epsilon - 1} \frac{\lambda}{P_{K-1}} \right)^{1-\epsilon} \frac{1}{K - 1} \left( \frac{\epsilon}{\epsilon - 1} \right)^{1-\epsilon} (1 - \epsilon) \lambda^{-\epsilon} \frac{P_{K-1}^{-1}}{K - 1} - \left( \frac{\epsilon}{\epsilon - 1} \frac{\lambda}{P_K} \right)^{1-\epsilon} \frac{1}{K - 1} \left( \frac{\epsilon}{\epsilon - 1} \right)^{1-\epsilon} (1 - \epsilon) \lambda^{-\epsilon} \frac{P_K^{-1}}{K} =$$

$$\left( \frac{\epsilon}{\epsilon - 1} \frac{\lambda}{P_{K-1}} \right)^{1-\epsilon} \frac{1}{K - 1} \left( \frac{\epsilon}{\epsilon - 1} \right)^{1-\epsilon} (1 - \epsilon) \lambda^{-\epsilon} \left( \frac{P_{K-1}^{2(\epsilon-1)}}{(K - 1)^2} - \frac{P_K^{2(\epsilon-1)}}{K^2} \right)$$

Combine the two:

$$\frac{d(s_{K-1} - s_K)}{d\lambda} = \frac{d\hat{s}_{K-1}}{d\lambda} - \frac{d\hat{s}_K}{d\lambda} - 2(1 - \frac{1}{\epsilon}) \left[ \frac{d\hat{s}_{K-1}}{d\lambda} \hat{s}_{K-1} - \frac{d\hat{s}_K}{d\lambda} \hat{s}_K \right] =$$

$$\left( \frac{\epsilon}{\epsilon - 1} \right)^{1-\epsilon} (1 - \epsilon) \lambda^{-\epsilon} \left( \frac{P_{K-1}^{-1}}{K - 1} - \frac{P_K^{-1}}{K} \right) - 2(1 - \frac{1}{\epsilon}) \left( \frac{\epsilon}{\epsilon - 1} \lambda \right)^{1-\epsilon} \left( \frac{P_{K-1}^{-1}}{K - 1} - \frac{P_K^{-1}}{K} \right) =$$

$$\left( \frac{\epsilon}{\epsilon - 1} \right)^{1-\epsilon} (1 - \epsilon) \lambda^{-\epsilon} \left( \frac{P_{K-1}^{-1}}{K - 1} - \frac{P_K^{-1}}{K} \right) \left[ 1 - 2(1 - \frac{1}{\epsilon}) \left( \frac{\epsilon}{\epsilon - 1} \lambda \right)^{1-\epsilon} \left( \frac{P_{K-1}^{-1}}{K - 1} + \frac{P_K^{-1}}{K} \right) \right] =$$
\[
\left(\frac{\epsilon}{\epsilon - 1}\right)^{1-\epsilon} (1 - \epsilon) \lambda^{-\epsilon} \left(\frac{P_{K-1}^{K-1}}{K - 1} - \frac{P_{K}^{K-1}}{K}\right)[1 - 2(1 - \frac{1}{\epsilon})(\hat{s}_{K-1} + \hat{s}_K)]
\]

It was shown in the previous result that \(\frac{P_{K-1}^{K-1}}{K - 1} - \frac{P_{K}^{K-1}}{K} > 0\), and \(1 - \epsilon < 0\) for \(\epsilon > 1\) therefore the expression is negative (decreasing in marginal cost) as long as:

\[
1 - 2(1 - \frac{1}{\epsilon})(\hat{s}_{K-1} + \hat{s}_K) > 0
\]

\[
\hat{s}_{K-1} + \hat{s}_K < \frac{1}{2\epsilon - 1}
\]

**Investment Rule**

This part provides the derivation for the optimal investment rule as discussed in chapter 3. Consider the value of firm with productivity \(i\) at sector \(j\) and entry signal \(\phi^q\). Then call the expected value of the firm conditional on the entry signal and successful innovation \(CV_1\). In the case that innovation is unsuccessful we call the continuation value \(CV_0\). The problem of the firm can be written as:

\[
V(\phi_i, \mu_j, \mu_{agg}) = (1 - fr \times D) \pi \ast (\phi_i, \mu_j, \mu_{agg}) - \frac{wb \times x^2}{2} + \beta \max \{0, \left[1 - e^{-x} \ e^{-x}\right] \times \left[CV_1 \ CV_0\right] \}
\]

If the final expression is equal to zero then \(x = 0\), otherwise differentiate with respect to \(x\):

\[
\frac{\partial V}{\partial x} = -wbx + \beta e^{-x} CV_1 + \beta \ast (1 - e^{-x}) \frac{\partial CV_1}{\partial x} - \beta e^{-x} CV_0 + \beta \ast e^{-x} \frac{\partial CV_0}{\partial x}
\]

where:

\[
\frac{\partial CV}{\partial x} \ast \beta \ast (1 - e^{-x_{co}}) \frac{\partial V}{\partial x} = 0
\]

Substituting this result in the First Order Condition gives:

\[-wb\ + \beta e^{-x} CV_1 - \beta e^{-x} CV_0 = 0\]

Call \(\Delta V = CV_1 - CV_0\),

\[
\frac{\beta \Delta V}{wb} = xe^x
\]

This gives the investment rule:

\[
x = W\left(\frac{\beta \Delta V}{wb}\right)
\]

Where \(W(.)\) is the Lambert W function.
C.2 Calibration and Numerical Method

Here, I describe the numerical algorithm used to solve the model. I make an initial guess for $N, M$, the steady state sectoral distribution and wage. I discretise the (idiosyncratic) productivity state to $K$ different values. I then solve for the Bellman equation described in the model section using value function iteration. At this stage, and given the distribution, the labour demand by firms can be calculated. Given the labour supply (normalised to 1) I solve for the wage and iterate until convergence. This gives the policy functions for the firm, including the deterring strategy and investment in innovation. These policy functions combined with the entry distribution can be used to write the transition matrix. I then find the steady state vector associated with the transition matrix. I endogenise $N$ the number of firms such that the value of incumbent firms distributed at the steady state level (approximately) equals $S$ the sunk cost of entry. The value will be approximate as $N$ is an integer and therefore I choose the value such that increasing the number of incumbents to $N + 1$ drives the mean value below $S$. I endogenise $M$ the number of entrants such that given signal $\phi^q$, and the distribution of entrants $H$ the free entry condition is satisfied. I iterate over these values until convergence (fixed point argument).

It should be noted as this is a dynamic oligopolistic competition, firms at every time period give the best response to their competitors strategies. This means when solving the value functions, the decision of firm cannot be considered in isolation from the other firms in the same sector (the sectoral state). Therefore, at each stage, I solve the problem of $N$ firms ($K$ different types) together, and check that the incentive compatibility condition as in (3.13) and the ability condition (3.18) are consistent with decisions of firms.

Distribution of entrants and signals for entry is assumed to be a truncated Pareto distribution with probability density function:

$$G_e L^{G_e} \phi^{-G_e}$$

$L$ denotes the lower bound and $H$ is the upper bound. In the case of entrant’s distribution these values are determined by the bounds of the productivity space. In the case of the signal for entry (determining the relative position of entrants with respect to incumbents) the lower bound is 1 (= $\gamma^0$) stating that entrants attach a positive probability in being able to copy the technology of the existing firms. The upper bound is chosen to be $\gamma^3$ meaning for the highest entry signal, entrants will attach a positive probability in being $\gamma^3$ times more productive than the current market leader. I estimate the model choosing $H$ to be $\gamma^2$ and $\gamma^4$. Estimations for productivity growth, welfare and other targeted moments are robust, but the current choice provides a better fit for untargeted moments. Any value above $\gamma^4$ becomes computationally costly.

Finally, I calculate productivity growth as the weighted average of growth of incumbents through innovation, increase in productivity through entry of more productive firms, and exit of less productive firms. The weights are the sales share of each group.
Welfare

The part provides more details on the welfare analysis of chapter 3. Figure C.1 shows the response of consumption in a long horizon to changes in antitrust. Table C.1 decomposes welfare of capitalists into capital- and profit-owners. Finally table C.2 provides a conservative estimate of the impact of antitrust on inequality, by assuming those dependent on wage income are 14% of US population. This is the upper bound presented in Lee (2019).

![Welfare response to ruling out all anticompetitive practices](image)

**Figure C.1: Welfare response to ruling out all anticompetitive practices**

**Table C.1: Breakdown of welfare of capitalists into capital owner and profit owner**

<table>
<thead>
<tr>
<th></th>
<th>Welfare</th>
<th>Consumption (immediate)</th>
<th>Consumption (after 50 years)</th>
<th>Break even year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Panel A</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capitalist</td>
<td>0.00</td>
<td>-0.27</td>
<td>0.07</td>
<td>41</td>
</tr>
<tr>
<td>Capital owner</td>
<td>0.28</td>
<td>-0.06</td>
<td>0.37</td>
<td>10</td>
</tr>
<tr>
<td>Profit owner</td>
<td>-0.57</td>
<td>-0.69</td>
<td>-0.54</td>
<td>149</td>
</tr>
<tr>
<td><strong>Panel B</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capitalist</td>
<td>-0.03</td>
<td>-0.20</td>
<td>0.02</td>
<td>46</td>
</tr>
<tr>
<td>Capital owner</td>
<td>0.12</td>
<td>-0.06</td>
<td>0.19</td>
<td>16</td>
</tr>
<tr>
<td>Profit owner</td>
<td>-0.35</td>
<td>-0.47</td>
<td>-0.31</td>
<td>127</td>
</tr>
</tbody>
</table>

**Table C.2: The effect on antitrust law on inequality - a conservative estimate**

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>strict</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\psi_{cl} = 1$</td>
<td>$\psi_{cl} = 0.6$</td>
</tr>
<tr>
<td>consumption per worker</td>
<td>1</td>
<td>1.12</td>
</tr>
<tr>
<td>consumption per capitalist</td>
<td>4.57</td>
<td>4.41</td>
</tr>
<tr>
<td>P90 - P10 ratio</td>
<td>4.57</td>
<td>3.93</td>
</tr>
</tbody>
</table>