NORTHWESTERN UNIVERSITY

Essays on Investment and Capital in the Macroeconomy

A DISSERTATION

SUBMITTED TO THE GRADUATE SCHOOL
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

for the degree

DOCTOR OF PHILOSOPHY

Field of Economics

By

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EVANSTON, ILLINOIS

June 2017

Abstract

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Both chapters of this dissertation relate to the aggregate value of corporations in an economy. In particular, they relate to the ratio of the aggregate total market value of corporations over the replacement cost of their recorded capital. The first chapter introduces a model that can explain why this ratio systematically averages below unity and why there are large cross-country differences in this ratio. The second chapter introduces a model that can explain the systematic upward trend in the ratio over the last three decades with increased business internationalization.

Acknowledgment

I am extremely grateful to my advisors, Lawrence Christiano, Martin Eichenbaum, and Matthias Doepke for their continuous guidance and support.

The first chapter of this dissertation also profited from comments by or conversations with Luigi Bocola, Janice Eberly, Robert J. Gordon, Guido Lorenzoni, Giorgio Primiceri, and Mark Witte as well as seminar participants at Northwestern University.

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Chapter 1: Why Is Installed Capital Worth So Little?

1.1 Introduction

This chapter builds on two key facts about the aggregate Tobin's Q, defined as the ratio of the aggregate value of installed capital, i.e. the aggregate value of all firms of an economy, divided by its replacement cost.[1] First, the average value of the aggregate Tobin's Q in all of the countries I consider is significantly below unity. That is, installed capital is, on average, worth substantially less than its replacement cost. Second, there are large, systematic differences in the value of the aggregate Tobin's Q across countries. For example, the average value of the aggregate Tobin's Q in Germany or Japan is roughly half of the average value of the United States (US) or the United Kingdom (UK). For ease of exposition, I denote aggregate level Q simply by Q. I denote the corresponding firm-level object by q. A detailed explanation of the data and comments on the measurement of Q are found in the next section.

In the simple neoclassical model, Q should be equal to one. Allowing for unrecorded intangible capital, say of the type emphasized by Prescott and McGratten (2010), makes the data even more puzzling. This type of capital enters the numerator of Q because the market values such capital. But since it is unrecorded, it does not enter the denominator of Q. So,

[1] At the firm-level, Tobin's q is defined as the total market value of a firm (debt and equity) divided by the replacement cost of the firm's capital. The aggregate Tobin's Q is the sum of all firm-level numerators divided by the sum of all firm-level denominators.

other factors equal, observed Q should be bigger than one, not smaller than one, as in the data. If a country's Q averaged below unity due to shorter periods of low Q, interrupted by periods of Q above unity, then aggregate shocks to the economy could serve as an explanation. This, however, is not the case in any of the countries in my sample. Moreover, aggregate investment is always positive, despite the fact that Q is persistently below unity. This suggests that to explain the data, heterogeneous firms are required. Aggregate investment is positive because some firms have q's equal to, or greater than, unity. But, obviously, many firms must have q's less than unity, given the observed Q.

In this chapter, I develop an analytically tractable general equilibrium model in which firms face idiosyncratic productivity shocks and capital adjustment costs. In the dynamic steady state of the model, Q can be significantly below unity.

To see the intuition for this result, consider the following simple model. A large number of firms produce a homogenous output good using capital and labor as input. Firm-level technology is either at a high or low state. Idiosyncratic shocks make firms move from one state to the other. The state of technology of any firm is perfectly observable, and the probabilities to switch from one state to the other are so that there is persistence in the state of technology. Firms at the high state of technology make high profits in order to make up for the fact that they might drop to the low state. As a result, the value of the firm is a combination of the high profits at the high state and the low profits at the low state. Since the state of a firm is perfectly observable, new capital will only be installed in firms at the high state of technology. That is, all new capital initially operates at the high state. In a dynamic steady state, a no-arbitrage argument combined with the fact that all firms produce the same output good, implies that the value of a firm at the high state of technology has to be identical to the cost of the capital the firm uses. In other words, firms at the high state of technology have a firm-level q at unity.[2]

Firms at the low state of technology are firms that invested in the past, when they were at the high state of technology, but were subsequently impacted by a negative shock. Capital irreversibility implies that they cannot immediately disinvest their capital. Those firms have a q below unity. Persistence in the state of a firm's technology implies a significant difference between the q at the high and low state, resulting in a Q significantly below unity. The theoretical support of Q in this baseline model is the entire interval between zero and one.

The fundamental driving force in my model is the distribution of a shock across firms. A natural question is, whether to get low levels of Q, an excessive cross-sectional dispersion on that shock must be used. In order to show that the mechanism is quantitatively relevant, I develop a version of the baseline model that is suited to be calibrated to match Compustat firm-level data. Specifically, I require that my model be consistent with the cross-sectional dispersion of the return on capital in the Compustat data. A shortcoming of the baseline model is the strong correlation of investment and q at the firm level. In the data, this correlation, however, appears to be low. In order to break the absolute correlation, I incorporate investment adjustment costs into the model.

While the baseline model can account for key qualitative features of the data, it suffers from two shortcomings. First, it cannot account for the lowest values of Q observed in my sample. Second, it cannot account for the systematic cross-country differences in Q. To address these shortcomings, I remove the adjustment cost on capital and assume, instead,

[2] It is important to note that homogeneity of the output good is only used for simplicity. The same result could be derived under monopolistic competition if firms are subject to a per period fixed cost.

that all the adjustment costs are on labor. In particular, I assume there is an adjustment cost to reduce labor but not to increase it. In the model, labor adjustment costs can have the same qualitative implications on Q as capital adjustment costs if labor and capital are non-separable in the production function. The reason for this is simple: if downward-adjusting labor is sufficiently costly, firms cannot cut their labor-force to zero after being hit by a negative shock. If labor and capital are non-separable, firms might continue to use capital even when firm-level productivity is low.[3] So this type of firm will have a very low firm-level q. Since the labor share is higher than the capital share, labor adjustment costs can be more powerful than capital adjustment costs.

The rationale for using costs to downward-adjusting labor simple. I think of capital adjustment costs as, by and large, the result of technological constraints. These constraints should not vary much across countries. By contrast, labor adjustment costs might predominantly be the result of regulation, which varies significantly across countries. I use the OECD[4] index of employment protection to assess the plausibility of this theory. As predicted by the model, a simple regression of employment protection on Q shows a strong and significant negative correlation.

This chapter's content closely relates to Sargent's 1980 work, which studies aggregate investment using a model based on Q. In Sargent's model, the Q is at unity in steady state and below unity in response to an aggregate shock. The baseline model introduced in this chapter is essentially a simplified but idiosyncratic version of the aggregate model of Sargent (1980).

[3]If the production function is Cobb-Douglas, firms continue to use capital at the low state.
[4]The Organization for Economic Co-operation and Development

I am not the first author to point out that a persistent Q below unity is puzzling. Robertson and Wright (2005) address the question of why Q averages below unity in the United States. They introduce a model in which stock-market data, reflecting the valuation of minority shareholders, does not reflect the actual value of firms, since minority shareholders do not have access to the same information controlling shareholders have access to. Robertson and Wright conclude, however, that in order to get levels of Q around the average observed in the US, the noise that minority shareholders are subject to would have to be extremely large. In fact, it would have to be so large that it would be the main driving force of stock market prices. Piketty (2014), whose data I use in this chapter, mentions that a Q below unity is puzzling and points out the interesting differences across countries. Piketty does not engage in an analytical discussion, but mentions that limited control over a firm by the owners of a firm could play a role in some countries. In particular, Piketty argues that if shareholders are forced to engage in a relationship with other stakeholders like employees, this could reduce the Q. My model, based on labor adjustment costs, can, to some extent, be considered an analytical formulation of this idea.

McGrattan and Prescott (2005) study changes in Q in the US and the UK during the 1970s and 1980s using a model based on taxes and subsidies. In their model, Q can be below unity. This, however, requires strong assumptions about how taxes and subsidies affect the valuation of capital.

Several authors have introduced models in partial or general equilibrium in which the q of a firm or a sector can be below unity. The implications of adjustment costs on average and marginal q of the firm have influentially been studied by Hayashi (1982). Kogan (2001) introduced a tractable general equilibrium model with irreversible investment in a two sector economy to study investment. The key contribution of this chapter on the model side is the development of a model that easily allows aggregation to Q in general equilibrium. As a result, the model introduced in this chapter allows to study the effects of different types and magnitudes of adjustment costs on Q.

The theory put forward in this chapter relates to a series of other studies. First, the model suited to match the firm-level data relates to Eberly et al (2008 and 2012), who show that models incorporating investment adjustment costs best fit the firm-level investment data. Since Q is, by construction, affected by unrecorded intangible capital, this chapter also relates to studies on the level of intangible capital, including Hall (2001), Corrado et al (2009), McGrattan and Prescott (2010), and Corrado et al (2013). Finally, this chapter also relates to the literature studying movements in the aggregate stock market, including Greenwood and Jovanovic (1999), Laitner and Stolyarov (2003), and Peralta-Alva (2007).

The remainder of this chapter is structured as follows. Section 1.2 explains the data and discusses measurement issues of the value of installed capital and its replacement cost. Section 1.3 develops the baseline model and discusses basic results. Section 1.4 relaxes some simplifying assumptions of the baseline model and brings the model to the firm-level data. Section 1.5 extends the framework to labor adjustment costs and discusses cross-country differences. A final section concludes.

1.2 Data and measurement of Q

1.2.1 Q data

The data necessary to calculate the Q of the US, i.e. data of the total value of installed capital and its replacement cost, is available from the 'Integrated Macroeconomic Accounts for the United States' of the BEA[5] and the Federal Reserve Bank of St. Louis. The data begins in the last quarter of 1951 and averages at .77. Wright (2004) calculates a Q series that spans the period 1900-2002 and averages at .69. Figure 1 depicts both of these series. The data exhibits only one relevant spike above unity since 1900 – the sharp increase in stock prices in the 1990s, a period generally referred to as the dot-com bubble. More details about different methods of measuring Q can be found in Wright (2004).

Data for other developed economies is available from the online appendix of Piketty (2014) for the period 1970-2010. The data is depicted in figure 2 and includes seven of the eight largest advanced economies. Data for Italy, which would complete the list of the eight largest advanced economies, is not available. The data for Australia begins in 1990. The averages over the whole sample for each country are .79 for Australia, .77 for Canada, .62 for France, .41 for Germany, .42 for Japan, .84 for the UK, and .80 for the US.

1.2.2 Measurement of Q

Since the numerator of Q is calculated from market data, measurement errors should be concentrated in the denominator, i.e. in the replacement cost of capital. I identify two main issues related to the measurement of the replacement cost of capital: first, unrecorded

[5] U.S. Bureau of Economic Analysis

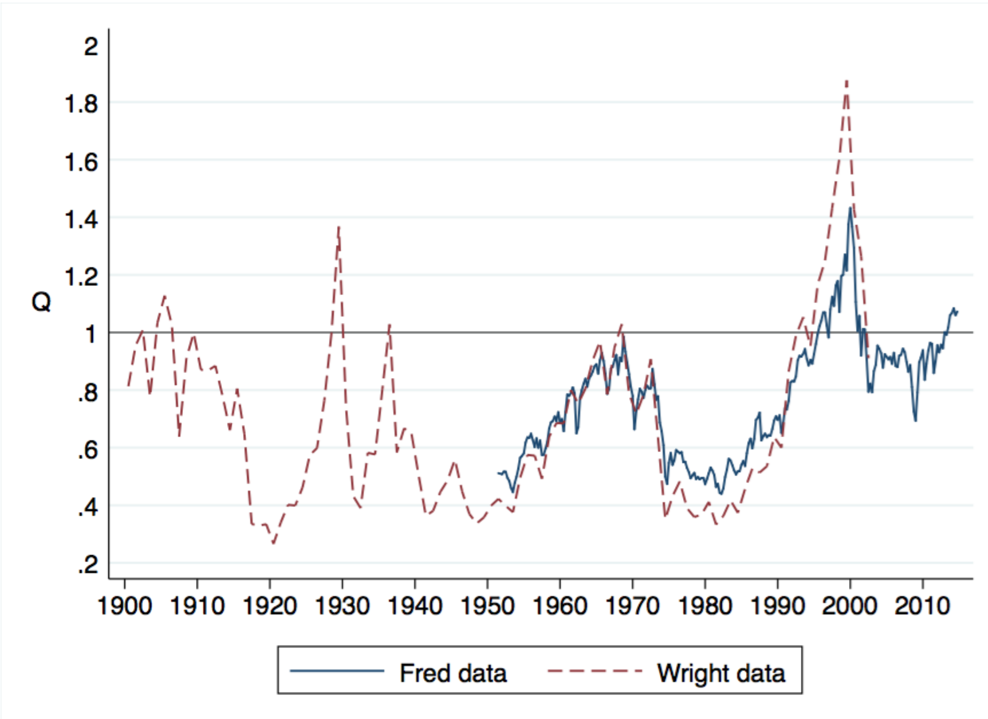


Figure 1: Economy-wide aggregate value of installed capital divided by its replacement cost (Q) for non-financial corporate businesses in the US. Solid line: Author's calculation using quarterly data from the Federal Reserve Bank of St. Louis. Dashed line: Annual data from the online appendix of Wright (2004).

intangible capital, which can impose an upward bias on the measured Q, and second, vintage capital, which can impose a downward bias on the measured Q.

Intangible capital is capital accumulated through spending on research and development, marketing, and hiring among others. I refer to unrecorded intangible capital as, in the case of the US, the national income and product accounts (NIPA) account for some intangible capital. Several authors, including Hall (2001) and Corrado et al (2009), however, argue that a substantial fraction of intangible capital is not recorded by the NIPA. Corrado et al (2013) make a comparable argument for other countries in my sample. Furthermore, Corrado et al (2009) and McGrattan and Prescott (2010) argue that intangible capital is increasingly

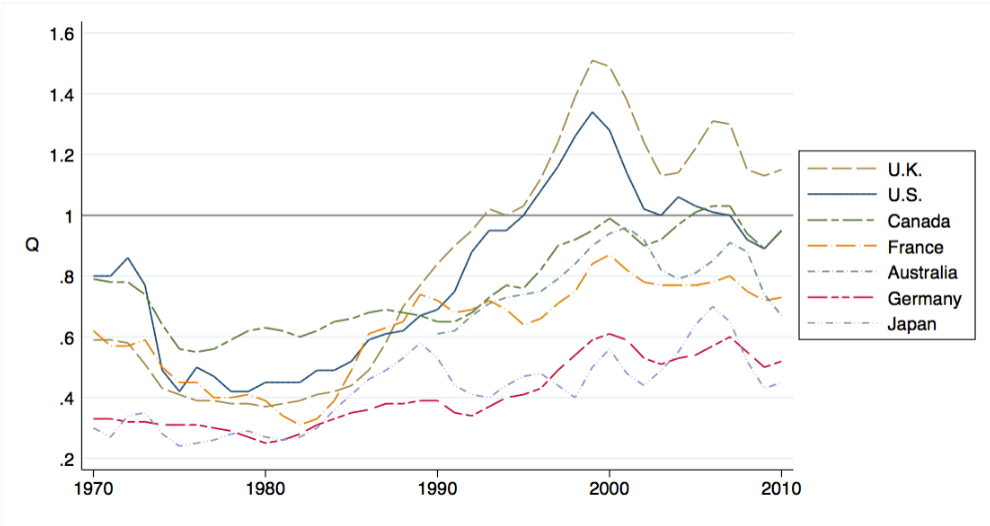


Figure 2: Economy-wide aggregate value of installed capital divided by its replacement cost (Q) for non-financial corporate businesses of seven developed economies. Annual data for 1970-2010 from the online appendix of Piketty (2014).

important and the levels of unrecorded intangible capital have risen over the course of the past 30 years. While the exact level of unrecorded intangible capital remains speculation, two things can be said with a degree of certainty. First, the existence of unrecorded intangible capital makes the puzzle of low-measured Q's even stronger. Secondly, it is likely that the systematically higher Q's observed in many countries since the 1990s can, at least partially, be attributed to increasing levels of unrecorded intangible capital.

If the quality of investment goods gets better over time, but installed capital is vintage, this might impose a downward bias on the measured Q if the accounting framework does not adequately account for this effect. Gordon (1990) shows that, due to increasing quality, the real price of equipment in the US has decreased at an average rate of 2-3% p.a. since 1950. There is no evidence for such a trend in the price of structures. Theoretically, the accounting framework should account for this. It is, however, possible to place an upward bound on this effect in the US by assuming that the accounting framework does not account for vintage capital at all. The depreciation rate on equipment is usually assumed to be large, with 10% being a lower bound. A 10% depreciation rate implies that the average age of equipment is 5 years. If quality improves at a rate of 3% p.a. (the upper end of Gordon's 1990 estimate), this means that the book value of equipment is 15% higher than the actual replacement cost of this equipment. According to the NIPA, equipment accounts for roughly half of the total physical capital of corporations. Accordingly, vintage capital could, at max, impose a 7.5% downward force on the measured Q in the US.

Unrecorded intangible capital and vintage capital, accordingly, have opposing effects on the measured Q. However, even the most conservative estimates of intangible capital are above the maximal downward force that vintage capital can impose on the measured Q. I therefore argue that, if anything, the measured Q is above the actual Q.

1.3 A simple general equilibrium model of Q

In this section I introduce the baseline model of Q. When solving the model, I focus on the dynamic steady state. A dynamic steady state is characterized by unvarying aggregate variables. I show that Q can be significantly below unity in the dynamic steady state.

1.3.1 Model

Model setup Production takes place in firms. There are a large number of firms which are all a priori identical. The production function for every firm j is given by

$$Y_j = A_j K_j^{\alpha} N_j^{1-\alpha}, \tag{1}$$

where A_j is a level of technology, K_j is physical capital, N_j is labor, and where $\alpha \in (0, 1)$. All firms produce the same output good, which can be used as capital-good or for consumption. The price of a unit of uninstalled capital in terms of consumption units is accordingly fixed at unity. Labor is supplied by a large number of households, each of whom split their time between labor and leisure. Households use their income for consumption or saving. It is assumed that households have concave utility in both consumption and leisure. The utility function is furthermore so that households supply a positive amount of labor. Households discount the future at the discount rate $\beta \in (0, 1)$, implying a positive saving rate in steady state. Households save by buying shares of a mutual fund, which, in turn, owns the good-producing firms. The sole purpose of the mutual fund is to diversify the risk of single firms. Firms buy capital from the mutual fund in return for shares of the firms, which entitle them to future profits. That is, firms own their capital and accordingly make positive profits as return on capital. This assumption is made to simplify the algebra and does not affect the q of a firm. Any investment conducted in a given period is available for production in the next period.

Firms are subject to idiosyncratic shocks to technology. In any period, firm-level technology can take one of two states, the high state H or the low state $L < H$. The state of technology for every firm is perfectly observable. For every firm, technology follows a Markov process characterized by a probability to move from the high to the low state, ϕ_d, and a probability to move from the low to the high state, ϕ_u. There are no aggregate technology shocks. Capital is irreversible. That is, once a unit of capital is installed in a firm, it operates in this firm until the unit of capital dies, which happens with probability δ.

For simplicity, and without loss of generality, I assume that whenever firms make an investment, they know the state of technology they will operate at in the next period. Firms, however, have no knowledge of technology beyond the Markov probabilities of technology after the next period. In other words, every period is split into two sub-periods where in the first sub-period the previous period's investment becomes effective, labor is hired, and production takes place. In the second sub-period, the next period's state of technology is revealed and firms make their investment decision.

In order to calculate Q in the steady state of this model, the steady state prices of capital invested in firms in the high, and in the low state, respectively, have to be found. For simplicity, I price firms in the first of the two sub-periods explained above.

Profit maximization and labor choice As the labor market is not subject to any frictions, firms hire labor as to maximize the current period's profits. Firms are characterized by their states of technology and the amounts of capital they have installed. It is instructive to switch to per-unit-of-capital calculations so that all firm subscripts can be dropped. In everything that follows, lower case letters with K subscripts denote variables defined per unit of capital.

Output per unit of capital for firms at the high and low levels of technology, respectively, is given by

$$y_K(a) = an_K(a)^{1-\alpha},$$

where $a \in A = \{L, H\}$. Profits per unit of capital are given by $\pi_K(a) = y_K(a) - wn_K(a)$ where w is the wage rate. Profit maximization implies that labor demand per unit of capital is given by

$$n_K(a) = \left((1-\alpha)\frac{a}{w}\right)^{\frac{1}{\alpha}}. \tag{2}$$

Firms make positive profits since they own the capital they use. Given (2), profits per unit of capital used by a firm at technology $a \in A$ are given by

$$\pi_K(a) = \alpha\left[a\left(\frac{1-\alpha}{w}\right)^{1-\alpha}\right]^{\frac{1}{\alpha}}. \tag{3}$$

Defining γ as the percentage of low technology compared to high technology, i.e. $L = \gamma H$ with $0 \leq \gamma < 1$, profits per unit of capital relate in the form[6]

$$\pi_K(L) = \gamma^{\frac{1}{\alpha}}\pi_K(H). \tag{4}$$

The value of a unit of installed capital Denoting the values of units of capital currently operating at H and L with $v_K(H)$ and $v_K(L)$ respectively, the value functions for the two states take the form

$$v_K(H) = \pi_K(H) + \beta(1-\delta)\left[(1-\phi_d)v'_K(H) + \phi_d v'_K(L)\right], \quad \text{and} \tag{5}$$

$$v_K(L) = \pi_K(L) + \beta(1-\delta)\left[(1-\phi_u)v'_K(L) + \phi_u v'_K(H)\right], \tag{6}$$

[6]The exponent $1/\alpha$ represents the amplification mechanism imposed by labor, as all firms have to pay the same wage rate.

where prime-superscripts denote the succeeding period's variables. Imposing steady state and jointly solving (5) and (6) gives

$$v_K(H) = \mathcal{M}\left\{[1-\beta(1-\delta)(1-\phi_u)]\,\pi_K(H) + \beta(1-\delta)\phi_d\pi_K(L)\right\}, \quad \text{and} \tag{7}$$

$$v_K(L) = \mathcal{M}\left\{[1-\beta(1-\delta)(1-\phi_d)]\,\pi_K(L) + \beta(1-\delta), \phi_u\pi_K(H)\right\}, \tag{8}$$

where $\mathcal{M} = \left\{[1-\beta(1-\delta)(1-\phi_d)][1-\beta(1-\delta)(1-\phi_u)] - \beta^2(1-\delta)^2\phi_d\phi_u\right\}^{-1}$ is a multiplier. As the replacement cost of capital is fixed at unity, and since firms have no value other than the value of their capital, the firm-level q's at the high and low state are simply given by

$$q(H) = v_K(H) \quad \text{and} \quad q(L) = v_K(L),$$

respectively.

Equilibrium Since firms produce a homogenous output good, and since the production function has constant returns to scale, investment only takes place in firms at the high state of technology.

Proposition 1. *In a dynamic steady state equilibrium, $q(H) = 1$ and $q(L) < 1$.*

Proof. *See appendix.*

Given that investment only takes place in firms at the high state of technology, and given a large number of firms, the equilibrium fraction of economy-wide capital operating at the high level of technology is characterized by the Markov probabilities and the depreciation rate, and given by

$$\mu_K = \frac{(1-\delta)\phi_u + \delta}{(1-\delta)(\phi_u + \phi_d) + \delta}. \tag{9}$$

The fraction of capital operating at the low level of technology is accordingly $1 - \mu_K$.[7] It is easy to see that $1 > \mu_K > \delta$. Q is hence given by

$$Q = \mu_K + (1 - \mu_K)q(L), \tag{10}$$

which, using (7) and (8) together with (4), can be rewritten as follows

$$Q = \mu_K + (1-\mu_K)\frac{[1-\beta(1-\delta)(1-\phi_d)]\,\gamma^{\frac{1}{\alpha}} + \beta(1-\delta)\phi_u}{[1-\beta(1-\delta)(1-\phi_u)] + \beta(1-\delta)\phi_d\gamma^{\frac{1}{\alpha}}}. \tag{11}$$

Equation (10) together with proposition 1 captures the qualitative result of the simple model: under the existence of idiosyncratic shocks, capital irreversibility, and information about the state of technology of firms, Q is below unity.

It is interesting to note that the steady state Q can be depicted without defining household utility beyond of what is given above. The exact shape of household utility only matters for the total amount of capital installed in the economy (and accordingly for all other absolute variables), but, provided a unique equilibrium with positive labor exists, the exact shape of household utility does not matter in calculating the relative value of capital. Since the share of capital at the high and the low states of technology is entirely defined by the law of

[7] Note that the fraction of capital operating at the high level of technology is not identical to the fraction of firms operating at the high level of technology. As new capital is only installed in firms operating at the high level of technology, in the dynamic steady state, the share of capital installed at the high state of technology is larger than the share of firms operating at the high state of technology.

motion of capital, the exact shape of household utility also does not matter for Q.

1.3.2 Characteristics of Q in the simple model

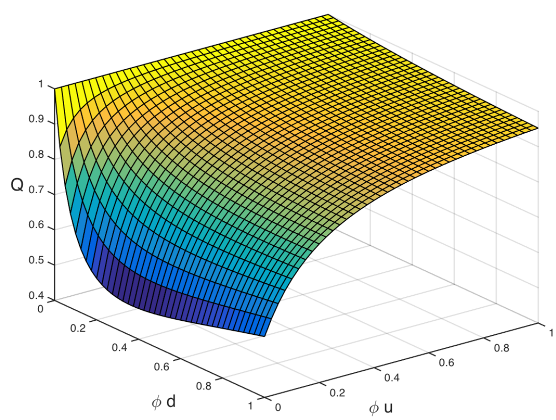
The steady state Q depends on six parameters: the capital share α, the discount factor β, the depreciation rate δ, the percentage difference between the high and the low states of technology γ, and the two switching probabilities ϕ_u and ϕ_d. The parameters α, β, and δ, are standard parameters and Q is not very sensitive to changes in the parameters around standard values. I therefore set these parameters to the standard annual values of $\alpha = .33$, $\beta = 1.03^{-1}$, and $\delta = .1$ and concentrate this discussion on the remaining parameters.

	$\gamma = .5$, $\phi_d = \phi_u = .2$	$\gamma = .5$, $\phi_d = 1, \phi_u = 0$	$\gamma = 0$, $\phi_d = \phi_u = .2$	$\gamma = 0$, $\phi_d = 1, \phi_u = 0$
Q	.87	.57	.84	.1
$v_K(H)$	1	1	1	1
$v_K(L)$	.66	.53	.58	0
μ_K	.61	.1	.61	.1

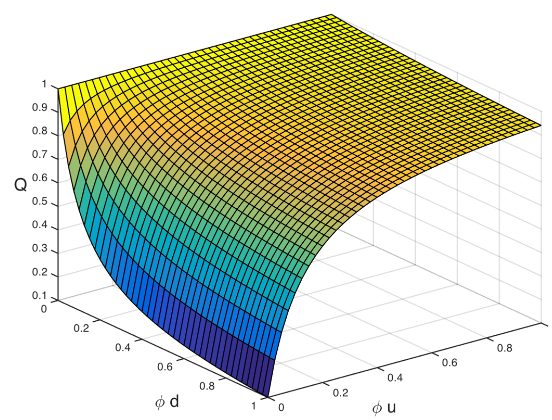
Table 1: Q and its components for different parameter combinations. Other parameters: $\alpha = .33$, $\beta = 1.03^{-1}$, $\delta = .1$. $v_K(H)$ is the value of a unit of capital at technology H; $v_K(L)$ is the value of a unit of capital at technology L; μ_K is the fraction of total capital at technology H.

Table 1 numerically shows Q and its components for four examples of the remaining three parameters, and figure 3 graphically displays Q for two values of γ and the whole spectrum of the switching probabilities. As explained above, and as can be seen in table 1, $v_K(H)$ is always at unity, and Q depends on μ_K and $v_K(L)$. It is easy to see from (11) that there is a strict positive relation between Q and γ, since γ only affects $v_K(L)$, but not μ_K (which can also be seen in table 1). Q is furthermore positively related to ϕ_d since a decrease in ϕ_d reduces both, μ_K and $v_K(L)$, but the effect of ϕ_u on Q is ambiguous (compare equations

(9) and (11), and figure 3). The support of Q is $(\delta, 1)$, where the lower bound of δ is the case depicted in the fourth column of table 1.[8] This case is, of course, only of theoretical nature as it means that capital only produces output in the first period of its existence, and subsequently falls to the bad state of technology, with a zero probability of ever returning to the good state.



(a) $\gamma = 0.5$



(b) $\gamma = 0$

Figure 3: Q for different values of ϕ_u and ϕ_d if γ is 0.5 and 0 respectively.

The conclusion of this exercise is straightforward: Q strongly depends on the three non-standard parameters γ, ϕ_d, and ϕ_u, but the support of Q is large and there exists a wide range of these parameters in which Q is significantly below unity.

1.3.3 Investment implications and investment adjustment costs

The mechanism introduced above has strong investment implications. Firms only invest when they are at the high state of technology (i.e. when their q is high), and firms disinvest

[8] As δ depends on the time horizon, which can be chosen arbitrarily small, the theoretical support of the model is $Q \in (0, 1)$.

otherwise. This is related to the well-known problem that q-theory, which says exactly that firms with high q's should invest and vice versa, does not hold very well in the data. In other words, in the data, the correlation between firm-level investment and q is positive, but low. It is not the intention of this chapter to discuss why this correlation is low, but it is important to show that the mechanism introduced above does not entirely depend on a very strong correlation. In order to break the absolute correlation of q and investment, i.e. the absolute correlation of the state of technology and investment, I incorporate costs to downward-adjusting investment. This is related to the work of Eberly et al (2008 and 2012) who show that models with investment adjustment costs best explain the investment behavior of firms. In the baseline model, incorporating costs to downward-adjusting labor forces firms at the low state of technology (i.e. firms with low q's) to keep investing.

The type of adjustment costs incorporated in the model is as simple as possible. Firms can downward adjust their investment up to a fraction $\theta \in (0, 1)$, for free. Any downward adjustment beyond this is infinitely costly. That is, in any period, a firm's investment hast to be at least $1-\theta$ times the investment of the previous period. Adjusting investment upward is not subject to any costs. As a result, the level of investment might have (and in equilibrium will have) an additional negative value since investment obliges to future investment, which might not be profitable. These values are characterized by the value functions

$$v_I(H) = v_K(H) - 1 + ... \tag{12}$$

$$...\beta\left[(1-\phi_d)\max\{(1-\theta)v_I'(H), v_I'(H)\} + \phi_d \max\{(1-\theta)v_I'(L), v_I'(L)\}\right], \text{ and}$$

$$v_I(L) = v_K(L) - 1 + ... \tag{13}$$

$$...\beta\left[(1-\phi_u)\max\{(1-\theta)v_I'(L), v_I'(L)\} + \phi_u \max\{(1-\theta)v_I'(H), v_I'(H)\}\right],$$

where $v_I(H)$ and $v_I(L)$ denote the value of the stock of investment per unit of investment at the high or the low state of technology, respectively, including the one-time gain or loss of investment. Prime superscripts again denote the next period's variables. $v_K(H)$ and $v_K(L)$ still describe the value of a unit of capital at the high and the low state respectively, and the value functions for $v_K(H)$ and $v_K(L)$ are still given by (5) and (6), but proposition 1 no longer holds. The new steady state equilibrium condition is given by the proposition below.

Proposition 2. *In a dynamic steady state equilibrium,* $v_I(H) = 0$, $v_I(L) < 0$.

Proof. *See appendix.*

Using the first part of proposition 2 (the equilibrium condition) in (12) and (13), imposing steady state and making use of (7) and (8) pins down $v_I(L)$, $v_K(H)$, and $v_K(L)$. It is important to note that in steady state $v_K(H)$ is no longer at unity. $v_K(H)$ is above unity in order to make up for the negative value of a state of investment, which has to be accepted when investing an additional unit of capital. In this model, the firm-level q's are given by the sum of the value per capital and the value of the state of investment net of the first period gain. That is, a firm's q depends on the firm's state of technology, the firm's stock of capital k, and the firm's investment level i, and is given by

$$q(H,k,i) = \frac{kv_K(H) + i\beta\phi_d(1-\theta)v_I(L)}{k}, \quad \text{and}$$
$$q(L,k,i) = \frac{kv_K(L) + i\beta(1-\phi_u)(1-\theta)v_I(L)}{k}.$$

Q is then given by the capital-weighted average of all firm-level q's

In order to evaluate the effect of the investment adjustment costs on both, Q and the correlation of investment and capital, I set the parameters of the model to exemplary values and simulate 10,000 companies over 10,000 periods (discarding the first 2,000 periods from the sample) for different values of θ. The parametrization as well as the results are given in table 2. The first column sets $\theta = 1$ (i.e. no investment adjustment costs) and shows the absolute correlation of investment and capital in this model. Columns two and three repeat the exercise, incorporating the investment adjustment costs with the adjustment parameter θ set to .25 and .1 respectively.

	no inv. adj. cost	inv. adj. cost ($\theta = .25$)	inv. adj. cost ($\theta = .1$)
Q	.72	.81	.84
Corr(q, i/k)	1	.59	.47

Table 2: Exemplary comparison of Q and the correlation coefficient of firm-level q and investment in the models with and without investment adjustment costs. Parameters: $\alpha = .33$, $\beta = 1.03^{-1}$, $\delta = .1$, $\gamma = .5$, $\phi_d = .4$, $\phi_u = .1$.

Table 2 shows that the investment adjustment costs significantly reduce the correlation between investment and q on the firm level. While the impact of the mechanism on Q is reduced, as can be seen in table 2, it is not reduced at too large of a magnitude.

1.4 Model calibration with firm level data

I have established above that the baseline model is able to generate low levels of Q in the dynamic steady state. The core mechanism of the model has to do with the cross-sectional distribution of a firm-level shock. A natural question to ask is whether cross-sectional dispersion on that shock has to be excessively large in order to get a Q as low as observed in the data. To check this, I now turn to the cross-sectional dispersion of the rate of return on owning shares of a firm. Since the model abstracts from debt, the counterpart to owning shares of a firm in the model is owning equal shares of equity and debt in the Compustat firm-level data. I do not look at the dispersion of firm-level q's as, in the data, this dispersion is excessively large and driven by extreme outliers.[9]

In order to compare the model with the data, I first derive a more realistic version of the baseline model introduced in the previous section. In particular, I build on the model with investment adjustment costs but relax two simplifying assumptions. First, technology is no longer limited to two states, but rather given by a broad continuum of states. Secondly, the investment adjustment costs are no longer one-sided; a two-sided adjustment costs implies that some firms will have a q above unity, and the continuum of states implies that the value of capital is no longer binary, but also given by a continuum.

[9] These outliers might be explained by measurement errors in the denominator, or, to some extend, by intangible capital.

1.4.1 Model

Model setup There is a large number j of firms. Every firm's production function is given by

$$Y_j = (A_j K_j)^\alpha N_j^{1-\alpha},$$

where Y_j, A_j, K_j, and N_j are output, technology, capital, and labor of firm j, respectively. The exponent α on technology is included to simplify the algebra. A firm's technology, A_J, is drawn from the interval $A = [\underline{a}, \bar{a}]$ and evolves according to a modified Markov process. With probability ϕ, technology remains unchanged to the previous period. With probability $1 - \phi$, the firm is subject to a technology shock. Conditional upon receiving a shock, the probability distribution for every technology is non-state contingent and given by the probability function $f(\cdot)$, with density $F(\cdot)$. It is assumed that $F(\cdot)$ is once integrable. Adjusting investment in any direction is subject to costs. In any period, firms can increase or reduce their investment by a fraction $\theta_u \in (0, 1)$ or $\theta_d \in (0, 1)$ respectively, without any adjustment costs. Increasing or reducing investment beyond this is infinitely costly. In order to ensure an equilibrium, θ_u and ϕ are so that $\phi(1 + \theta_u) < 1$. Labor is not subject to any adjustment costs. Furthermore, the same assumptions on household utility as in section 1.3 apply.

Profit maximization and labor choice Output per unit of capital installed in a firm at technology a is given by

$$y_K(a) = a^\alpha n_K(a)^{1-\alpha},$$

where $n_K(a)$ is labor per unit of capital in a firm at technology a. Profits per unit of capital are given by $\pi_K(a) = y_K(a) - w n_K(a)$ where w is the wage rate. Profit maximization implies that a firm at technology a will hire

$$n_K(a) = a \left(\frac{1-\alpha}{w} \right)^{\frac{1}{\alpha}} \tag{14}$$

units of labor per unit of capital. Accordingly, profits per unit of capital are given by

$$\pi_K(a) = a\alpha \left(\frac{1-\alpha}{w} \right)^{\frac{1-\alpha}{\alpha}} \equiv a\mathcal{P}(w), \tag{15}$$

where I define $\mathcal{P}(w) = \alpha \left(\frac{1-\alpha}{w} \right)^{\frac{1-\alpha}{\alpha}}$ to save on notation.

Capital dynamics The continuum of states of technology implies that at any point in time there has to exist an $\tilde{a} \in A$, above which it is profitable for firms to increase investment and vice versa. Total investment at state a is characterized by

$$I'(a) = \begin{cases} (1+\theta_u)\left[\phi I(a) + (1-\phi) f(a) I\right] & \text{if } \ a > \tilde{a} \\ (1-\theta_d)\left[\phi I(a) + (1-\phi) f(a) I\right] & \text{if } \ a < \tilde{a} \end{cases} \tag{16}$$

where I is total investment in the economy, given by

$$I = \int_{a \in A} I(a) da. \tag{17}$$

Imposing steady state and using (16) in (17) gives

$$1 = \frac{(1-\phi)(1-\theta_d)}{1-\phi(1-\theta_d)} F(\tilde{a}) + \frac{(1-\phi)(1+\theta_u)}{1-\phi(1+\theta_u)} \left[1 - F(\tilde{a})\right], \tag{18}$$

which characterizes the steady state $\tilde{a}$ given $F(\cdot)$ and a set of parameters. The stock of capital at state a is characterized by

$$K'(a) = (1-\delta) \left[\phi K(a) + (1-\phi) f(a) K\right] + I(a),$$

where K is the total capital in the economy, given by

$$K = \int_{a \in A} K(a) da.$$

The value of a unit of installed capital The value of a unit of capital installed in a firm at technology a is given by

$$v_K(a) = \pi_K(a) + \beta(1-\delta)[\phi v'_K(a) + (1-\phi)\mathcal{C}'_K], \tag{19}$$

where prime variables denote the next period's variables and where

$$\mathcal{C}_K = \int_{a \in A} f(a) v_K(a) da$$

is a constant.

In steady state,

$$\mathcal{C}_K = \frac{\mathcal{P}(w)}{1 - \beta(1-\delta)} \left[\bar{a} - \int_{\underline{a}}^{\bar{a}} F(a) da \right]. \tag{20}$$

The value of investment The value of a unit of investment in a firm at technology a is given by

$$\begin{aligned} v_I(a) &= v_K(a) - 1 + \beta \left[\phi \max\{(1-\theta_d) v_I'(a), (1+\theta_u) v_I'(a)\} + (1-\phi) \mathcal{C}_I' \right] \\ &\equiv v_K(a) - 1 + \beta \hat{v}_I(a), \end{aligned} \tag{21}$$

where

$$\mathcal{C}_I = \int_{a \in A} f(a) \max\{(1-\theta_d) v_I(a), (1+\theta_u) v_I(a)\} da$$

is a constant. It is important to note that this is the value of investment net of the capital cost, which is normalized at unity. I use this notation since it allows for a very simple equilibrium condition below.

Equilibrium A steady state equilibrium is characterized by the following proposition.

Proposition 3. *In a dynamic steady state equilibrium,* $v_I(\tilde{a}) = 0$.

Proof. *See appendix.*

Proposition 3 implies that in steady state,

$$\mathcal{C}_I = \left[1 - \frac{\beta(1-\phi)(1-\theta_d)}{1-\beta\phi(1-\theta_d)}F(\tilde{a}) - \frac{\beta(1-\phi)(1+\theta_u)}{1-\beta\phi(1+\theta_u)}(1-F(\tilde{a}))\right]^{-1} \times ...$$
$$...\left\{\frac{1-\theta_d}{1-\beta\phi(1-\theta_d)}\left[F(\tilde{a})(v_K(\tilde{a})-1) - \frac{\mathcal{P}(w)}{1-\beta\phi(1-\delta)}\int_{\underline{a}}^{\tilde{a}} F(a)da\right] + ... \right. \tag{22}$$
$$\left. ...\frac{1+\theta_u}{1-\beta\phi(1+\theta_u)}\left[(1-F(\tilde{a}))(v_K(\tilde{a})-1) - \frac{\mathcal{P}(w)}{1-\beta\phi(1-\delta)}\int_{\tilde{a}}^{\bar{a}} F(a)da\right]\right\}.$$

1.4.2 Calibration using Gaussian shocks to technology

In order to close the model, an assumption about the distribution of shocks has to be made. I assume that $a = e^b$, and that b is drawn from a truncated normal distribution. The truncation of the normal distribution is so that technology a is within its bounds $\underline{a}$ and $\bar{a}$. Specifically, I assume $b \sim N(0, \sigma^2)$ and $\ln(\underline{a}) \leq b \leq \ln(\bar{a})$.[10] As a result, $f(a)$ and $F(a)$ are the PDF and CDF respectively of a truncated lognormal distribution.

To find the moments of the calibrated model, I simulate 10,000 firms over 10,000 periods and discard the first 2000 periods. A firm's q depends on the firm's state of technology a, stock of capital k, and investment level i, and is given by

$$q(a,k,i) = \frac{kv_K(a) + i\beta\hat{v}_I(a)}{k}. \tag{23}$$

Q is the capital weighted average of all firm-level q's. That is, the model can be simulated

[10]The zero mean is a simple normalization of the overall level of technology.

using (18)-(23) along with proposition 3.

In the model, the rate of return on owning a share of a firm is given by

$$\kappa = ln\left(\frac{q' + \pi'}{q}\right).$$

The counterpart in the data is the change in the market value of equity and debt corrected for dividends and interest and adjusted for inflation. I approximate the market value of debt with the book value of debt which, if anything, reduces the volatility of the measured rate of return.

In the model, the averaged cross-sectional dispersion and the averaged time-series dispersion of the rate of return are identical. In the data, however, there are small differences. While the cross-sectional variance of the rate of return averaged over time is at .084, the time-series variance averaged over all firms is at .104. This difference is, however, small and can be attributed to the limited time-horizon of the data. I accordingly target a variance in the range of .09-.1 when calibrating the model.

The calibration strategy looks as follows. The three parameters with easily observable economic implications, i.e. α, β, and δ are set to values that match the data. That is, α is set to the average capital share .33., the discount factor β is set to match the average of the rate of return, and δ is set to the average depreciation rate in the firm level data. The remaining six parameters, θ_u, θ_d, ϕ, $\underline{a}$, $\bar{a}$, and σ are calibrated as to match the average Q, the average time-series and cross-section variance of the one-period return of owning a share of a firm, and the correlation of q and relative investment. All parameters are given in table 4.

	Data	Model
Q	.79	.79
Var(κ), cross-section	.084	.097
Var(κ), time-series	.104	.097
Corr(q, i/k)	.12	.17

Table 3: Calibration: Results.

α	β	δ	θ_u	θ_d	ϕ	$\underline{a}$	$\bar{a}$	σ
.33	1.05^{-1}	.08	.4	.15	.65	0	10	3

Table 4: Calibration: Parameter choice.

The simulation results are summarized in table 3. I conclude that the model is able to produce reasonably low levels of Q while still exhibiting a realistic dispersion in the rate of return.

1.5 Labor adjustment costs and cross-country differences

The model introduced above has two major shortcomings. First, assuming a realistic distribution of shocks, it cannot explain extremely low levels of Q. Secondly, it cannot explain the cross-country difference in the average level of Q observed in the data. In this section, I fix these shortcomings using costs to downward-adjusting labor. Even though the focus of my analysis is the value of capital, the mechanism introduced in the previous two sections does not necessarily require costs to the adjustment of capital or investment to work. It requires a reason for firms at low levels of technology to continue production and use some capital. Costs to labor adjustment can satisfy this criterion as long as the production function is non-separable.

The rationale for using labor adjustment costs to explain cross-country differences lies in the different nature of capital vs. labor adjustment costs. I think of capital adjustment costs as, by and large, the result of technological constraints. These constraints should not vary much across countries. By contrast, labor adjustment costs might predominantly be the result of regulation, which varies a lot across countries.

Below I introduce a model of Q that is in its nature comparable to the models above, but it is based on labor adjustment costs instead of capital or investment adjustment costs. I again focus on the dynamic steady state of the model. For simplicity, and for the sake of comparability, I start with a setting with just labor adjustment costs and no cost to capital adjustment. Furthermore, I go back to the simple setting with two states of technology as in section 1.3. To demonstrate the possible magnitude of the mechanism, I introduce a model based on capital and labor adjustment costs in a second step. In a last step I use the OECD index of employment protection to assess my theory.

1.5.1 Model based on labor adjustment costs

Model setup The model setup is, up to the adjustment costs, identical to the setup in section 1.3. The production function is given by (1). There are two states of technology: a high state H, and a low state L. The percentage difference between the two states is given by γ, i.e. $L = \gamma H$. The probability to move from the high to the low state of technology and vice versa is given by the Markov probabilities ϕ_d and ϕ_u respectively. When firms face an investment decision they know the next period's state of technology for sure, but beyond that they only know the Markov probabilities. Furthermore, the same assumptions on household utility, as in section 1.3, apply. The only difference compared to section 1.3 is that capital is no longer irreversible, but therefore there exist labor adjustment costs. In any period, a firm can only reduce labor without any adjustment costs by a factor θ, where $\theta \in (0, 1)$. Any adjustment beyond this is infinitely costly. That is, in any period, a firm's labor force has to be at least $1 - \theta$ times the previous period's labor force.[11] Upward-adjusting labor is not subject to any cost.

In the previous two sections, I have simplified the notation by depicting all firm-level variables per unit of capital. Accordingly, I now depict all firm-level variables as per-unit-of-labor variables. Any of these variables are denoted in lower case letters with an N subscript.

Profit maximization and capital choice In contrast to the previous sections, an opportunity cost of capital, given by the interest rate r plus the depreciation rate δ, is needed. Since there are no aggregate shocks, $r = \beta^{-1} - 1$ holds in equilibrium. As a result, firms buy or sell capital per unit of labor so as to maximize $\pi_N(a) = y_N(a) - rk_N(a) - w$, implying capital per unit of labor

$$k_N(a) = \left(\frac{a\alpha}{r+\delta}\right)^{\frac{1}{1-\alpha}},$$

where $a \in \{L, H\}$.

Profits per unit of labor are therefore given by

$$\pi_N(a) = a^{\frac{1}{1-\alpha}} \left(\frac{\alpha}{r+\delta}\right)^{\frac{\alpha}{1-\alpha}} - w, \tag{24}$$

[11]This type of labor adjustment cost is particularly realistic if layoffs are very costly. In this case, firms might only downward adjust employment by not replacing employees that leave the firm voluntarily for other jobs or for retirement, which should be a roughly constant fraction of the total number of employees.

where it is again assumed that firms own their capital.

The value of a hired unit of labor The value of a hired unit of labor in a firm at the high and low states of technology is denoted by $v_N(H)$ and $v_N(L)$ respectively. The value functions are given by

$$\begin{aligned} v_N(H) =& \pi_N(H) + ... \\ & ...\beta\left[(1-\phi_d)\max\{(1-\theta)v_N'(H), v_N'(H)\} + \phi_d \max\{(1-\theta)v_N'(L), v_N'(L)\}\right], \text{ and} \end{aligned} \tag{25}$$

$$\begin{aligned} v_N(L) =& \pi_N(L) + ... \\ & ...\beta\left[(1-\phi_u)\max\{(1-\theta)v_N'(L), v_N'(L)\} + \phi_u \max\{(1-\theta)v_N'(H), v_N'(H)\}\right], \end{aligned} \tag{26}$$

where prime superscripts denote the next period's variables.

Equilibrium Since firms produce a homogenous output good, and since the production function has constant returns to scale, only firms at the high state of technology increase their labor-force.

Proposition 4. *In a dynamic steady state equilibrium,* $v_N(H) = 0$ *and* $v_N(L) < 0$.

Proof. *See appendix.*

Given proposition 4, in steady state, profits at the high and the low states of technology relate in the form

$$\pi_N(H) = -\frac{\beta\phi_d(1-\theta)}{1-\beta(1-\phi_u)(1-\theta)}\pi_N(L). \tag{27}$$

Equations (24), (26), and (27) characterize the value of a hired unit of labor in a firm at the low state of technology

$$v_N(L) = \frac{(\frac{\alpha}{r+\delta})^{\frac{\alpha}{1-\alpha}}(L^{\frac{1}{1-\alpha}} - H^{\frac{1}{1-\alpha}})}{1-\beta(1-\theta)(1-\phi_u-\phi_d)}.$$

The fraction of labor hired in firms at the high state of technology is given by

$$\mu_N = \frac{1-(1-\phi_u)(1-\theta)}{1-(1-\phi_u-\phi_d)(1-\theta)}.$$

I can use this to calculate the fraction of capital used by firms at the high state of technology

$$\mu_K = \frac{\mu_N}{\mu_N + (1-\mu_N)\gamma^{\frac{1}{1-\alpha}}}.$$

The firm-level q's are then given by the value of capital (which is fixed at unity per unit of capital) plus the value imposed through the stock of labor (zero at the high state and negative at the low state). I.e. the firm-level q's are given by

$$q(H) = 1 + v_N(H) = 1, \quad \text{and}$$

$$q(L) = 1 + \frac{v_N(L)}{k_N} = 1 - \frac{\left(\gamma^{-\frac{1}{1-\alpha}} - 1\right)\frac{r+\delta}{\alpha}}{1-\beta(1-\theta)(1-\phi_u-\phi_d)}.$$

Q is then given by

$$Q = \mu_K + (1-\mu_K)q(L).$$

1.5.2 Characteristics of Q in the model based on labor adjustment costs

Table 5 compares the model based on capital irreversibility from section 1.3 with the model based on labor adjustment costs of this section using an exemplary parametrization. For comparability, I set $\delta = \theta = .1$. This implies that when firms are at the low state, they reduce their capital in the model based on capital irreversibility at the same speed that they reduce their labor in the model based on labor adjustment costs. As can be seen in the first row of table 5, the model based on labor adjustment costs results in a lower Q than the model based on capital irreversibility. The main reason for this is simple – The labor share $1 - \alpha$ is larger than the capital share α.

	model with capital irreversibility ($\delta = .1$)	model with labor adjustment costs ($\theta = .1$)	model with both adjustment costs ($\delta = \theta = .1$)
Q	.85	.74	.62
$q(H)$	1	1	1
$q(L)$	.74	.31	.33
μ_K	.44	.63	.44
μ_N	.79	.44	.44

Table 5: Exemplary comparison of the models with capital irreversibility of section 1.3.1, with labor adjustment costs of section 1.5.1, and with capital and labor adjustment costs of section 1.5.3. Parameters: $\alpha = .33$, $\beta = 1.03^{-1}$, $\phi_d = .4$, $\phi_u = .2$, $\delta = .1$, $\gamma = .6$. $q(H)$ is the q of a firm at technology H; $q(L)$ is the q of a firm at technology L; μ_K is the fraction of total capital at technology H; μ_N is the fraction of total labor at technology H.

Since firms have to pay the equilibrium wage rate even when they are at the low state of technology, $q(L)$ can be negative if the labor adjustment costs are sufficiently restrictive. If $q(L)$ is sufficiently negative, theoretically, even Q can be negative. This is, of course, a theoretical result based on high labor adjustment costs, a sufficient combination of the

Markov probabilities, and the assumptions that firms cannot go bankrupt but rather keep existing at a negative firm value.

1.5.3 Model with adjustment costs to capital and to labor

While, everything else equal, the model based on labor adjustment costs produces lower levels of Q than the model based on capital adjustment costs, it is straight forward that a model based on both types of costs would result in an even stronger mechanism.[12] To quantify the potential Q of an economy that is subject to both types of adjustment costs, I consider the most simple version of such a model. The setup is identical to the model with labor adjustment costs above, but labor and capital are subject to a bounded range of downward-adjustability. For simplicity, I assume that this range is identical for capital and labor and, as above, captured by the parameter θ. That is, in any period, capital and labor can be downward-adjusted without any costs up to a fraction θ, while any adjustment beyond this is infinitely costly.

Profit maximization and the ratio of labor to capital As a result of the two costs, both, capital and labor, become state variables for firms. However, as the cost parameter is identical for capital and labor, the ratio of capital to labor is constant over time and identical over firms. As in section 1.3, I define n_K as the amount of labor per unit of capital. n_K is

[12] This can be seen in table 5. As $q_H = 1$, Q is a combination of $q(L)$ and the fraction of capital operating at the low state $(1 - \mu_K)$. While $q(L)$ is low in the model based on labor adjustment costs, the fraction of capital operating at the low state is high in the model based on capital adjustment costs.

set by firms at the high state as to maximize profits, and given by

$$n_K \;=\; n_K(H) \;=\; n_K(L) \;=\; \left((1-\alpha)\frac{H}{w}\right)^{\frac{1}{\alpha}}.$$

When firms drop to the low state of technology, n_K stays constant due to the unique adjustment parameter for capital and labor, making state indicators redundant.

Given the unique ratio of labor to capital, captured by n_K, it is instructive to use composite units, where each composite unit consists of one unit of capital and n_K units of labor. In everything that follows, variables per composite unit are denoted in lower case letters with G subscripts. Profits per composite unit at the high and low state of technology are given by

$$\pi_G(H) = H\left((1-\alpha)\frac{H}{w}\right)^{\frac{1}{\alpha}-1} - w\left((1-\alpha)\frac{H}{w}\right)^{\frac{1}{\alpha}}, \quad \text{and} \tag{28}$$

$$\pi_G(L) = L\left((1-\alpha)\frac{H}{w}\right)^{\frac{1}{\alpha}-1} - w\left((1-\alpha)\frac{H}{w}\right)^{\frac{1}{\alpha}}, \tag{29}$$

where (28) is a rearranged version of (3) evaluated at $a = H$.

The value of a composite unit The value functions for composite units at the high and the low state of technology, respectively, are given by

$$v_G(H) = \pi_G(H) + \beta\big[(1-\phi_d)\max\{(1-\theta)v'_G(H) - (\delta-\theta), v'_G(H) - \delta\}... \tag{30}$$

$$... + \phi_d \max\{(1-\theta)v'_G(L) - (\delta-\theta), v'_G(L) - \delta\}\big], \text{ and}$$

$$v_G(L) = \pi_G(L) + \beta\big[(1-\phi_u)\max\{(1-\theta)v'_G(L) - (\delta-\theta), v'_G(L) - \delta\}... \tag{31}$$

$$... + \phi_u \max\{(1-\theta)v'_G(H) - (\delta-\theta), v'_G(H) - \delta\}\big].$$

Equilibrium The dynamic steady state equilibrium of this economy is a combination of propositions 1 and 4.

Proposition 5. *In a dynamic steady state equilibrium, $v_G(H) = 1$ and $v_G(H) < 1$.*

Proof. *See appendix.*

Equations (28)-(31) together with proposition 5 pin down $v_G(H)$. The fraction of composite units at the high state of technology is given by

$$\mu_G = \frac{(1-\theta)\phi_u + \theta}{(1-\theta)(\phi_u + \phi_d) + \theta}.$$

Finally, Q is given by

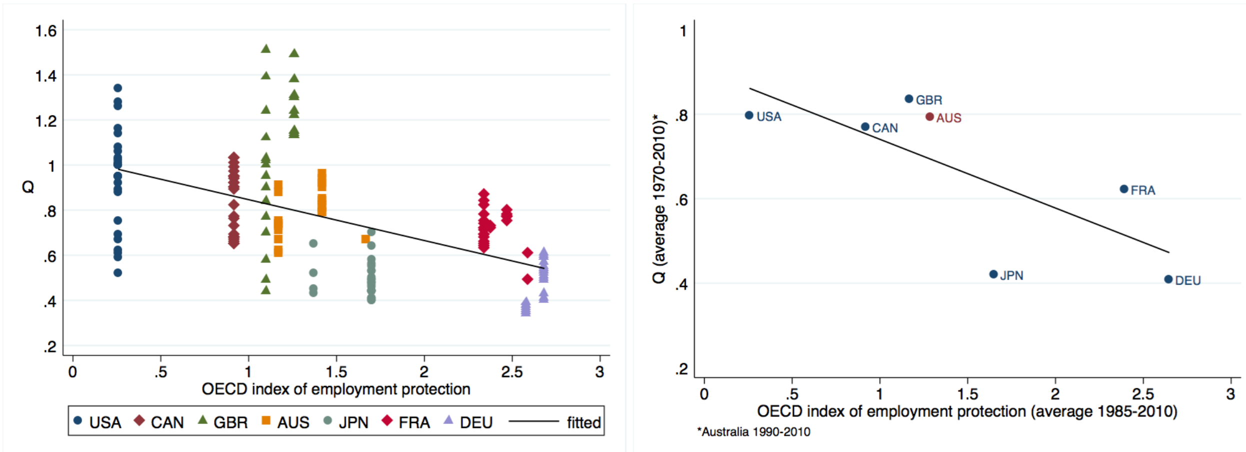
$$Q = \mu_G + (1-\mu_G)v_G(L).$$

The last column of table 5 depicts the model values using an exemplary parametrization and compares the values to the models of section 1.3.1 and 1.5.1, i.e. the models based on just capital irreversibility and just labor adjustment costs, respectively. Unsurprisingly, the model based on both, capital and labor adjustment costs, results in the lowest Q.[13] It is, however, interesting to note that, given the parametrization, the reason for this is not a lower $q(L)$, but only a higher fraction of capital at the low state. This implies that the model with both adjustment costs reduces Q but does not necessarily increase the dispersion of firm level q's.

1.5.4 Employment protection and cross-country differences

The key assumption of the model above is that downward-adjusting labor is costly while upward-adjusting labor is not subject to any costs. Employment protection regulations can constitute exactly this kind of labor adjustment costs. The OECD publishes an index of employment protection starting in 1985 for all countries that are covered by my Q data. Figure 4a plots the Q data on the index of employment protection year by year. In order to cover the whole timespan of the Q data, and since the index for employment protection does not change much, figure 4b repeats the exercise with the sample averages.

[13] Since the exemplary parametrization of table 5 sets $\delta = \theta$, capital adjustment costs as introduced in this section (1.5.3) are identical to capital irreversibility as used in section 1.3.



(a) Yearly plot 1985-2010.

(b) Sample averages.

Figure 4: Q versus OECD strictness of employment protection. Data from Piketty (2014) and the OECD.

Figure 4 depicts what the model with labor adjustment costs predicts – the value of installed capital is much lower in countries with higher employment protection. A linear regression with and without time fixed effects is significant at the 1% level (table 6). In the regression with time fixed effects, the R^2 is at a high 55%.

Variable	**I**	**II**
OECD index of employment protection	-.181***	-.183***
	(.021)	(.018)
Constant	1.028***	1.031***
	(.035)	(.031)
Time fixed effects	no	yes
N	177	177
R^2	.300	.546

Table 6: Estimation results: OLS regression on Q.

It is important to note that explicit employment protection laws, as captured by the OECD index of employment protection, are not the only type of regulation that can impose frictions to downward-adjusting labor. Unions, or regulation about employee participation might have comparable effects.

1.6 Concluding remarks

In this chapter, I presented a solution as to why Q averages below unity in all developed economies covered by my data. The solution heavily relies on idiosyncratic shocks combined with capital or labor adjustment costs, but does not require any other frictions, like distortionary taxes.

I also offered an explanation for the systematic differences in Q across countries. This part required the inclusion of heterogeneous levels of labor adjustment costs across countries. In the model, the level of labor adjustment costs has important implications for firm values. Higher labor adjustment costs reduce the average value of firms, while it increases the volatility of firm values. The model, furthermore, has implications for firm characteristics. If labor adjustment costs are high, the average ratio of capital per employee is low. In a model with credit constraints, higher labor adjustment costs would imply higher credit constraints under weak assumptions. The results of this chapter accordingly suggest that studies targeting these variables in countries with low levels of Q should take into account labor adjustment costs.

The theory introduced in this chapter also has implications for q-theory at the firm level. While, in the model, q-theory holds up to the effects of investment adjustment costs, this can be changed if firms are large and diversified. If a corporation is, in fact, a combination of many smaller firms, i.e. if the corporation is sufficiently diversified, then, in the model, the characteristics of such a corporation would be close to the characteristics of an entire economy. That is, the corporation would have a q below unity combined with positive and rather constant levels of investment. As an example, in my data, the q of General Electric, arguably the most diversified company in the S&P 500, is below unity in most quarters and, for most of the time, very close to the Q of the US.

Applying the model to study changes in Q over time is beyond the scope of this chapter. It is, however, clear that the model offers several channels to do so. The two most straightforward channels are changes in the distribution of idiosyncratic shocks over time and changes in the regulation of labor markets.

A puzzle with respect to movements in Q over time is the low stock market valuation in the US and other countries in the 1970s and early 1980s. It has been argued that the low valuation during this time is particularly puzzling since, at the same time, technological progress and innovation was high. Jovanovic and Greenwood (1999) address this puzzle and argue that new technologies might be developed by new firms, and that it takes time until these firms are recorded in the data. As a result, there exists a downward bias on the measured value of capital during a time of high innovation. In the class of model introduced in this chapter, the same result can be derived even if new firms are perfectly observed. In the model, if growth is incorporated, the absolute level of technology does not matter for Q, but the relative level of technology matters for the firm level q's. If innovation is, for some time, driven by new (and accordingly small) firms, then a large share of capital (and potentially labor) is at a comparably low state of technology resulting in a low Q.

Laitner and Stolyarov (2003) offer an explanation for the low stock market valuation in the 1970s and early 1980s, based on intangible capital. In their data, Q is above unity before the time of low stock market valuation. They argue that this is an indicator for the existence of high levels of intangible capital before the collapse of stock prices in the early 1970s. Wright (2005), however, shows that the data used in Laitner and Stolyarov (2003) is wrong and Q was, in fact, below unity. This chapter offers an explanation for how relevant levels of intangible capital and a Q around or below unity can co-exist.

The strong movements of Q in the UK might be addressed with changing labor market regulation, in particular, the labor market reforms under Margaret Thatcher. While the OECD index of employment protection has not changed much during Thatcher's premiership, Thatcher is known for having increased the relative power of employers over employees. This can be interpreted as a reduction of the costs to downward-adjusting labor. A comparable argument, presumably at a lower magnitude, can be made for the US under Ronald Reagan.

Chapter 2:

Business Internationalization and the Aggregate Tobin's Q

2.1 Introduction

Over the course of the last three decades, the ratio of the aggregate total market value of corporations over the replacement cost of their recorded capital, the aggregate Tobin's Q, has exhibited a strong upward trend in all of the countries I consider.[14] In everything that follows, I simply refer to this ratio as Q. In this chapter, I argue that increased business internationalization, especially the increase in international trade, might have been a driving force for this trend.

An increase in the market value of corporations' relative to the replacement cost of their recorded capital is an indicator for a change in corporations intangible capital.[15] In this chapter, I argue that a significant part of intangible capital can be understood as having invented a differentiated good. Differentiated goods are commonly used in the trade literature to motivate trade. Compared to standard models with differentiated goods, the key difference in this chapter is that I assume differentiated goods, referred to as elaborated goods below, have to be invented. Once a differentiated good has been invented by a firm, the firm can exclusively produce and sell the good for several periods. As a result, owning the rights

[14] The countries I consider are Australia, Canada, France, Germany, Japan, the United Kingdom, and the United States (US).

[15] I refer to recorded capital as accounting frameworks do attempt to record some of the intangible capital.

and technology to produce an elaborate good constitutes a stock of intangible capital.[16] I furthermore assume that firms can also produce an undifferentiated simple good. This type of good does not have to be invented; it can be produced by any firm, and it is identical in all countries. As a result of this setup, elaborated goods are sold internationally (either via trade or foreign direct investment) so that households in all countries can consume all goods that have been invented. In other words, trade is motivated via monopolistic competition in the standard way as introduced by Krugman (1979). The key goal of this chapter is to show that increased business internationalization can result in a shift from simple to elaborate goods, which leads to an increased stock of intangible capital. If intangible capital is imperfectly recorded, this in turn results in an increased Q.

As pointed out by McGrattan and Prescott (2010), intangible capital deserves attention as it is, by definition, imperfectly measured. If an economy shifts towards more intangible capital, as suggested by the increased Q, then gross domestic product (GDP) might be underestimated. Furthermore, if the investment share in tangible investment does not change substantially, then increased investment in intangible implies an increased stock of total capital. This can in turn affect other important variables like corporate profits or the labor share. It is accordingly important to know why an economy shifts towards more intangible capital, and how this intangible capital affects output (measured and real) and utility. In contrast to McGrattan and Prescott (2010), in this chapter increased intangible investment is not a result of a shift in technology, but rather a shift in a country's openness. This is an important difference as a shift in technology affects the growth rate of labor productivity.

[16]It is fair to assume that several types of investment usually classified as investments in intangibles, like research and development, marketing, or organizational spending, are necessary to set up an elaborate good.

The invention of elaborate goods in this chapter does not affect long-run output as new elaborate goods only increase household utility and do not affect the production technology.

The model introduced in this chapter relates to McGrattan and Prescott (2009), who introduce a model based on firm-specific capital to study foreign direct investment. The setup for elaborate goods in this chapter is similar to firm-specific capital in McGrattan and Prescott (2009). Empirical evidence for an increase in intangibles investment in the US is given by Hall (2001) and Corrado et al (2009). Empirical evidence for increased investment in intangibles in the other countries I consider is given Corrado et al (2013). Several authors have documented a decline in the labor share over the same timespan as Q has increased for the US and other countries, including Rodriguez and Jayadev (2010), Karabarbounis and Neiman (2012 and 2014), and Elsby et al (2013). Somewhat in line with the ideas of this chapter, Koh et al (2015) find that intellectual property is the main driver of the declining US labor share. Besen (2016) argues that, for the US, the increase in corporate profits and Q is related and potentially explained by increased lobbying.

The remainder of this chapter is structured as follows. Section 2.2 summarizes the data on which this chapter is based. Section 2.3 introduces the model, explains its results, and conducts the analysis. A final section concludes.

2.2 Data

Q is defined as the ratio of the aggregate total market value of US corporations over the replacement cost of their recorded capital. Data spanning the last three decades for seven of the eight largest advanced economies is depicted in figure 2. More historical data for the US is depicted in 1. Further details on the calculation of Q are given in chapter 1. While Q

is subject to strong low frequency movements, it showed a clear upward trend over the past three decades in all of the countries I consider. An explanation for why Q averages below unity despite the existence of intangible capital is given in chapter 1.

Data on the trade shares as a percentage of GDP for the countries I consider is available from the World Bank for the period 1960-2015.[17] Figure 5 depicts this data, indexed so that the value of each country equals 100 in the year 2015. Over the past four decades, all countries have experienced a strong increase in the importance of international trade.

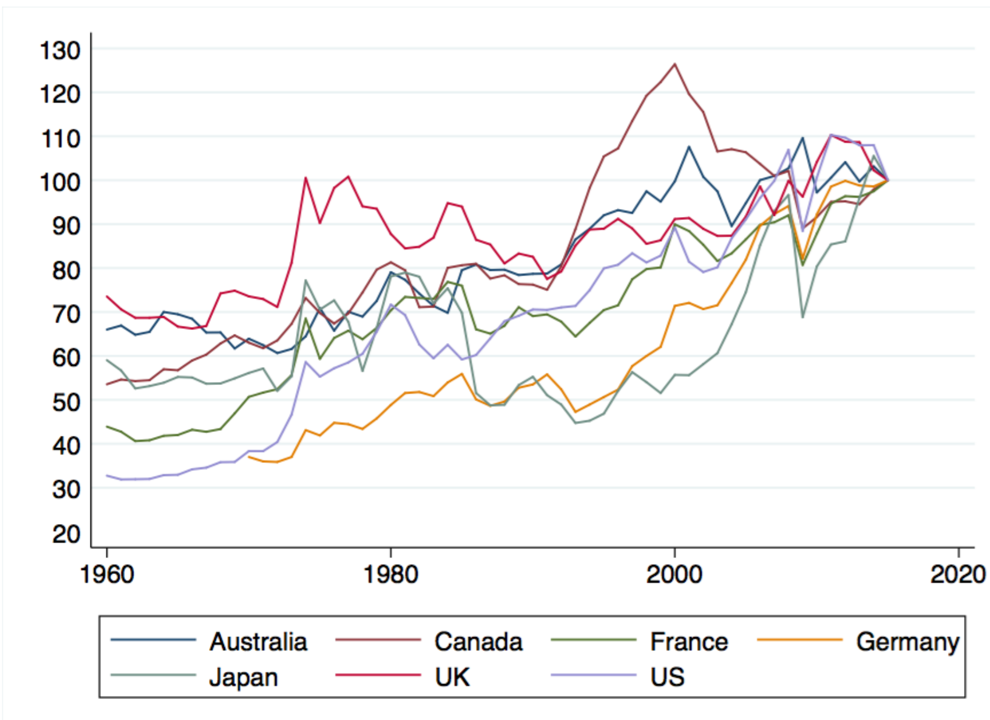


Figure 5: Trade share as a percentage of GDP (Indexed: 2015 = 100). Datasource: The World Bank.

[17]The data for Germany starts in 1970.

2.3 Model

This section introduces a model that can link business internationalization and Q. In the model, the existence of elaborate goods which have to be invented constitute intangible capital. The goal of the model is to show that investment in intangibles as a share of GDP is a function of the market size. As the model does not exhibit any interesting transitionary dynamics, I focus on the steady state of the model when solving the model and when conducting my analysis.

2.3.1 Setup

The economy constitutes of L workers, each of whom provides one unit of labor per period (inelastically), and firms that produce two types of consumption goods. The first type of good, henceforth referred to as simple good, is a homogenous good that can be produced by any firm without any barriers to market entry. The second type of good, henceforth referred to as elaborate goods, are differentiated goods which have been invented by a firm and can only be produced and sold by this firm. Households consume both types of goods. The simple good also serves as capital good.[18] For the production of both types of goods as well as for the innovation of new elaborate goods both, capital and labor, serve as inputs.

Production of the simple good The simple good can be produced by any firm at constant returns to scale without any barriers to market entry. The production function for

[18]Restricting elaborate goods to consumption goods (but not some type of capital good) does not affect the key results of the model.

every firm is given by

$$x_S = \mu_S^{-1} k_S^{\alpha} l_S^{1-\alpha},$$

where k_S and l_S are capital and labor, respectively, used towards the production of the simple good, and where x_S is the output of the simple good. As all firms are subject to the same technology, and as the output good is homogenous, a representative firm is used in everything that follows. As a result, k_S and l_S are total capital and labor, respectively, used in the simple good sector, and x_S is the total output of the simple good. As mentioned above, the simple good serves as consumption good and as capital good. Accordingly, while in equilibrium total production equals total consumption of each elaborate good, total production of the simple good equals total consumption plus total production of new capital goods. If a unit of the simple good is used as capital capital good, it is subject to the depreciation rate δ_K.

Innovation of elaborate goods In order to invent an elaborate good, a firm has to employ γ_L units of labor and use γ_K units of capital for one period. Once an elaborate good has been invented, it can be produced starting in the next period. In every successive period, it still exists with probability $1 - \delta_E$. For simplicity, I assume that every type of elaborate good is invented by a separate firm indexed by i subscripts. The total number of elaborate goods is denoted by n.

Production of elaborate goods Once a firm has invented an elaborate good, it can exclusively produce the good making use of the production technology

$$x_{E,i} = \mu_E^{-1} k_{E,i}^{\alpha} l_{E,i}^{1-\alpha},$$

where $k_{E,i}$ and $l_{E,i}$ are capital and labor used by firm i, respectively, and where $x_{E,i}$ is the total output of firm i's elaborate good.

Household utility Depicting per household consumption of the simple good by c_S and per household consumption of firm i's elaborate good by $c_{E,i}$, total household utility U is given by the utility function

$$U \;=\; u_S(c_S) + \psi \sum_{i=1}^{n} u_E(c_{E,i}) \;=\; \sigma^{-1} c_S^{\sigma} + \psi \sum_{i=1}^{n} \sigma^{-1} c_{E,i}^{\sigma},$$

where $0 < \sigma < 1$. The rationale for using this type of utility function is that, theoretically, a large number of elaborate goods could be invented, but, given the cost of inventing elaborate goods, only a number n exists. Households value each elaborate good equally and have decreasing utility in each good. Households discount the future at the discount rate $\beta \in (0, 1)$.

Ownership of capital and firms Households save part of their labor income to buy capital goods and rent them out to firms. Furthermore, households own all firms via a mutual fund.[19] While the representative firm producing the simple good does not have an

[19] The only function of the mutual funds is to diversify the risk of individual elaborate good producing firms (the risk being that the good stops to exist.)

intrinsic value, elaborate good producing firms own the rights and technology to produce their good, make profits on selling the good to compensate for the cost of innovating the good, and hence have a positive firm value. All profits are distributed to the workers via the mutual fund. Firms rent capital from the households to use it for production. The equilibrium interest rate for capital goods is denoted by r. The total costs of capital is denoted by

$$R = r + \delta_K.$$

2.3.2 Equilibrium

In everything that follows, I use the simple good as numeraire, i.e. I set $p_S = 1$.

Cost of producing a unit of an output good Cost minimization implies that the simple good producing firm chooses[20]

$$\frac{k_S}{l_S} = \frac{\alpha}{1-\alpha}\frac{w}{R}, \tag{32}$$

and, equivalently, every elaborate good producing firm chooses

$$\frac{k_{E,i}}{l_{E,i}} = \frac{\alpha}{1-\alpha}\frac{w}{R}. \tag{33}$$

[20]The numeraire $p_S = 1$ is imposed in the cost function.

The production function together with (32) implies that in order to produce one unit of the simple good, the representative simple good producing firm chooses a set $\{\bar{k}_S, \bar{l}_S\}$ given by

$$\bar{k}_S = \mu_S \left(\frac{\alpha}{1-\alpha} \frac{w}{R} \right)^{1-\alpha}, \quad \text{and} \tag{34}$$

$$\bar{l}_S = \mu_S \left(\frac{\alpha}{1-\alpha} \frac{w}{R} \right)^{-\alpha}. \tag{35}$$

Accordingly, making use of (33), every elaborate good producing firm chooses a set $\{\bar{k}_E, \bar{l}_E\}$ given by

$$\bar{k}_E = \mu_E \left(\frac{\alpha}{1-\alpha} \frac{w}{R} \right)^{1-\alpha}, \quad \text{and} \tag{36}$$

$$\bar{l}_E = \mu_E \left(\frac{\alpha}{1-\alpha} \frac{w}{R} \right)^{-\alpha}. \tag{37}$$

Given (34)-(37), the cost of producing a unit of the simple good is given by

$$z_S = \mu_S \left(\frac{R}{\alpha} \right)^{\alpha} \left(\frac{w}{1-\alpha} \right)^{1-\alpha}, \tag{38}$$

and the cost of producing a unit of any of the elaborate goods is given by

$$z_E = \mu_E \left(\frac{R}{\alpha} \right)^{\alpha} \left(\frac{w}{1-\alpha} \right)^{1-\alpha}. \tag{39}$$

Demand for goods Demand for the simple good and each elaborate good is characterized by

$$\dot{u}_S(c_S) = \lambda p_S\,, \quad \text{and} \tag{40}$$

$$\dot{u}_E(c_{E,i}) = \psi^{-1}\lambda p_{E,i}, \tag{41}$$

where λ is a multiplier on a budget constraint, and where I use Newton's notation for derivatives of the utility sub-functions.

Pricing of simple goods Free entry to the simple good sector implies that the price of the simple good, p_S, is given by

$$p_S = z_S. \tag{42}$$

As the simple good serves as the numeraire, this implies that $z_S = 1$, and, from (38) and (39), $z_E = \frac{\mu_E}{\mu_S}$.

Pricing of elaborate goods Elaborate good producing firms make positive profits to make up for the cost of inventing the good. These profits are given by

$$\pi_{E,i} = (p_{E,i} - z_E)x_{E,i}.$$

Profit maximization given household utility results in the pricing equation

$$p_{E,i} = \left(\frac{\ddot{u}_E(c_{E,i})}{\dot{u}_E(c_{E,i})} c_{E,i} + 1 \right)^{-1} z_E = \sigma^{-1} z_E. \tag{43}$$

Equilibrium consumption Since all elaborate good producing firms are subject to the same production technology, and all elaborate goods enter utility in the same way, in equilibrium, all prices and quantities of the elaborate goods are identical, i.e.

$$p_{E,i} = p_E, \quad x_{E,i} = x_E, \quad c_{E,i} = c_E, \quad k_{E,i} = k_E, \quad l_{E,i} = l_E, \quad \pi_{E,i} = \pi_E.$$

Taking the ratio of (40) and (41), and making use of the pricing equations (42) and (43) gives a direct relationship of the relative consumption of the simple and each elaborate good

$$c_S = c_E \left(\psi \sigma \frac{\mu_S}{\mu_E} \right)^{\frac{1}{\sigma - 1}}. \tag{44}$$

Equilibrium on the capital market On the market for capital goods, the equilibrium one period interest rate is given by

$$r = \beta^{-1} \frac{MU}{MU'} - 1,$$

where $MU = p_S^{-1} \dot{u}_S(c_S) = p_E^{-1} \psi \dot{u}_E(c_E)$, and where MU' depicts the respective price weighted marginal utility of the next period.

Zero profits of inventing an elaborate good I denote the value of owning the rights and technology to produce an elaborate good by v. This value is characterized by

$$v = \pi_E + (1 - \delta_E)\frac{E(v')}{1 + r}, \tag{45}$$

where prime superscripts denote the next period's variables. Free entry up to the cost of innovation implies that the cost of inventing a new elaborate good has to be equal to the expected discounted value of owning the rights and technology to produce an elaborate good, i.e.

$$\frac{E(v')}{1 + r} - \gamma_L w - \gamma_K R = 0. \tag{46}$$

Market clearing and resource constraint Production of each elaborate good has to meet consumption of the respective good, implying

$$x_E = Lc_E. \tag{47}$$

As the simple good is used for consumption and as capital good, market clearing is given by

$$x_S = Lc_S + [K' - (1 - \delta_K)K] + [n' - (1 - \delta_E)n]\gamma_K, \tag{48}$$

where prime superscripts denote the next period's variables. That is, total production of the simple good has to meet consumption of the simple good, but it also has to meet the amount of the simple good that has to be produced in order to be used as capital good. The total stock of capital is given by

$$K = k_S + nk_E + (n' - (1-\delta_E)n)\gamma_K$$
$$= x_S\bar{k}_S + nx_E\bar{k}_E + (n' - (1-\delta_E)n)\gamma_K. \tag{49}$$

Finally, total labor supply has to meet total labor demand, implying

$$\bar{l}_S x_S + n\bar{l}_E x_E + \gamma_L[n' - (1-\delta_E)n] = L. \tag{50}$$

Prime superscripts again denote the next period's variables. The first term on the left hand side is labor demand for the production of the simple good, the second term is labor demand for the production of elaborate goods, and the third term is labor demand for the innovation of new elaborate goods.

2.3.3 Steady state

In steady state, the interest rate r is given by

$$r = \beta^{-1} - 1, \tag{51}$$

and, accordingly, the gross rental rate R is given by

$$R = \delta + \beta^{-1} - 1. \tag{52}$$

Using the fact that $z_S = 1$ in (38) gives the equilibrium wage

$$w = (1-\alpha)\mu_S^{\frac{1}{\alpha-1}}\left(\frac{\alpha}{R}\right)^{\frac{\alpha}{1-\alpha}}. \tag{53}$$

Imposing steady state on (45) and (46) implies that steady state profits per elaborate good are given by

$$\pi_E = (\delta_E + r)(\gamma_L w + \gamma_K R). \tag{54}$$

Combining (54) with the definition of profits, given by $\pi_E = (p_E - z_E)x_E$, and making use of the pricing equation (43) gives the steady state quantity of each elaborate good

$$x_E = \frac{(\delta_E + r)(\gamma_L w + \gamma_K R)}{(\sigma^{-1} - 1)z_E}. \tag{55}$$

Combining (44) with (47)-(49) implies that the quantity of the simple good is given by

$$x_S = \frac{1}{1 - \delta_K \bar{k}_S}\left[x_E\left(\psi\sigma\frac{\mu_S}{\mu_E}\right)^{\frac{1}{\sigma-1}} + \delta_K n x_E \bar{k}_E + \delta_E n \gamma_K\right]. \tag{56}$$

Finally, imposing steady state on (50) gives

$$\bar{l}_S x_S + n\bar{l}_E x_E + \gamma_L \delta_E n = L. \tag{57}$$

2.3.4 Q as a function of the market size

Equations (34)-(39), (51)-(53), and (55)-(57) are a set of 12 equations with 12 endogenous variables ($\bar{k}_S$, $\bar{k}_E$, $\bar{l}_S$, $\bar{l}_E$, z_S, z_E, r, w, x_S, x_E, n) that characterizes the steady state of the model as a function of the exogenous variable L and the parameters of the model.

	$L = 100$	$L = 200$	$L = 500$	$L = 1000$
n/L (elaborate goods per capita)	2.84	5.79	7.55	8.14

Table 7: Number of elaborate goods as a function of the market size. Parameters given by table 8.

Table 7 shows the steady state number of elaborate goods per capita for an exemplary parametrization given by table 8. This ratio represents the core of the model: As the population increases, the economy shift away from producing the simple good and shifts to inventing and producing new elaborate goods. As a result, the steady state number of elaborate goods per capita, and accordingly also the steady state investment in intangibles, increases with an increased population. As can also be seen in table 7, this effect flattens off at some point when household consumption is dominated by elaborate goods. The point at which this happens, of course, depends on the parametrization of the model.

α	β	δ_K	δ_E	$\frac{\mu_S}{\mu_E}$	γ_L	γ_K	ψ	σ
.33	1.03^{-1}	.1	.1	1	.3	.5	.05	.5

Table 8: Model exercise: Parameter choice.

If investment in new elaborate goods was perfectly accounted for as investment, then Q would be at unity in the model. However, intangibles are, by definition, hard to account for and, presumably, mostly expensed as operating costs.[21] If investment in intangibles is wrongly expensed as operating costs, then Q is given by

$$Q = \frac{K + nv}{K}.$$

Total (tangible) capital K appears in both, the numerator and the denominator. The term nv represents the total value of intangible capital. As markets correctly value intangible capital, but books do not, the term appears in the numerator but not in the denominator.[22] Depending on the state of the economy and the exact accounting framework, in the model, Q can easily increase at a magnitude comparable to the increase observed in the data in response to a significant change in openness.

Two annotations to this exercise are necessary. First, in the model, Q is strictly larger than one, while Q appears to average below unity in the data (figures 1 and 2). An explanation for why Q averages below unity can be found in chapter 1. The reasons put forward in chapter 1 are, however, orthogonal to the analysis conducted in this chapter and therefore ignored in here. Second, it is worth noting that if intangibles investment is imperfectly recorded, measured TFP falls with an increased population while Q (and household utility) increase.

[21] There has been a recent effort to better account for investment in intangibles. However, Corrado et al (2009) argue that the majority of investment in intangibles is still unrecorded.

[22] It is straight forward to see that if the accounting framework accounts for some but not all investment in intangibles, then a fraction of the term nv would appear in the denominator.

2.3.5 Comparative advantage

In the model introduced above, I did not model countries explicitly and solely concentrated on the market size effect. It is, however, straight forward to see that if countries were modeled explicitly, a difference in technology between countries could be implemented in the model. Based on this, a comparative advantage effect could be analyzed if one country is comparatively better at developing new elaborate goods. This could be particularly interesting with respect to the massive increase in the US's trade with China. Such an analysis is, however, beyond the scope of tis chapter.

2.4 Concluding remarks

In this chapter, I introduced a model that links business internationalization with intangibles investment and Q. I put forward the idea that some intangible capital can be understood as having invented a differentiated good. Based on this idea, I developed a model in which an increased market leads to a shift away from producing non-differentiated goods and a shift to inventing and producing more differentiated goods. As a result, increased openness (for trade and/or foreign direct investment) stimulates investment in intangibles, which increases Q. I argue that this mechanism can explain an increase in Q comparable to the increase observed in the data.

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Appendix

Proofs

Proof of proposition 1: First part of the proposition: (i) Suppose $q(H) > 1$: If $q(H) > 1$, firms at the high state of technology can make their existing shareholders better off by increasing the firms capital stock. As a result investment increases. Given (2), a constant labor force, and the assumptions on household utility, w has to increase to clear the labor market. Given (3) profits per unit of capital decrease. Given (5) and (6), $q(H)$ decreases. (ii) Suppose $q(H) < 1$: Same steps as above but vice versa. $q(H)$ increases. The second part of the proposition then follows directly from (7) and (8), and the fact that $\pi_K(H) > \pi_K(L)$.

Proof of proposition 2: The proof of the first part of proposition 2 is identical to the proof of the first part of proposition 1, where $q(H)$ is replaced by $v_I(H)$. The second part of the proposition then follows directly from (12) and (13), and the fact that $v_K(H) > v_K(L)$.

Proof of proposition 3: (i) Suppose $v_I(\tilde{a}) > 0$: If $v_I(\tilde{a}) > 0$, some firms with technology below $\tilde{a}$ can make their existing share holders better off by increasing investment implying that the capital stock K increases. Given (14), a constant labor force, and the assumptions on household utility, w has to increase to clear the labor market. Given (15), $\pi_K(a)$ decreases and which, given (19) and (21), implies that $v_I(\tilde{a})$ decreases. (ii) Suppose $v_I(\tilde{a}) < 0$: Same steps as above but vice versa. $v_I(\tilde{a})$ increases.

Proof of proposition 4: First part of the proposition: (i) Suppose $v_N(H) > 0$: If $v_N(H) > 0$, firms at the high state of technology can make their existing share holders better off by hiring more labor. Given a constant labor force and the assumptions on household utility w has to increase to clear the labor market. Given (24), profits per unit of labor would decrease. Given (25) and (26), $v_N(H)$ decreases. (ii) Suppose $v_N(H) < 1$: Same steps as above but vice versa. $v_N(H)$ increases. The second part of the proposition then follows directly from (25) and (26), and the fact that $\pi_N(H) > \pi_N(L)$.

Proof of proposition 5: The proposition follows directly from propositions 1 and 4.

Data appendix

Firm level q data: All firm level data is from the Compustat North America fundamentals quarterly database. I exclude all firms that are classified as Finance and Insurance (NAICS 52) or Real Estate and Rental and Leasing (NAICS 53) from my analysis. The numerator of the firm level q is defined as the sum of the equity market value (series CSHOQ multiplied with series PRCCQ) and the book value of debt (series LTQ). The denominator of the firm level q is defined as total assets (series ATQ) adjusted for inflation. To adjust for inflation I use the consumer price index for all urban consumers and all items from the Federal Reserve Bank of St. Louis. I furthermore assume for each firm that all of the respective firm's capital that was accumulated before the first observation was accumulated constantly and according to the average depreciation rate of that firm.