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Too much R&D - Vertical Differentiation in a Model of Monopolistic Competition

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Too Much R&D?
– Vertical Differentiation in a Model of Monopolistic Competition

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Abstract

This paper discusses a model of vertical and horizontal product differentiation within the Dixit-Stiglitz framework of monopolistic competition. Firms compete not only in prices and horizontal attributes of their products, but also in the quality that can be controlled by R&D activities. Based upon the results of a general equilibrium model, intra-sectoral trade and the welfare implications of public intervention in terms of research promotion are considered. The analysis involves a numerical application to ten basic European industries.

Keywords: R&D, Monopolistic Competition, Product Differentiation
JEL classifications: D43, F12, L13, L16

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1 Introduction

The concept of monopolistic competition has enjoyed great popularity since the seminal work of Dixit and Stiglitz (1977) – the beginning of the "second monopolistic revolution", as contemplated by Brakman and Heijdra (2004). This idea has penetrated different fields of research. Basic models of international trade utilize the monopolistically competitive framework (e.g., Krugman (1979, 1980), Dixit and Norman (1980)) as well as fundamental contributions within the endogenous growth literature (e.g., Romer (1987, 1990), Lucas (1988)).

An essential attribute in models of monopolistic competition is horizontal product differentiation, as described by Hotelling (1929) and advanced by Chamberlin (1933). Beside differentiation in terms of product characteristics (e.g., design, color or taste), newer literature considers quality as an additional vertical dimension of product space.[1] The corresponding branch of industrial organization was originated by Shaked and Sutton (1982, 1983, 1987) and Gabszewicz and Thisse (1979, 1980). Following the classification of Sutton (1991), Schmalensee (1992) distinguished Type 1 and Type 2 industries. While a Type 1 industry is characterized by horizontally differentiated (or homogenous) products, Type 2 firms compete not only in price and horizontal product attributes, but also in perceived quality. In this context, quality is influenced by R&D expenditures, so that a firm may increase its market share by increasing the quality of its product.

Beyond the oligopolistic market structures and the game-theoretical perspective of this field of Industrial Organization, this paper aims to establish a basic model of vertical product differentiation for further implementation in international trade. The main assumptions underlying this paper are referenced to the *New Economic Geography* (NEG). Initially introduced by Krugman (1991), the NEG aims to explain industrial agglomeration using the framework of monopolistic competition à la Dixit Stiglitz. The model here incorporates explicitly R&D activities, beyond the "anonymous" consideration within the fixed factor usually exercised in the NEG literature.[2]

Furthermore, we include endogenous quality in the seminal model of Dixit and Stiglitz (1977), and analyze both vertical and horizontal product differentiation. In order to consider the impact of R&D from a macroeconomic point of view, we design a general equilibrium model, where households offer unskilled labor and research personnel. Detached from an analysis of particular product markets, with a

[1] Furthermore, product differentiation is formalized by the *Goods Characteristics* approach, as pioneered by Lancaster (1966). See Tirole (1988), Chapter 2.

[2] See for instance the Footloose Entrepreneur Model of Ottaviano (1996) and Forslid (1999), where the fixed factor or human capital is inter-regionally mobile.

focus on the mechanisms in aggregates, we have chosen monopolistic competition, rather than the oligopolistic market structures that are discussed in the literature of Industrial Organization. This paper introduces the potential to model an explicit R&D sector and the analysis of economic policy instruments in terms of research promotion. Finally, we analyze the allocation outcome in the presence of vertical linkages by introducing a simple input-output relationship between firms in the manufacturing sector.

The paper is structured as follows. In Section 2, we build the basic model with one manufacturing industry. After partial-analytic analysis, we extend the model to endogenous wages and income, as well as a separate research sector. In Section 3, we introduce intermediate trade within the manufacturing sector and consider the comparative statics of market concentration and quality with respect to fixed costs. Section 4 discusses three policy instruments and their implications for social welfare: a) minimum quality standards, b) the control of research costs, and c) the optimal supply in the market for R&D services. A numerical application of the model to real economic data appears in Section 5: for ten European basic industries we compute quality, marginal research costs, and research elasticities. Finally, Section 6 presents a concluding discussion of the main findings and an outlook for future work.

2 The Model

Private Demand

Private households consume two types of goods: a) a homogenous good A produced by a Walrasian constant-return sector (often known as the agricultural sector), and b) differentiated industrial products provided by a manufacturing sector.[3] Consumer preferences follow a nested utility function of the form:

$$(1) \quad U = M^{\mu} A^{1-\mu},$$

where M denotes a concave subutility from the consumption of the continuum of n (potential) industrial goods:

$$(2) \quad M = \left[\sum_{i=1}^{n} (u_i)^{1/\sigma} (x_i)^{(\sigma-1)/\sigma} \right]^{\frac{\sigma}{\sigma-1}} \ , \ \sigma > 1 \ , u_i > 0.$$

While x_i is the quantity consumed of variety i, u_i denotes a product-specific utility parameter, henceforth labeled *product quality*, and σ is the constant substitution

[3] Henceforth, the traditional sector is treated as the numeraire.

elasticity between varieties.[4] Applying *Two-Stage Budgeting*, we obtain the demand function for a representative industrial product sort:

$$(3) \quad x^D = \mu Y u p^{-\sigma} P^{\sigma-1},$$

where μY represents the share in household income for industrial products, and p the market price. Here P is the price index, defined as:

$$(4) \quad P = \left[\sum_{i=1}^{n} u_i \left(p_i\right)^{1-\sigma} \right]^{\frac{1}{1-\sigma}} .$$

As it is easy to reproduce, the demand elasticity in terms of quantity is constant at σ, and in terms of quality it is 1. Interestingly, the price index contains information about product quality as a result of its being the minimum cost for a given subutility M. The higher the quality at constant prices, the lower the consumer costs for reaching a certain level of satisfaction. The demand increases linearly with respect to rising product quality, which results from constant substitution elasticity. Assuming a representative variety, substitution of (4) in (3) reveals a demand that depends upon market size, price, and firm number, but is independent of product quality.

Industrial Supply

Turning to the supply side of this model, the production of a particular variety requires labor as the only input. The corresponding factor requirement is characterized by a fixed and variable cost:

$$(5) \quad l^M = F + ax,$$

where M is mnemonic for manufacturing. Because of economies of scale and consumer preference for diversity, it is profitable for each firm to produce only one differentiated variety, so that the firm number is equal to the number of available product sorts. In addition to production, firms have a capacity for undertaking research activities. According to Sutton (1991), firms can control their product quality by research investments. In contrast with the original Dixit-Stiglitz framework, the proposed model producers have an additional degree of freedom to build up a monopolistic scope, in addition to horizontal product differentiation. Attaining

[4]The functional form of the subutility is based upon the numerical example of Sutton (1991), p. 48 et seq..

and maintaining a certain level of quality requires research expenditures, as given in equation (6).

$$(6) \quad R(u) = \frac{r}{\gamma} u^{\gamma} \ , \ \gamma > 1.$$

The parameter, r, represents a constant cost rate and γ the research elasticity. The research expenditure function shows a deterministic relation. Furthermore, it is convex, implying that increasing product quality requires more and more investments. After all, research is essential; – otherwise, product quality and simultaneously demand become zero.[5] The profit function of a manufacturing firm is given by:

$$(7) \quad \pi = px - R - wF - wax,$$

where w denotes the exogenous wage rate. From profit maximization follows the price-setting rule:

$$(8) \quad p^{*} = \left(\frac{\sigma}{\sigma - 1}\right) aw,$$

where the term in brackets is the monopolistic price mark-up, beyond the marginal production cost. Normalizing the variable production coefficient, a, by $(\sigma - 1)/\sigma$, the profit maximizing price becomes w.[6]
The optimum research policy can be derived from the first derivative of the profit function with respect to quality:

$$(9) \quad \mu Y u p^{-\sigma} P^{\sigma - 1} (p - wa) = r u^{\gamma}.$$

The term on the right-hand side of (9) represents the marginal research cost of increasing product quality, which can also be expressed as γR. The left-hand side shows the increase of the operating profit (profit less research costs), in response to a change in quality. From (9) follows the optimum quality of a particular firm:

$$(10) \quad u^{*} = \left(\frac{\mu Y w^{1-\sigma} P^{\sigma-1}}{\sigma r}\right)^{\frac{1}{\gamma - 1}}.$$

The choice of quality depends upon two factors: (a) research cost, and (b) degree of competition. The higher the cost rate, r, the lower is the product quality due

[5]Sutton (1991) assumes a minimum product quality of 1, even if no research is undertaken. For analytical convenience, we simplify this proposition.

[6]See Fujita et al. (1999), p.54 et seq..

to the optimum rule in (9). Decreasing competitive pressure may result from an increase of market size, a lower substitution elasticity, or a higher profit maximizing price; then firms compete in quality rather than in prices. In other words, firms expand their research activities as the degree of competition decreases. The firm behavior, in terms of firm number and quality, affects demand via the price index. An increase in firm number or competitive quality reduces the price index and thus the demand on a particular firm. Finally, the firm does not have funds to meet research expenditures, which can be seen by substituting the price index into (10):

$$(11)\quad u^{*}=\left(\frac{\mu Y}{\sigma r n}\right)^{\frac{1}{\gamma}}.$$

Equation (11) provides central information: the interdependency between market concentration (measured in number of firms) and product quality. The corresponding research expenditures respond positively to market concentration:

$$(12)\quad R^{*}=\frac{\mu Y}{\sigma\gamma n}.$$

Long Run Equilibrium

The long run equilibrium is characterized by free market entry and exit, and thus, a variable firm number. From the zero-profit condition, we obtain the equilibrium output of each firm:

$$(13)\quad x^{*}=\frac{\mu Y}{\gamma w n}+\sigma F.$$

Compared to the original Dixit-Stiglitz outcome, the equilibrium output depends not only upon exogenous parameters, but also upon the research expenditure. Therefore, firm size is determined by fixed cost of production, as well as by research expenditure and market size, respectively. From (13), we can derive the equilibrium labor input:

$$(14)\quad \left(l^{M}\right)^{*}=F+ax^{*}=\sigma F+\left(\frac{\sigma-1}{\sigma}\right)\frac{\mu Y}{\gamma w n}.$$

Because of the partial-analytic attribute of this model, the labor market is in equilibrium at the wage rate, w, so that labor supply is equal to the labor requirement of firms: $L^{M}=nl^{M}$. From this identity, the firm number can be derived using equation (14):[7]

$$(15)\quad n^{*}=\frac{L^{M}}{l^{M}}=\frac{1}{\sigma F}\left[L^{M}-\left(\frac{\sigma-1}{\sigma}\right)\frac{\mu Y}{\gamma w}\right].$$

[7] From (15) follows the non-negativity condition: $L^{M}>\left(\frac{\sigma-1}{\sigma}\right)\frac{\mu Y}{\gamma w}$.

General Equilibrium

Considering the model from a macroeconomic point of view, we adopt a simple general equilibrium framework. To internalize wages and income, we introduce a separate R&D sector receiving the corresponding expenditures of the manufacturing industry. We assume a linear constant-return technology, where one unit of R&D requires one unit of scientific input (e.g. research staff).[8] The traditional sector uses unskilled labor as input within a linear technology, where one unit of labor generates one unit of output. Because the homogenous good is the numeraire, the corresponding price is set to 1.

The long run GDP of the economy consists of the labor income, the agricultural revenues, and the earnings of the R&D sector:

$$(16)\quad Y = wL^M + L^A + nR.$$

Following Fujita et al. (1999), we normalize the manufacturing workforce, L^M, with λ, and the agricultural workforce, L^A, with $1-\lambda$, so that the total supply of unqualified labor is given by: $L = L^M + L^A$. Hence, the income becomes: $Y = w + nR$. We assume an inelastic labor supply, so that wages come from the so-called wage equation that determines the wage at which firms break even:

$$(17)\quad x^S = \mu Y u p^{-\sigma} P^{\sigma-1}.$$

This equality provides two essential conditions: the instant and simultaneous clearing of the factor market and of the product market. Solving this expression for the price and setting it equal to the wage rate, yields:

$$(18)\quad w^* = \left(\frac{\mu Y u P^{\sigma-1}}{x^*} \right)^{\frac{1}{\sigma}}.$$

We allow inter-sectoral labor allocation, so that the equilibrium wage rate is equal to 1. Turning to the R&D sector, the cost rate, r, results from the market equilibrium of research services: $rL^R = nR$. Using equation (12) and setting the total supply of R&D services, L^R, equal to 1, the research cost rate is given by:

$$(19)\quad r = \frac{\mu Y}{\sigma \gamma}.$$

[8] In fact, instead of considering an autonomous sector, it may be possible to regard R&D as an in-house process of the manufacturing industry that is staffed from a particular labor market.

Equation (19) implies important results: a) the cost rate increases with increasing market size and decreasing homogeneity of downstream products, b) it decreases with rising research elasticity. The first comes from the firm's quality policy, where the research expenditures rise with a lower degree of competition. The second is the implicit argument of marginal research cost. Finally, the income can be expressed as:

$$(20) \quad Y = \frac{\sigma\gamma}{\sigma\gamma - \mu}.$$

Substituting this expression, in combination with the price index and the equilibrium output (13), into wage equation (18), and solving for n, we obtain the firm number:

$$(21) \quad n^* = \frac{\mu}{F}\left(\frac{\gamma - 1}{\sigma\gamma - \mu}\right).$$

Using this expression, the equilibrium firm size is given by:

$$(22) \quad x^* = \sigma F\left(\frac{\gamma}{\gamma - 1}\right).$$

For the equilibrium rate of research services, we obtain:

$$(23) \quad r^* = \frac{\mu}{\sigma\gamma - \mu},$$

so that product quality and research expenditures become:

$$(24) \quad u^* = \left[\frac{F}{\mu}\left(\frac{\gamma\left(\sigma\gamma - \mu\right)}{\gamma - 1}\right)\right]^{\frac{1}{\gamma}}$$

$$(25) \quad R^* = \frac{F}{\gamma - 1}.$$

From (22) one can see, that firm size depends upon exogenous parameters, but is times the term in brackets higher than the firm size of the original Dixit-Stiglitz model. In addition, the higher γ, implies that the more expensive the quality improvement, the lower the firm size, as a result of a higher price competition, and the lower the quality. The relation between quality and market concentration is described by:

$$(26) \quad u = \left(\frac{\gamma}{n}\right)^{\frac{1}{\gamma}}.$$

The lower the firm number, the higher the research expenditures and product quality. The reason is straightforward: a decreasing firm number increases demand and profits due to the price index. Because research is financed by sales revenues, the capacity for R&D investments expands and thus increases product quality. The opposite relationship can be derived from the market clearing condition $npx = \mu Y$. The firm number with respect to quality is given by:

$$(27) \quad n = \frac{\mu\gamma(\gamma-1)(\sigma\gamma-\mu)}{\gamma^2\sigma F(\sigma\gamma-\mu) - \mu^2(\gamma-1)u^\gamma}.$$

The simple market size argument indicates that product quality increases the firm number: the higher the quality, the higher the R&D expenditures and thus the corresponding household income, which increases the market size and results in new firm entries.[9] The overall relationship between quality and firm number complies with the results of Sutton (1998), where increasing market concentration accompanies high R&D intensity:

$$(28) \quad \frac{R}{px} = \frac{\mu(\gamma-1)}{\sigma F\gamma(\sigma\gamma-\mu)n} = \frac{1}{\sigma\gamma}.$$

As is apparent in equation (28), R&D intensity is negatively correlated with firm number. In the equilibrium, it is dependent upon substitution and research elasticity only, implying that R&D intensity declines with increasing homogeneity of products and increasing research effort.

Stability of Equilibrium

We assume free market entry and exit in response to firm profits, following the adjustment process: $\dot{n} = f(\pi), f(0) = 0, f' > 0$.[10] We consider the case where an additional firm decides to enter the market. Consequently, the price index decreases, thus reducing demand for a particular variety. Without quality improvement, firms see losses due to constant output, which eventually lead to market exits. But because firms have the capacity to improve quality by research investments, they may counteract this development. A higher firm number reduces the financial resources for R&D via price index, as mentioned above. Hence, product quality, demand, and profits decrease. The results are firm exits and a return to the former equilibrium.

[9]Function (28) has a pole at $u = \left[\frac{\gamma^2\sigma F(\sigma\gamma-\mu)}{\mu^2(\gamma-1)}\right]^{1/\gamma}$, that is always below the equilibrium value (24).

[10]See Neary (2001).

This phenomenon can be illustrated by totally differentiating the profit function with respect to price, quantity and quality:[11]

$$(29)\quad d\pi = \frac{p}{\sigma}dx + \left[\frac{\mu\left(\gamma-1\right)}{\sigma\gamma-\mu}u^{\gamma-1}\right]\frac{du}{u}.$$

Firm profits respond only to changes in demand and quality, while they are not affected by prices due to the price-setting rule. An increase in demand always gives rise to profits, and thus, to the market entry of new firms. The same applies with quality improvement. This dependency becomes apparent by expressing the profit function subject to quality only:

$$(30)\quad \pi = \left(\frac{\gamma-1}{\gamma}\right)ru^{\gamma} - wF.$$

The upper diagram in Figure 1 shows the profit function (30) with parameter settings $\gamma = 2$, $r = 1$, $F = 1$, and $\mu = 0.2$, $\sigma = 2$, for the lower diagram, respectively.

[Insert Figure 1 about here]

According to the total differential (29), an increase in product quality out of the equilibrium makes profits increase due to rising demand, leading to market entries of new firms. As given by equation (26), a decreasing market concentration is accompanied by lower R&D investments, reducing the product quality, until the equilibrium is again reached.

3 Vertical Linkages

In this section, we extend the model by a simple input-output structure, where the manufacturing industry uses differentiated intermediate products from an imperfect upstream sector, in accordance with Ethier (1982). Instead of considering two separate sectors, we aggregate them to one manufacturing industry, as practised by Krugman and Venables (1995). With this approach, vertical linkages become horizontal, and inter-sectoral allocation intra-sectoral. The major implications are: a) the industry uses a fixed proportion of its output as input again, b) the technical substitution elasticity for intermediates is identical to σ, c) firms have the same

[11]See Appendix.

quality preferences as consumers, and d) the price index for intermediates is the same as for final products. The corresponding production function is:

$$(31)\quad F + ax = Zl^{1-\alpha}I^{\alpha} \quad , \quad I = \left[\sum_{i=1}^{n} (u_i)^{1/\sigma} (x_i)^{(\sigma-1)/\sigma}\right]^{\frac{\sigma}{\sigma-1}},$$

where Z represents a level parameter, which is normalized by $(1-\alpha)^{\alpha-1}\alpha^{-\alpha}$, and I an input composite of a continuum of differentiated products. From two-stage budgeting, we obtain the cost function, which is the analogue of the expenditure function of consumers:

$$(32)\quad C = (F + ax)\, w^{1-\alpha}P^{\alpha} + R.$$

The intermediate demand function is:

$$(33)\quad x^u = \alpha\,(C - R)\, up^{-\sigma}P^{\sigma-1},$$

where u denotes *upstream*. The total demand for a particular variety is composed of consumer and intermediate demand, x^d and x^u:

$$(34)\quad x^D = x^d + x^u = up^{-\sigma}P^{\sigma-1}\left[\mu Y + n\alpha\,(C - R)\right],$$

where the term in square brackets represents the total expenditures, E, for industrial products. Equation (34) reflects the forward and backward linkages between firms. The more firms produce in the economy, the higher the intermediate demand, which in turn increases firm number. By contrast, as the number of firms increases, the price index decreases, implying a decrease of procurement costs for intermediates on one hand, and an increase of competition on the other hand. The interaction between these two forces is crucial for the model dynamics in this section.
From profit maximization, we obtain the same price-setting rule as in the previous section:

$$(35)\quad p^* = w^{1-\alpha}P^{\alpha},$$

where the term on the right hand side describes marginal cost as a composite of wage rate and intermediate prices. The optimum product quality is given by:

$$(36)\quad u^* = \left(\frac{x^D w^{1-\alpha}P^{\alpha}}{\sigma r}\right)^{\frac{1}{\gamma}}.$$

The associated research investments are:

$$(37) \quad R^{*} = \frac{x^{D} w^{1-\alpha} P^{\alpha}}{\gamma\sigma}.$$

Using this expression, the equilibrium firm size results from the zero-profit-condition:

$$(38) \quad x^{*} = \sigma F \left(\frac{\gamma}{\gamma - 1}\right),$$

which is the same as in the model without vertical linkages. Turning to the labor market, the equilibrium wage rate follows from the wage equation:

$$(39) \quad \left(w^{1-\alpha} P^{\alpha}\right)^{\sigma} = \frac{u P^{\sigma-1} E}{x}.$$

Due to inter-sectoral labor mobility, the wage rate is 1. In the research market, the equilibrium price for R&D services can be expressed with equations (37) and (38) as:

$$(40) \quad r = \left(\frac{1}{\gamma - 1}\right) nFP^{\alpha}.$$

A noteworthy result is that the optimum quality (36) becomes with (38) and (40) the simple relationship between firm number and quality, like (26) in the previous section. For the determination of the equilibrium firm number, we bear in mind that the total expenditures on manufacturing output are the same as the aggregate turnover of the industry: $E = npx$. Using equations (32)-(40), the firm number with respect to quality is:

$$(41) \quad n^{*} = \left[\frac{\mu(\gamma - 1)}{F(\sigma\gamma(1-\alpha) + \alpha - \mu)}\right]^{\frac{(1-\sigma)(1-\alpha)}{(1-\sigma)(1-\alpha)+\alpha}} u^{\frac{\alpha}{(\sigma-1)(1-\alpha)-\alpha}}$$

The firm number is unique and positive if the denominator of the term in square brackets fulfills the following condition:

$$(42) \quad \sigma\gamma > \frac{\mu - \alpha}{1 - \alpha},$$

which is always valid. A close look at equation (41) reveals that the impact of quality on market concentration depends upon the denominator of the corresponding exponent:

$$(43) \quad \frac{\partial n}{\partial u} \gtrless 0 \quad \Rightarrow \quad 1 \gtrless \left(\frac{1}{\sigma - 1}\right)\left(\frac{\alpha}{1 - \alpha}\right)$$

The direction of change in the firm number with respect to a change in quality is not positive definite, as it is in equation (28). In fact, the correlation depends upon the strength of two competing forces. Increasing quality raises R&D investments and simultaneously consumer and intermediate demand. Additionally, the increasing quality reduces the price index and dampens demand reduction, but increases the prices again, via the monopolistic price-setting rule. The overall effect implies a net reduction of demand. In contrast, increasing quality means higher research expenditures, implying a smaller budget for intermediates. Actually, the production cost $(C - R)$ can be expressed as: $FP^{\alpha}\left(\frac{\gamma\sigma-1}{\gamma-1}\right)$. It is apparent that a decreasing price index results in lower production costs, reducing the intermediate demand due to the constant cost share α. Generally, the direction of change depends upon the strength of the forward linkage and the direct demand effect.
Turning to the second central variable, the equilibrium product quality can be derived from (37), (39), and (41), leading once again to equation (26). This result, in conjunction with the total differential of the profit function (see Appendix), ensures a unique, globally stable equilibrium at:

$$\text{(44a)}\ u^* = \gamma^{\frac{\alpha}{\gamma(1-\sigma)(1-\alpha)+\gamma\alpha-\alpha}}\left[\frac{\mu(\gamma-1)}{\gamma F(\sigma\gamma(1-\alpha)+\alpha-\mu)}\right]^{\frac{(1-\sigma)(1-\alpha)}{\alpha-\gamma(1-\sigma)(1-\alpha)-\gamma\alpha+\alpha}}$$

$$\text{(44b)}\ n^* = \gamma^{\frac{\alpha-\gamma(1-\sigma)(1-\alpha)}{\alpha-\gamma(1-\sigma)(1-\alpha)-\gamma\alpha+\alpha}}\left[\frac{\mu(\gamma-1)}{\gamma F(\sigma\gamma(1-\alpha)+\alpha-\mu)}\right]^{\frac{\gamma(\sigma-1)(1-\alpha)}{\gamma(\sigma-1)(1-\alpha)-\alpha(\gamma-1)}}.$$

At this point, we take a close look at the effects of changes in the fixed (production) cost, F, on market concentration and quality. On condition of (42), the direction of change depends upon the exponents of the terms in brackets:

$$\text{(45a)}\ \frac{\partial u}{\partial F} \lesseqgtr 0 \quad \Rightarrow \quad \left(\frac{\gamma}{\gamma-1}\right) \lesseqgtr \left(\frac{1}{\sigma-1}\right)\left(\frac{\alpha}{1-\alpha}\right)$$

$$\text{(45b)}\ \frac{\partial n}{\partial F} \gtreqless 0 \quad \Rightarrow \quad \left(\frac{\gamma}{\gamma-1}\right) \lesseqgtr \left(\frac{1}{\sigma-1}\right)\left(\frac{\alpha}{1-\alpha}\right).$$

This result differs from that of the single-sector model, where the equilibrium market concentration is positively correlated with fixed cost. The reason is straightforward: an increase in fixed cost leads to a decrease in profits and to an accompanying market exit of firms. With vertical linkages, an increase in F, implying a rising factor requirement, causes an increase in the intermediate demand, which gives rise to firm profits and market entries. The relation between cost effect and forward linkage determines the response of market concentration to the fixed cost.[12] The

[12] In the original Dixit-Stiglitz model with vertical linkages, the condition (45b) is: $\frac{\partial n}{\partial F} \gtreqless 0 \Rightarrow 1 \gtreqless \left(\frac{1}{\sigma-1}\right)\left(\frac{\alpha}{1-\alpha}\right)$.

response of quality to changing fixed cost is reversed to firm number, as it becomes apparent at the inequality signs. As is shown in the previous section and is apparent in the quality policy (36), firm number and quality are negatively correlated due to the price index.
Summarizing the outcomes of this section, we can make the following statements: 1) There is a unique and definite equilibrium, due to condition (42). 2) In contrast to the single sector model, the market clearing function (41) can also be downward sloping. In this context, a positive (negative) slope implies weak (strong) linkages between manufacturing firms , so that inequality (43) qualifies as a measure for the classification of industries in terms of their sectoral coherence. 3) The equilibrium shows a different behavior with respect to changes in the exogenous variables, as we have seen at the example of the fixed cost, F. An economic policy must regard the strength of the sectoral linkages, in order to meet the welfare maximizing objectives. In the next section, we consider the impact of political instruments. Based on these results, we derive a framework for a research-promoting policy.

4 Welfare Analysis

With respect to the allocation outcome in imperfect markets, we consider basic economic policy instruments in this section. We depart from the view of a social planner with the capacity to control central macroeconomic variables, but assume rather from a practical point of view that the state has limited possibilities in its instruments. With this approach, we determine the welfare of the market allocation in order to compare it with a situation, in which the state disposes of the potential to control a) the quality by minimum standards, b) the research cost rate, and c) the supply of R&D activities.

Minimum Quality Standards

At first, we compare the effects of state-controlled quality standards with the unregulated equilibrium in terms of welfare losses. Assuming a given quality $\bar{u}$, the research investments become:

$$(46)\quad R = \frac{r}{\gamma}\bar{u}^{\gamma}.$$

With this expression, the equilibrium output is:

$$(47)\quad x = \sigma\frac{r}{\gamma}\bar{u}^{\gamma} + \sigma F.$$

The firm number can be expressed with (47) and $1 + nR$ for the household income as:

$$(48)\quad n = \frac{\mu}{\frac{r}{\gamma}\bar{u}^{\gamma}(\sigma - \mu) + \sigma F}.$$

From the research market equilibrium, we obtain $1 = \frac{n}{\gamma}\bar{u}^{\gamma}$. In combination with equation (46), the research cost rate is given by:

$$(49)\quad r = \frac{\mu\bar{u}^{\gamma} - \gamma\sigma F}{\bar{u}^{\gamma}(\sigma - \mu)}.$$

Substituting (49) into (48), yields equation (26). For establishing a socially optimal quality, we choose welfare as a function of consumer utility. From household optimization, we obtain maximum utility as the real income of households:[13]

$$(50)\quad W = YP^{-\mu}.$$

Without external intervention, social welfare is:

$$(51)\quad W^{*} = \gamma^{\frac{\mu}{\sigma-1}}\left[\frac{\sigma\gamma}{\sigma\gamma - \mu}\right]\left[\frac{\mu}{F}\left(\frac{\gamma - 1}{\gamma(\sigma\gamma - \mu)}\right)\right]^{\frac{\mu(\gamma-1)}{\gamma(\sigma-1)}}.$$

With respect to quality regulation, the welfare function becomes with equations (48) and (49):

$$(52)\quad W = \left[\frac{\sigma\bar{u}^{\gamma} - \gamma\sigma F}{\bar{u}^{\gamma}(\sigma - \mu)}\right]\left(\gamma\bar{u}^{1-\gamma}\right)^{\frac{\mu}{\sigma-1}}.$$

The limiting values of the hyperbolic welfare function are $-\infty$ for $u \to 0$, and 0 for $u \to \infty$. The unique maximum value, the target for a quality policy, is given by:

$$(53)\quad \bar{u} = \left[\left(\frac{\gamma}{\gamma - 1}\right)\frac{F}{\mu}\left(\gamma(\sigma - 1) + \mu(\gamma - 1)\right)\right]^{\frac{1}{\gamma}}.$$

It is easy to prove that the socially optimal product quality is always lower, as in the model without regulation. Figure 2 presents the welfare function for the parameter constellation, as in the previous illustration.

[Insert Figure 2 about here]

[13] We neglect the term $\mu^{\mu}(1 - \mu)^{1-\mu}$.

The establishment of quality standards implies a welfare gain due to a reduction of market concentration. Research investments and quality turn out to be too high without regulation; and consequently, the firm number too low, as a result of market imperfections.[14] These findings cause several problems for real economic policy: a) if quality is too high, minimum standards fail the welfare optimum, b) in turn, maximum standards are not practicable, implying an indirect control via alternative political instruments, c) variation in model premises may change these outcomes. For example, assuming bounded rationality of consumers or information asymmetry, could lead to systematic underestimation of quality with the result of an equilibrium that is socially too low. Setting quality standards means a welfare maximum. In contrast, removing these deficiencies on the demand side (e.g., by public information) results in unregulated quality, that is too high again. Besides these exceptions, we concentrate on the impact of indirect quality control by variations of the research cost rate.

Optimal Control of Research Costs

The state can control research costs by subsidization and taxation, as well as by a state-owned or state-regulated research sector. The argument for public intervention is the failure not of the research market itself, but rather of the corresponding downstream sector. The choice of a research cost rate is linked with excess supply or demand, so that case differentiation is required for the derivation of the welfare function.

First, we consider a cost rate above the equilibrium value, so that the demand for R&D becomes a bottleneck. While household income, firm number, and firm size remain constant, quality decreases due to the firmt́s product policy. Although research investments do not change, employment in the R&D sector declines. The welfare function with respect to the research cost rate can be expressed as:

$$(54)\quad W\left(r > r^{*}\right) = \left[\frac{\sigma\gamma}{\sigma\gamma - \mu}\right]\left[\left(\frac{F\gamma}{\gamma - 1}\right)\frac{\mu\left(\gamma - 1\right)}{F\left(\sigma\gamma - \mu\right)}\right]^{\frac{\mu}{\sigma - 1}} r^{\frac{\mu}{\gamma(1-\sigma)}}.$$

The terms in square brackets are positive: welfare decreases monotonically with increasing cost rate, so that a scale-up of r leads always to welfare losses.

If the cost rate is set below the equilibrium value, the demand for R&D services is larger than the market capacity. Consequently, quality becomes:

$$(55)\quad u = \left[\frac{\gamma\sigma F}{\mu - r\left(\sigma - \mu\right)}\right]^{\frac{1}{\gamma}},$$

[14]This complies with the results of the seminal Dixit-Stiglitz model. See the introduction of Brakman and Heijdra (2004), p. 19 et seq., for instance.

The welfare function is now:

$$(56)\quad W\left(r<r^{*}\right)=\left(1+r\right)\gamma^{\frac{\mu}{\gamma(\sigma-1)}}\left[\frac{\mu\left(1+r\right)-r\sigma}{\sigma F}\right]^{\frac{\mu(\gamma-1)}{\gamma(\sigma-1)}}.$$

The limiting values of equation (56) are $\left(\frac{\mu}{\sigma F}\right)^{\frac{\mu(\gamma-1)}{\gamma(\sigma-1)}}$ for $r\rightarrow 0$ and $-\infty$ for $r\rightarrow\infty$.[15] From (56), the welfare maximizing research cost rate is:

$$(57)\quad r_{max}=\frac{\mu\left[\mu\left(\gamma-1\right)+\sigma-\gamma\right]}{\sigma\left[\gamma\left(\sigma-1\right)-\mu\right]+\mu\left[\gamma-\mu\left(\gamma-1\right)\right]}.$$

Because of possible negative values of (57), the socially optimal research cost rate is defined as:

$$(58)\quad \bar{r}=\begin{cases} r_{max}\ \forall\ \mu\left(\gamma-1\right)>\sigma+\gamma \\ 0\ \forall\ \mu\left(\gamma-1\right)\leq\sigma+\gamma. \end{cases}$$

If we complete the welfare function for the whole range of r, we must consider both equations (54) and (56). The graphs intersect at their lower and upper limits: the non-regulated equilibrium r^{*}. Overall, we obtain a continuous but non-differentiable welfare function. Figure 3 depicts the socially optimal and unregulated research cost rate and the corresponding welfare values with the parameters above.

[Insert Figure 3 about here]

It is a noteworthy fact that reducing quality to the optimum level, is only realizable by a reduction of the research cost rate. This seems to be contrary to intuition and partial analytical results. In general, this dependency can be traced to a disequilibrium in the research market and the special characteristics of the Dixit-Stiglitz framework. Due to a research price below the equilibrium value, the fixed supply of researchers is rationed to firmťs increased demand. Research investments, R, become r/n. Consequently, these expenditures begin to decrease and overall fixed costs decline. As a result, decreasing average costs and constant break even output cause an entry of new firms. The increased firm number and lower research expenditures correspond with decreasing quality, as equation (26) indicates. Finally, lower income and quality, as well as a higher firm number occur, compared with the

[15]If $\left(\frac{\gamma-1}{\gamma}\right)<\left(\frac{\sigma-1}{\mu}\right)$ holds, the codomain of r is $]0,\frac{\mu}{\sigma-\mu}[$ due to a negative root. The upper limit is greater than the equilibrium cost rate without regulation, so that it is not a part of the total (piecewise-defined) welfare function (54) and (56).

unregulated equilibrium. The decrease of the price index more than compensates for the decrease of the nominal household income.[16]

Supply of Research Activities

An alternative policy instrument exists in the control of the supply of R&D services and scientific personnel. In practice, activities range from a totally state-controlled research sector to direct promotion (e.g., by funding programs). We intentionally neglect the financing of public market intervention, but rather consider the impact on allocation and welfare.

In Section 2, we set the price inelastic supply of R&D equal to 1. Here we relax this restriction and allow L^R to be non-zero positive. As a result, the equilibrium research cost rate becomes:

$$(59)\quad r^* = \frac{\mu}{L^R\left(\sigma\gamma - \mu\right)},$$

where income remains constant at (20). The equilibrium quality can now be expressed as:

$$(60)\quad u^* = \left[\frac{FL^R\gamma\left(\sigma\gamma - \mu\right)}{\mu\left(\gamma - 1\right)}\right]^{\frac{1}{\gamma}}$$

In general, with increasing research supply, firms are able to improve quality without increasing their research investments, so that market concentration and firm size remain unchanged. If the firm number is constant with increasing quality, the price index declines, ultimately increasing real income and welfare. These results imply that an increase in R&D supply leads to better quality with unaffected market concentration. However, an economic policy may increase social welfare, but it fails to meet the welfare maximum.

5 Numerical Application

In this section, we adapt the modeling results to real economic data and aim to determine quality and research costs for selected European industries. The required data, extracted from the EUROSTAT online data base, contain firm number, turnover, and estimated R&D expenditures for 2003. For the corresponding substitution elasticities, we use the OLS-estimated values of Hummels (1999), Table 4. For the simulation, we make the following assumptions:

[16]The derivative of the price index with respect to research cost is: $\left[\left(\frac{\gamma-1}{\gamma(1-\sigma)}\right)\left(\frac{\mu--\sigma}{\mu-r(\sigma-\mu)}\right)\right]P < 0$, where the denominator of the second fraction is always positive (see equation (54)).

- We assume monopolistic competition for the industry to be considered. For this case, we must choose a sufficient degree of aggregation to avoid monopolistic or oligopolistic market structures and corresponding deviations from the model of symmetric and independently acting (one product) firms. On this note, we must solve a trade-off, where a too-high aggregation leads to substitution elasticities that tend to be too low (smaller than 1). In this simulation, we choose two-digit industries, in one case, a three-digit industry.

- Implementing a general equilibrium model requires the consideration of multiple industries. In this case, we choose a particular industry to analyze within the manufacturing sector of the model and adopt the Walrasian sector for the others. Hence, we assume a competitive market structure for the residual economy.

- Through inter-sectoral mobility, we allow workers to move between sectors. This may be critical, depending on type of work and industry.

- Because we simulate a closed economy, international trade relations are excluded. For the definition of an economic area with a high degree of domestic trade, we choose the European Union (EU-25) and neglect its transcontinental trade.

- With regard to R&D, we assume a 1:1 relationship between research and the manufacturing sector, and thus neglect cross-sectoral research activities and potential spill-over effects, just as we do not allow for knowledge exchange between firms.

- R&D investments are employed only for quality improvements, including also the design of new and improved products. Research activities for cost reduction cannot be separated from the official statistic data and are inevitably integrated in the R&D expenditures.

- Finally, we rule out any public interventions and assume infinitely fast adjustment processes, as well as an instantaneous and deterministic effect of R&D on quality.

Table 1 reveals the simulation output for ten industries. For the computation of research elasticity, equation (30) is used. The research cost rate r is determined by equation (23), where the income share for manufactures, μ, is the ratio of the respective industrial turnover and the GDP (2003) earned in the EU-25. With the values for r and γ, quality can be computed with the use of equation (6). The marginal research costs come from the derivative of the same equation.

[Insert Table 1 about here]

Results
Overall, we obtain only a rough estimation for the magnitudes of calibrated real parameters. Having at first a look at the quality column, we obtain a widely spread distribution. It is obvious that quality correlates with R&D intensity, where research-intensive branches (e.g., Pharmaceutics or Computers) show large values for quality.
Research elasticities indicate strong divergence across the industries. The parameter tends to be high for branches with a low research intensity (e.g., Foods, Basic Metals and Metal Manufactures) versus research-intensive sectors with a high γ (e.g., Pharmaceutics or Computers). In this context, we observe a relatively distinct relationship between substitution and research elasticity, where a low σ, which indicates a high product differentiation, corresponds with a high γ. This indication leads to the assumption that R&D investments are used not only for quality improvements, but also for horizontal product differentiation.
Furthermore, we observe large differences for the research cost rate, r: the highest values are in the Automotive and Pharmaceutical industries, the lowest value are in Metal Production and Metal Manufactures. An obvious reason might be the lower demand for R&D services and personnel in the latter cases.
The column headed with $\partial R/\partial u$ shows marginal research costs. Again, the lowest values correspond with the highest research intensities (e.g., Pharmaceutics, Computers and Medical Instruments).
Finally, the last column displays the welfare-maximizing research cost rate, in accordance with equations (57) and (58). It is apparent that these values are low, if not 0. Based on these results, an economic policy should decrease the cost rates to the particular values. This result implies almost costless research for reducing quality to the welfare maximum level, a result that is arguable in the context of real markets. The next section discusses this issue, summarizes the most important outcomes of this paper, and presents an outlook for future research.

6 Conclusions

In the course of this paper, several results confirm an inverse relationship between market concentration and research intensity in monopolistic competitive markets. Equation (26), the zero-profit condition, shows a simple relationship between firm number and quality, controlled by the exogenous research elasticity. Furthermore, this paper illustrates the opposite dependence in (28), where quality determines market size and thus firm number. The interaction between these two mechanisms generates an equilibrium, where firm number increases with increasing research elasticity, a higher degree of horizontal differentiation, and a lower production fixed cost. In contrast, quality increases with lower research, higher substitution elasticity, and increasing fixed cost. In this context, we explored the possibility that in equilibrium research intensity is determined by only research and substitution elasticity.

The implementation of vertical linkages leads to partially different results. We obtain a unique and globally stable equilibrium, and equation (26) remains unchanged. However, the outcomes of the comparative statics depend upon the strength of the vertical linkages.

Political intervention is legitimatized by a welfare loss due to imperfect markets. We have determined that unregulated quality is above the social optimum, with the implication that minimum quality standards do not impact the allocation outcome. An alternative instrument is the price control of R&D services. Surprisingly, the research cost rate must be reduced to meet the lower welfare maximizing quality. As a consequence, firm number increases, thus reducing the price index at constant nominal household income, ultimately implying a higher real income. An increase in R&D capacities leads to an increase in welfare but not to the corresponding maximum. Ultimately, a social planner that aims to reach a certain level of maximized welfare is supposed to combine research price instruments with an adapted control of R&D supply.

The numerical application was conceived to quantify the magnitude of the model outcomes with the imputation of real data, considering the strong restriction of the underlying assumptions. It may be pointed out that an advanced simulation analysis using statistical data requires a detailed econometric foundation. However, the results computed in this paper reveal a wide spread in quality across the corresponding industries. Using the suggested approach, we consider aggregates of industries and products. The results tend to be sufficient to compare differentiated products within one sector, but less adequate for comparison across industries (e.g., cars and computers). Based on the outcomes of this simulation, the welfare maximizing research cost rate would be zero, or almost zero. In consideration of these extreme results, we must keep in mind that the policy here aims to correct market failures and not to promote technology development, for example.

In the face of the underlying assumptions, the model has two weaknesses: a) the industry-specific R&D sector, and b) the absence of knowledge spillover effects. Indeed, the model could describe a more realistic picture if we implement R&D that supplies several sectors, as it is observable in fields of fundamental research. Likewise, it may be interesting to consider the internal R&D of one firm that generates externalities for other firms in the corresponding industry. In this context, the quality of a particular firm i is not only dependent upon the input of its own research input, $u_i\left(L_i^R\right)$, but also upon the R&D efforts of the whole sector: $u_i\left(L_i^R, \sum_{j=1}^n L_j^R\right)$. However, these issues will be part of future work.

This paper is intended to provide a foundation for implementing vertical product differentiation and R&D for international trade. It opens the possibility of analyzing the impact of trade integration on quality and research investments, and, in turn, the effects of R&D on spatial concentration and specialization. Based on the extensions, we can model the implications of factor mobility (even in terms of scientific labor force) and agglomeration by inter-sectoral linkages. Furthermore, on the basis of the policy instruments considered in this paper, we can determine the impact of quality standards as trade barriers, and draw conclusions for a location-oriented R&D policy.

7 Technical Appendix

Derivation of Cost Function and Intermediate Demand

The optimization problem on the lower stage is:

$$(61)\quad min.\ \sum_{i=1}^{n} p_i x_i^u \quad s.t.\ \ I = \left[\sum_{i=1}^{n} (u_i)^{1/\sigma} (x_i)^{(\sigma-1)/\sigma}\right]^{\frac{\sigma}{\sigma-1}}$$

The compensated demand for intermediates results from the first-order conditions:

$$(62)\quad x^u = u\left(\frac{P}{p}\right)^{\sigma}.$$

The upper stage of optimization is given by:

$$(63)\quad min.\ C = PI + wl + R \quad s.t.\ \ F + ax = Zl^{1-\alpha} I^{\alpha}.$$

From the first-order conditions we obtain:

$$(64)\quad l = \left(\frac{1-\alpha}{\alpha}\right)\frac{PI}{w}.$$

Substituting this expression into the general cost function, leads to:

$$(65)\quad I = \frac{\alpha(C-R)}{P}.$$

Equation (65) can now be inserted into the compensated intermediate demand (62), from which the intermediate demand function (33) follows.

Total Differential of the Profit Function
Starting from the profit function:

$$(66)\quad \pi = \mu Y u p^{1-\sigma} P^{\sigma-1} - aw\mu Y u p^{-\sigma} P^{\sigma-1} - wF - \frac{r}{\gamma} u^{\gamma},$$

and substituting $w + n\frac{r}{\gamma}u^{\gamma}$ for the income and $p\,(nu)^{\frac{1}{1-\sigma}}$ for the price index, we obtain:

$$(67)\quad \pi = \frac{\mu}{\sigma n} + \frac{\mu r}{\sigma \gamma} u^{\gamma} - wF - \frac{r}{\gamma} u^{\gamma}.$$

Solving equation (11) for n and using the expression for Y as above, leads to:

$$(68)\quad n = \left(\frac{\mu \gamma}{\sigma \gamma - \mu} \right) \frac{1}{r u^{\gamma}}.$$

Equation (68) describes the dependency between n and u. If we set $\frac{\mu}{\sigma\gamma-\mu}$ for r, and substitute (68) into the (67), totally differentiating the profit function yields the expression (29).
In Section 3, the total differential is:

$$(69)\quad d\pi = \left[\frac{1}{\sigma} \right] dx + \left[\underbrace{\left(\frac{\alpha}{(1-\sigma)(1-\alpha)} \right)}_{<0} \underbrace{\left(\frac{\mu - (\gamma\sigma - \alpha(\gamma\sigma - 1))}{\gamma\sigma + \gamma\alpha(1-\sigma) - \mu} \right)}_{<0} FP \right] \frac{du}{u}.$$

As in the model without linkages, profits and firm number respond positively on demand and quality. For a further detailed analysis of the disaggregated model, see Kranich (2006).

References

Brakman, S. and Heijdra, B. (eds): 2004, *The Monopolistic Competition Revolution in Retrospect*, Cambridge University Press, Cambridge UK.

Chamberlin, E.: 1933, *The Theory of Monopolistic Competition*, Harvard University Press, Cambridge MA.

Dixit, A. K. and Stiglitz, J.: 1977, Monopolistic competition and optimum product diversity, *American Economic Review* **67**, 297–308.

Dixit, A. and Norman, V.: 1980, *The Theory of International Trade*, The MIT Press, Cambridge UK.

Ethier, W.: 1982, National and international returns to scale in the modern theory of international trade, *American Economic Review* **72**, 389–405.

Forslid, R.: 1999, Agglomeration with human and physical capital: an analytically solvable case, *CEPR Discussion Paper 2102*, Centre for Economic Policy Research.

Fujita, M., Krugman, P. and Venables, A.: 1999, *The Spatial Economy*, The MIT Press, Cambridge, London.

Gabszewicz, J. and Thisse, J.: 1979, Price competition, quality and income disparities, *Journal of Economic Theory* **20**, 340–359.

Gabszewicz, J. and Thisse, J.: 1980, Entry (and exit) in a differentiated industry, *Journal of Economic Theory* **22**, 327–338.

Hotelling, H.: 1929, Stability in competition, *Economic Journal* **39**, 41–47.

Hummels, D.: 1999, Toward a geography of trade costs, *GTAP Working Paper 17*.

Kranich, J.: 2006, The strength of vertical linkages, *Working Paper Series in Economics 20*, University of Lueneburg, Lueneburg.

Krugman, P.: 1979, Increasing returns, monopolistic competition, and international trade, *Journal of International Economics* **9**, 469–480.

Krugman, P.: 1980, Scale economies, product differentiation, and the pattern of trade, *American Economic Review* **70**, 951–959.

Krugman, P.: 1991, Increasing returns and economic geography, *Journal of Political Economy* **99**, 483–499.

Krugman, P. and Venables, A. J.: 1995, Globalization and the inequality of nations, *The Quarterly Journal of Economics* **110**, 857–880.

Lancaster, K.: 1966, A new approach to consumer theory, *Journal of Political Economy* **74**, 132–157.

Lucas, R. E.: 1988, On the mechanics of economic development, *Journal of Monetary Economics* **22**, 3–42.

Neary, P. J.: 2001, Of hype and hyperbolas: Introducing the new economic geography, *Journal of Economic Literature* **39**, 536–561.

Ottaviano, G.: 1996, Monopolistic competition, trade, and endogenuous spatial fluctuations, *CEPR Discussion Paper 1327*, Centre for Economic Policy Research.

Romer, P.: 1987, Growth based on increasing returns due to specialization, *American Economic Review* **77**, 56–62.

Romer, P. M.: 1990, Human capital and growth: Theory and evidence, *Carnegie-Rochester Conference Series* **32**, 251–286.

Schmalensee, R.: 1992, Sunk costs and market structure. a review article, *Journal of Industrial Economics* **40**(2), 125–134.

Shaked, A. and Sutton, J.: 1982, Relaxing price competition through product differentiation, *Review of Economic Studies* **49**, 3–14.

Shaked, A. and Sutton, J.: 1983, Natural oligipolies, *Econometrica* **51**, 1469–1484.

Shaked, A. and Sutton, J.: 1987, Product differentiation and industrial structure, *Journal of Industrial Economics* **36**, 131–146.

Sutton, J.: 1991, *Sunk Costs and Market Structure*, The MIT Press, Cambridge.

Sutton, J.: 1998, *Technology and Market Structure*, The MIT Press, Cambridge/MA, London.

Tirole, J.: 1988, *The Theory of Industrial Organization*, The MIT Press, Cambridge MA, London.

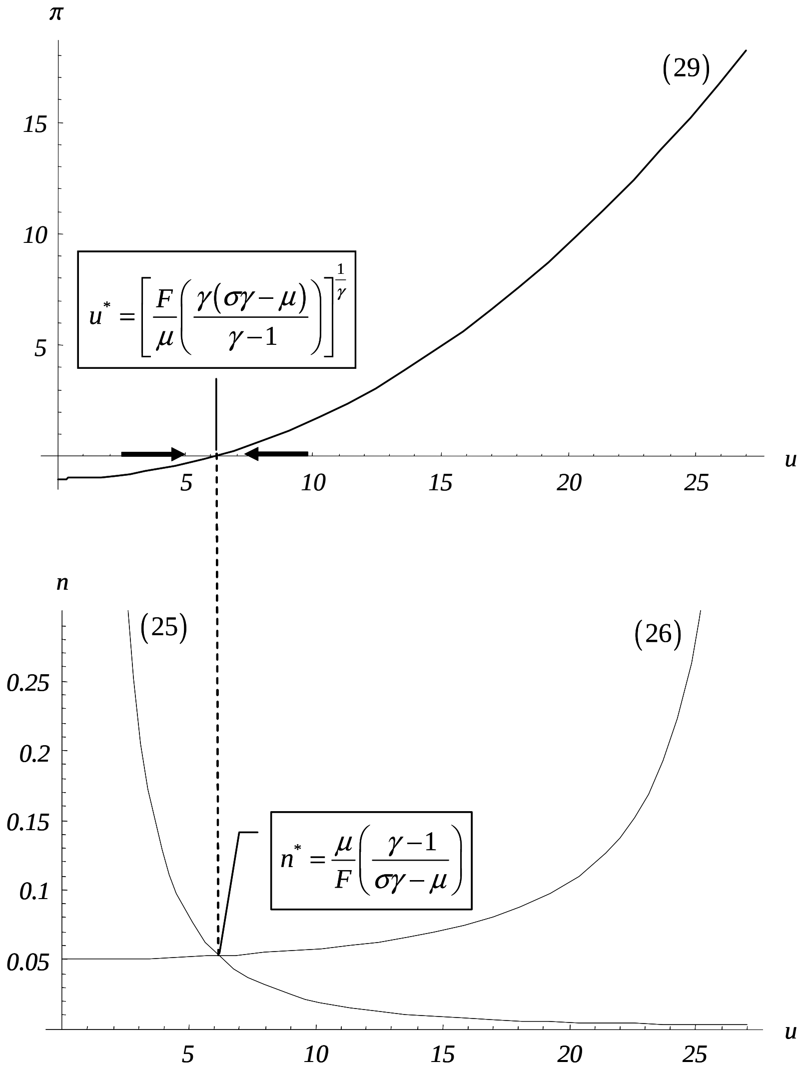

Figure 1: *Quality and Firm Number*

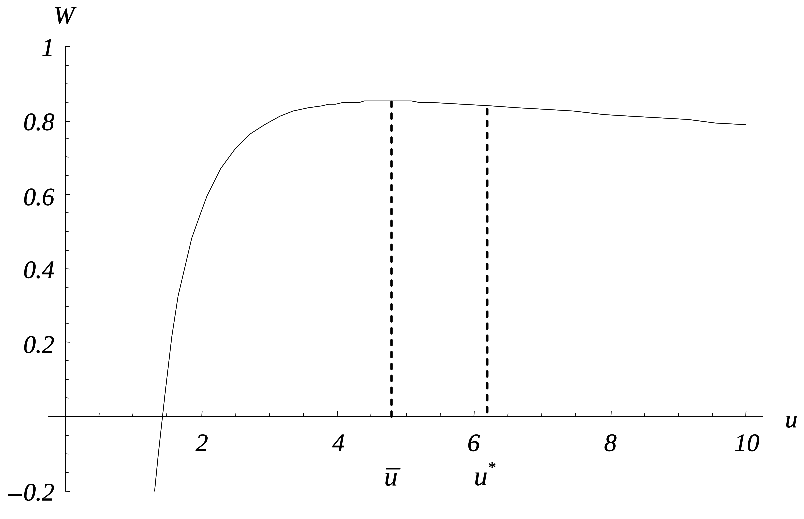

Figure 2: *Quality and Welfare*

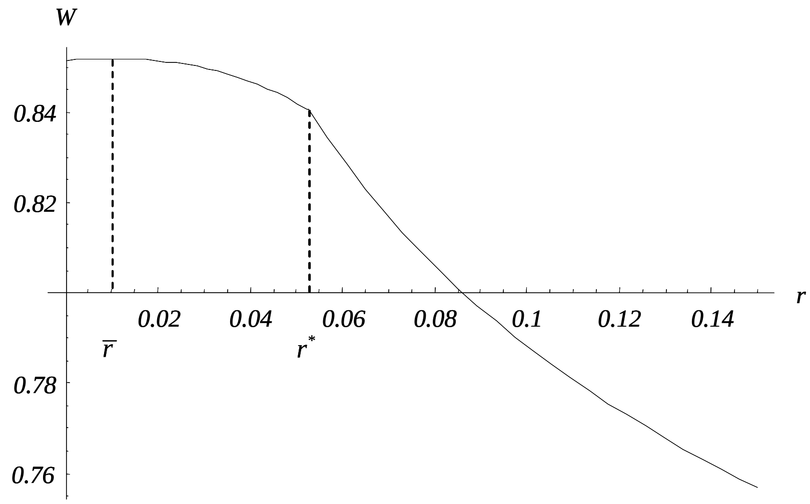

Figure 3: *Research Cost and Welfare*

Table 1: *Simulation Results for Selected Basic European Industries*

NACE	Industrial Sector	μ	n	nR in Mio. €	npx in Mio. €	R/px in Mio. €	σ	γ	r	u	$\partial R/\partial u$	r_{max}
DA	Food products, beverages and tobacco	0.0874	282,876	2,195	871,000	0.0025	3.40	116.7091	220.18	1.0739	0.8433	0.0000
DG24	Chemicals and chemical products (without pharmaceuticals	0.0427	26,604	7,550	425,988	0.0177	5.28	10.6860	757.75	2.1732	1.3954	0.0000
DG244	Pharmaceuticals	0.0177	4,111	15,647	176,013	0.0889	9.53	1.1804	1,571.67	847.2409	0.0053	0.0015
DH25	Rubber and plastic products	0.0229	61,430	2,181	228,358	0.0096	4.82	21.7227	218.78	1.4564	0.5295	0.0000
DJ27	Basic metals	0.0241	15,000	1,122	240,000	0.0047	3.53	60.5960	112.54	1.1912	3.8050	0.0000
DJ28	Fabricated metal products, except machinery and equipment	0.0372	370,000	1,271	371,055	0.0034	4.85	60.1936	127.48	1.1307	0.1829	0.0000
DK29	Machinery and equipment n.e.c	0.0501	157,244	9,669	499,212	0.0194	6.98	7.3969	970.62	2.2965	0.1981	0.0000
DL30	Office machinery and computers	0.0067	9,482	4,296	66,500	0.0646	11.02	1.4047	431.02	180.3889	0.0035	0.0004
DL33	Medical, precision and optical instruments, watches and clocks	0.0120	90,000	6,081	120,000	0.0507	6.72	2.9365	610.22	7.1689	0.0277	0.0004
DM34	Motor vehicles, trailers and semi-trailers	0.0741	16,921	20,364	739,000	0.0276	7.11	5.1040	2,046.44	4.8006	1.2795	0.0008

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