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Quality Improvements, the Structure of Employment, and the Skill−bias Hypothesis Revisited

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Abstract

This paper examines the impact of technological progress in the effectiveness of quality−improving, demand−enhancing activities on wage inequality and the employment structure in an ideal variety model of monopolistic competition. In a first step, it is shown that such technological change leads to a higher non−production employment share in the economy, in turn raising price mark−up factors for differentiated goods. Moreover, accounting for the fact that demand−enhancing activities are skill−intensive, the model provides a novel mechanism for the way in which new technologies affect the relative demand for skilled labor in the economy. Although an increased effectiveness of product innovations raises the demand for skilled labor in the differentiated goods sector, the impact on wage inequality is generally ambiguous if, in addition, there is a low−skilled intensive, homogenous goods sector. This is because higher mark−ups in the differentiated goods sector may shift the goods demand structure towards standardized goods. Finally, these results are compared with the impact of "skill−biased" process innovations, which have primarily been considered in the theoretical skill−bias literature. Using a simple illustration, it is argued that, once analytically distinguishing between production−related and quality−improving tasks, skill−biased process innovations do not necessarily lead to a rise in skill premia even in a one−sector model.

1 Introduction

New direct marketing, database marketing, customer relationship management and customer care are recent headlines in the business literature (e.g. Hallberg and Ogilvy, 1995; Shepard and Batra, 1998; Brown, 2001). For instance, customer profile data allow managers to correlate customer characteristics and types of purchases. In turn, this information can then be used to design products and customer services which are perceived as quality improvements by consumers. These possibilities are strongly related to the availability of new information and communication technologies. As Bresnahan (1999) points out:

> "*Marketing* managers now have the opportunity to know much more about customers. Computer databases provide the underpinnings for much analytical marketing thinking. Once research has discovered what customers want, the computerised production process can be changed to deliver it. This is typically not trivial, involving the definition of new services permitted by the expanded production opportunities." (Bresnahan, 1999, p.F409; italics original).

Note that this view of marketing is very different from informative advertising (e.g. Grossman and Shapiro, 1984) or even manipulative advertising (Solow, 1967). Rather, (database) marketing can be interpreted as R&D in a broader sense.

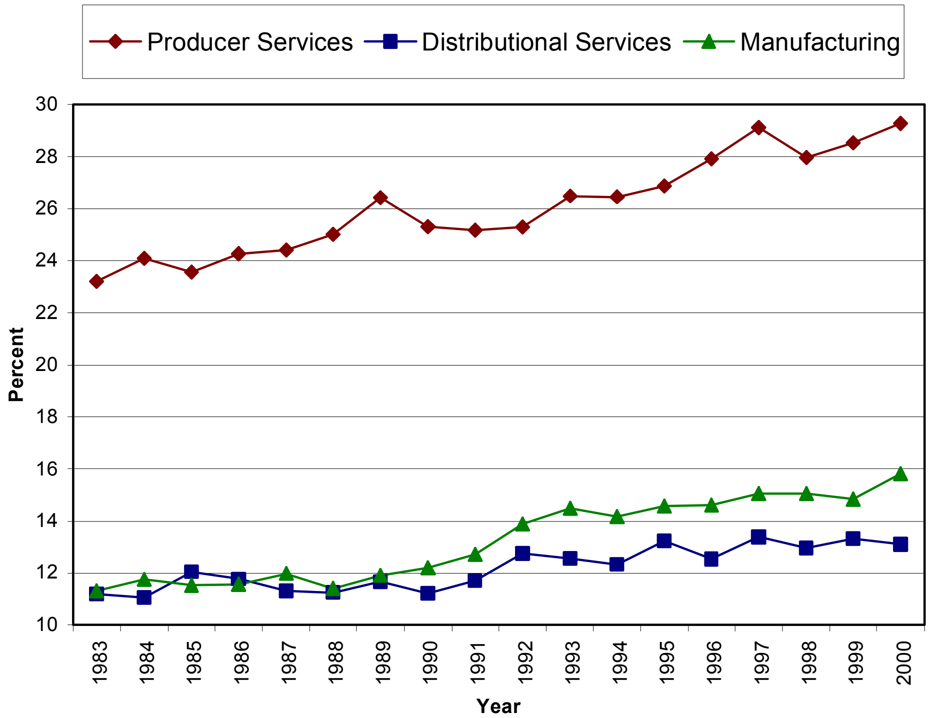
This paper examines the general equilibrium effects of technological progress in the effectiveness of these quality-improving, demand-enhancing activities (Sutton, 1991, 1998) on wage inequality and the employment structure. This is done by allowing firms to employ "marketing managers" in an ideal variety model of monopolistic competition (Lancaster, 1979; Helpman, 1981).

In a first step (i.e. in the basic model), the impact of such technological progress on both the employment share of marketing managers and horizontal concentration in a market with differentiated goods is examined, assuming a homogenous labor force. It is shown that firms reallocate labor towards demand-enhancing activities. This is consistent with recent shifts in the employment structure towards non-production employment in general, and towards managerial occupations in particular (e.g. Berman, Bound and Grichilis, 1994; Berman, Bound and Machin, 1998; Machin and van Reenen, 1998).

Fig. 1 shows that U.S. employment shares in managerial occupations in manufacturing, producer services and distributive services, respectively, have steadily increased between 1983 and 2000. For instance, the manager share in manufacturing has increased from 11.3 to 15.8 percent.[1] In the empirical literature on skill-biased technological change, such evidence has been taken as an important

[1] Data Source: Current Population Survey (CPS).
Refers to fulltime workers aged 19-65. Roughly following OECD (2000, ch.3), producer services are defined as banking, insurance, real estate, legal services, engineering, architectural, and

Figure 1: Employment shares in managerial occupations in the U.S.



indicator for technology-induced shifts in relative labor demand in favor of skilled workers.[2] However, the theoretical literature on this issue has not addressed shifts in the non-production employment share, as it has not analytically distinguished between production-related and non-production activities. In contrast, this paper specifies non-production tasks as demand-enhancing activities, performed by marketing managers. It is shown that a technology-driven shift in the employment structure towards non-production labor goes along with a rise in horizontal concentration. In fact, recent evidence reveals concentration processes (e.g. through mergers) in some key industries (e.g. Pryor, 2001a,b).

In a next step, the model is extended to a dual economy (i.e. two-sector) model. The differentiated goods sector represents the modern, skill-intensive sector in which

surveying services, accounting, auditing, and bookkeeping services, R&D and testing services, management and public relation services, and business and repair services. Distributive services consist of transportation, communication, wholesale and retail trade. Managerial occupations are defined exactly as in CPS.

[2]The reason for this is twofold. First, changes in the non-production employment share are highly correlated with changes in the share of skilled labor. Second, these changes have mainly occurred within rather than between firms, which is evidence for technology-related rather than trade-related factors of relative labor demand shifts towards skilled workers.

firms have incentives to incur (R&D) costs for designing products and customer services. In contrast, in the second sector standardized commodities are produced in a low-skilled intensive way. These assumptions account for the facts that managerial marketing tasks require “extraordinary management skills” (Bresnahan, 1999), but are only relevant for non-standardized goods.

This extension of the basic model allows us to revisit the hypothesis of so-called skill-biased technological change (e.g. Galor and Tssidon, 1997; Gregg and Manning, 1997; Acemoglu, 1998; Caselli, 1999; Lloyd-Ellis, 1999; Galor and Moav, 2000). In contrast to the existing literature on the skill-bias hypothesis which focuses on process innovations (affecting marginal production cost), this paper focuses on technological progress in marketing and product design (affecting non-production costs). This provides some novel results. First, since technological change fosters a reallocation of skilled labor towards skill-intensive, demand-enhancing activities it leads to a rise in concentration in the differentiated goods sector. Second, since higher concentration raises price mark-ups, relative goods demand shifts towards the low-skilled intensive, standardized goods sector. Due to this general equilibrium effect, the overall earning opportunities of low-skilled workers do not necessarily decline despite the relative labor demand shift towards skills in the differentiated goods sector.

Finally, the increased effectiveness of product innovations analyzed in the present paper is compared to the impact of “skill-biased” process innovations, which have been primarily considered in the skill-bias literature. It is shown that the latter kind of technological progress leads to a decrease in the non-production employment share, contrary to the empirical evidence. Moreover, due to this reallocation of skilled labor towards production-related tasks, the impact of skill-biased process innovations on wage dispersion is ambiguous. This is in stark contrast to the existing skill-bias literature, which has not taken the different nature of production-related and demand-enhancing activities into account.

The paper is organized as follows. Section 2 sets up the basic model. Section 3 analyzes the equilibrium of the basic model. Section 4 revisits the hypothesis of skill-biased technological change by allowing for a second sector and distinguishing skilled and unskilled labor. The last section concludes.

2 The Basic Model

There is a unit mass of consumers/workers. The labor market is perfect and labor is homogenous with an inelastic supply. There is a single sector with n firms, indexed by i. Firms can freely enter the market at costs $F \geq 0$ (i.e. n is endogenous). Each firm produces one variety of a horizontally differentiated good with identical technology in a monopolistically competitive environment. Following e.g. Helpman (1981) and Wong (1995), the varieties differ in one horizontal dimension of attributes, represented by different points on the circumference of a circle with unit length. (See Lancaster, 1979, for an illuminating discussion of the case in which products differ in many dimensions.) Each consumer has one "ideal", i.e. a most preferred variety, which characterizes a consumer's type. Types are uniformly distributed on the circumference of the circle of product attributes.

Remark 1: The "ideal variety" approach (originated by Lancaster, 1979) may be compared to the "love of variety" approach (Dixit and Stiglitz, 1977), which is often used in macroeconomic models with imperfect competition. In the latter type of model, consumers have a taste for variety in the sense that consuming an amount x of n goods gives a higher utility than consuming an amount nx of a single good. In contrast, in the "ideal variety" approach, consuming an amount nx of the most preferred variety gives a higher utility than consuming any other bundle of goods of this amount. The attractive feature of the Lancasterian type of model exploited in the present paper is that price mark-up factors depend on horizontal concentration. Note that, for instance, this plausible result does not hold in the Dixit-Stiglitz model under the usual CES-utility specification.

As common in ideal variety models, it is assumed that firms simultaneously choose prices and their "location" on the circumference of the circle of attributes. The extension in present paper is that, at the same time, firms can incur costs for demand-enhancing activities, by employing "marketing managers". Following Bresnahan (1999), activities of these workers involve, for instance, to evaluate customer data and to improve the design of both products and attached services accordingly. In an ideal variety model, quality improvements by a single firm imply that its product is customized to a broader range of consumers. Following the "endogenous sunk cost" approach of Sutton (1991, 1998) or "quality ladder" models of endogenous growth (e.g. Grossman and Helpman, 1991), which also allow for quality-improvements of horizontally differentiated products, the associated R&D costs are not reflected in marginal production costs.

2.1 Preferences and Technology

Preferences of a consumer with an ideal variety j (called "type j" hereafter) are represented by the following utility index:

$$X(j) = \sum_{i=1}^{n} x(i)Q(\delta(i,j), m(i)), \tag{1}$$

where $x(i)$ denotes the quantity of variety i and $Q(\delta(i,j), m(i))$ is the subjective quality which type j perceives regarding variety i. $\delta(i,j) \geq 0$ is the (shorter) arc distance between variety i and j on the circumference of the circle of product attributes, whereas $m(i)$ denotes the amount of marketing managers (i.e. non-production labor) employed by firm i. $Q(\delta, m)$ is a decreasing function of δ and an increasing function of m. Note that m is associated with "real" or "objective" quality characteristics of goods, whereas horizontal differentiation reflects differences in individual tastes. Allowing firms to employ marketing managers to perform quality-improving tasks in an ideal variety model is the theoretical innovation of this paper. For simplicity, Q is specified as

$$Q(\delta, m) = \frac{m^{\gamma}}{h(\delta)}, \; 0 < \gamma < 1. \tag{2}$$

Following Lancaster (1979), $h(\cdot)$ is called the "compensation function", where $h(0) = 1$, $h'(0) = 0$ and $h'(\delta) > 0$, $h''(\delta) > 0$ for all $\delta > 0$ is assumed.

The parameter γ represents the elasticity of subjective quality with respect to the amount of marketing managers, i.e. $\gamma = \frac{m}{Q}\frac{\partial Q}{\partial m}$.[3] An increase in γ thus means that marketing and product design activities become more *effective*. (The term "effectiveness" is adopted from Sutton, 1998.) For instance, computerization has allowed to collect customer data which can be used to identify the potential impact of quality improvements on product demand, conditional on the type of consumers (i.e. conditional on consumers' most preferred variety of the horizontally differentiated good).

The production function of each firm i is simply given by

$$x(i) = l(i), \tag{3}$$

where $l(i)$ denotes the amount of *production* labor employed by firm i.[4]

2.2 Demand

Denote the price of variety i by $p(i)$, expenditure of type j by $E(j)$ and demand of type j for variety i by $x^D(i, j)$. Moreover, define

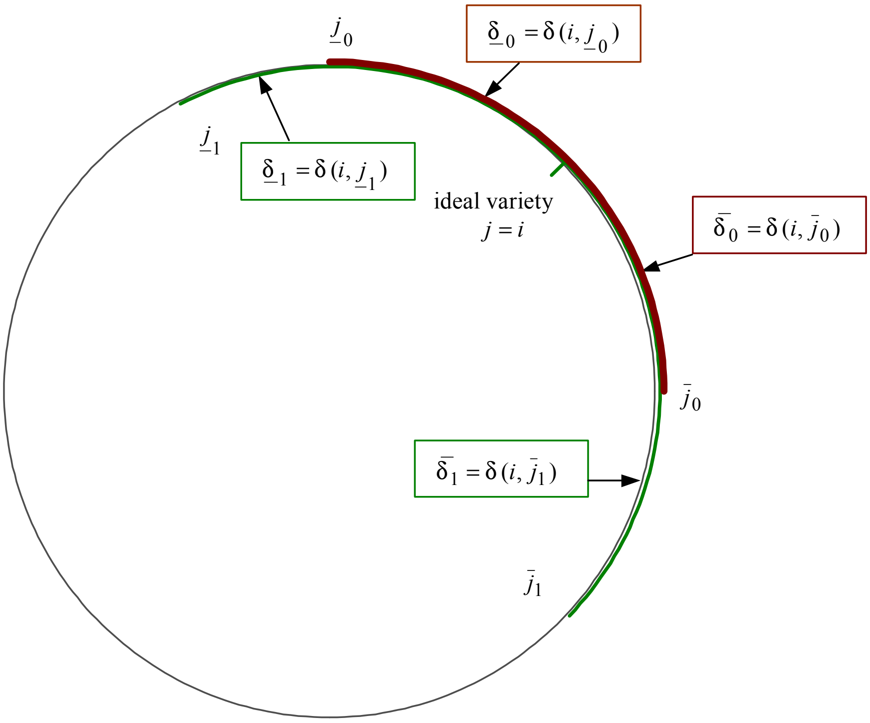
$$S(j, i) \equiv \frac{p(i)}{Q(\delta(i, j), m(i))}, \tag{4}$$

which is the price of variety i from the perspective of type j adjusted for subjective quality. According to (1), consumers do not value variety per se. Thus, all the demand by a type j goes to the good with the lowest $Q-$adjusted price perceived by her or him, i.e. $x^D(i, j) = E(j)/p(i)$ for $\arg\min_i S(j, i)$ and $x^D(k, j) = 0$ for all $k \neq i$. Denote $\underline{j}(i)$ and $\overline{j}(i)$ as the types who are exactly indifferent between variety i and the neighboring variety leftward and rightward to variety i, respectively, on the circumference of the circle of product attributes. Defining $\underline{\delta}(i) \equiv \delta(i, \underline{j}(i))$ and

[3] γ corresponds to the constant elasticity of the R&D cost schedule in Sutton (1998).

[4] Changes in labor productivity do not affect the key variables of this paper. Thus, for simplicity, productivity is normalized to unity.

Figure 2: The product circle of differentiated goods and the impact of quality improvements.



$\overline{\delta}(i) \equiv \delta(i, \overline{j}(i))$, $\underline{\delta}(i) + \overline{\delta}(i)$ equals the arc distance between $\underline{j}(i)$ and $\overline{j}(i)$. Thus, total demand $x^D(i)$ for good i is given by[5]

$$x^D(i) = \frac{(\underline{\delta}(i) + \overline{\delta}(i))E}{p(i)}, \quad i = 1, ..., n, \tag{5}$$

where E denotes the total expenditure in the economy.

The main idea in this paper is that by increasing $m(i)$, a firm i can raise the range $\underline{\delta}(i)+\overline{\delta}(i)$ and thus the demand it faces, all other things equal. That is, variety i is customized to a broader range of consumers. This is depicted in Fig. 2, where an increase in m raises both $\underline{j}$ and $\overline{j}$ from $\underline{j}_0$ and $\overline{j}_0$ to $\underline{j}_1$ and $\overline{j}_1$, respectively.

[5]Note that $x^D(i) = \int_{\underline{j}(i)}^{\overline{j}(i)} [E(j)/p(i)]\, dj$ and $E = \int_0^1 E(j)dj$, since preferences are uniformly distributed on a circumference of a circle with unit length.

3 Equilibrium

In this section, the equilibrium outcome is derived for the basic model. First, for a given number of firms n, the (symmetric) Nash equilibrium with respect to the "location" on the circumference of the circle of attributes, the amount of marketing labor and price setting is characterized. (Technical details of this derivation are fully spelled out in the proof of Lemma 1.) Second, the equilibrium number of firms n^* is determined under free entry. The results derived in this section turn out to be very useful for the extension of the basic model to a dual (i.e. two-sector) economy with skilled and unskilled labor in section 4.

3.1 Profit Maximization

Each firm i chooses a "location" on the circumference of the circle of product attributes as well as $m(i)$ and $p(i)$ in maximizing profits

$$\pi(i) = (p(i) - w)(\underline{\delta}(i) + \overline{\delta}(i))\frac{E}{p(i)} - wm(i) \tag{6}$$

(remember (5)), taking the "location", marketing labor and prices of all other firms $k \neq i$ as given. w denotes the nominal wage rate and thus marginal production costs, according to (3). The first-order conditions with respect to $m(i)$ and $p(i)$ read

$$(p(i) - w)\left(\frac{\partial\underline{\delta}(i)}{\partial m(i)} + \frac{\partial\overline{\delta}(i)}{\partial m(i)}\right)\frac{E}{p(i)} = w \tag{7}$$

and

$$\frac{p(i) - w}{w} = \frac{1}{\eta(i) - 1}, \tag{8}$$

respectively, where $\eta(i) \equiv -\frac{\partial x_i^D}{\partial p(i)}\frac{p(i)}{x_i^D}$ denotes the price elasticity of demand faced by firm i. (7) says that the marginal return of devoting labor resources to marketing and product design must equal marginal (non-production labor) costs. (8) reflects the standard result that the mark-up factor on output prices adversely depends on the demand elasticity $\eta(i)$.

Lemma 1 *There exists a symmetric equilibrium with $\underline{\delta}(i) = \overline{\delta}(i) = \frac{1}{2n}$, $m(i) = m$ and $p(i) = p$ for all i. In this equilibrium, we have for all i:*

$$\frac{\partial\underline{\delta}(i)}{\partial m(i)} + \frac{\partial\overline{\delta}(i)}{\partial m(i)} = \left[-\frac{\partial Q(\delta, m)/\partial m}{\partial Q(\delta, m)/\partial\delta}\right]_{\delta=\frac{1}{2n}} = \frac{\gamma}{2\varepsilon\left(\frac{1}{2n}\right)nm} \tag{9}$$

and

$$\frac{1}{\eta(i) - 1} = 2\left[-\frac{\delta}{Q(\delta, m)}\frac{\partial Q(\delta, m)}{\partial\delta}\right]_{\delta=\frac{1}{2n}} = 2\varepsilon\left(\frac{1}{2n}\right), \tag{10}$$

where $\varepsilon(\delta) \equiv \frac{\delta h'(\delta)}{h(\delta)}$ is the elasticity of the compensation function h with respect to δ.

Proof. See appendix. ■

According to (9), the incentive for each single firm to devote labor resources to quality improvements depends on two forces. First, the impact of an increase in non-production labor m on subjective quality Q (i.e. $\partial Q/\partial m$) and the impact of an increase in the distance δ of a variety from a consumer's ideal variety on Q (i.e. $|\partial Q/\partial \delta|$). To see why the latter plays a role, consider an increase in m of a single firm under two different scenarios, i.e. when $|\partial Q/\partial \delta|$ is high or low, respectively. Note that $|\partial Q/\partial \delta|$ low means that individuals have to be "compensated" rather little through an increase in "objective" quality (m) when the distance δ from a consumer's ideal variety is raised. In this case, a given "objective" quality improvement of a single product leads to a large increase in product demand. In contrast, if $|\partial Q/\partial \delta|$ is high, the same quality-improvement has little effect on demand for this product, since many consumers simply dislike this variety.[6] Note that, according to (9), the marginal return to non-production labor rises in the effectiveness γ of demand-enhancing activities.[7]

(10) says that goods market power of firms is higher when the subjectively perceived quality Q is more sensitive with respect to the distance δ from a consumer's ideal variety. With specification (2), (10) reproduces the result of Helpman (1981) and Wong (1995) with respect to the mark-up factor, i.e.,[8]

$$p(i) \equiv p = \left(1 + 2\varepsilon \left(\frac{1}{2n}\right)\right) w. \tag{11}$$

With a perfect labor market, there is full employment, i.e. $L_x + M = 1$, where $L_x = \sum_i l(i) \equiv nx$ and $M = \sum_i m(i) \equiv nm$ denote aggregate employment levels in production-related and non-production activities, respectively. Also note that goods market clearing implies $L_x = E/p$, according to (3) and (5). Using these facts, (7), (9) and (11) imply that for *any* given n, the equilibrium employment share of marketing managers (remember that total labor supply is normalized to unity) is given by

$$M^* = \frac{\gamma}{1+\gamma}. \tag{12}$$

Throughout the paper, superscripts (*) denote equilibrium levels *after* (free) entry of firms. Since the aggregate amount of non-production labor $M = nm$ derived for a given number of firms n does not depend on n, one can write $M = M^*$ in (12).

[6] For instance, if you prefer white wine to red wine, provided the respective prices and qualities are the same, the required quality-improvement of red wine which induces you to switch to red wine depends on the fact how much you preferred white wine in the first place.

[7] In contrast, any monotonic increasing transformation of $Q(\delta, m)$ would not affect the relationship between the two forces identified above, which determine the incentive of firms to incur R&D costs.

[8] In the extension of the ideal variety approach developed in the present paper, mark-up factors generally do not only depend on n, but also on m, according to (10). Thus, the specification (2) allows us to analyze a particularly simple case.

(This means that m decreases proportionally as n increases, due to the specification (2)).

Proposition 1 *If demand-enhancing activities become more effective (i.e. if γ increases), the equilibrium employment share M^* of marketing managers in the economy increases.*

Proof. By inspection of (12). ■

Proposition 1 is a direct implication of (9) and can be understood by the discussion of Lemma 1 above. That is, an increase in γ raises the marginal return of firms to devote labor resources to quality-improving activities. Note that an increase in M^* is consistent with the evidence presented in Fig. 1.

The next subsection considers the entry decision of firms.

3.2 Entry

Firms enter the market as long as gross profits $\pi = (p - w)x - wm$ are positive. Using $nx = L_x = 1 - M$ as well as (11) and (12), gross profits $\pi(i)$ of any firm i firm can be written as

$$\pi(i) = \frac{\left(2\varepsilon\left(\frac{1}{2n}\right) - \gamma\right) w}{(1+\gamma)n} \equiv \tilde{\pi}(n;\gamma). \tag{13}$$

Note that according to (10), the price elasticity of demand $\eta(i) = \eta$ (and thus the mark-up factor 2ε) depends on the number of firms n. In particular, as $n \longrightarrow \infty$, we have $\delta \longrightarrow 0$, $\varepsilon \longrightarrow 0$ and $\eta \longrightarrow \infty$. It is plausible to assume the following.[9]

Assumption 1: *In symmetric equilibrium, the price elasticity of demand η is non-decreasing in the number of firms n and strictly increasing for some n, i.e. $\varepsilon'(\delta) \geq 0$, with strict inequality for some δ.*

According to Assumption 1, $\tilde{\pi}(n;\gamma)$ is strictly decreasing in n, i.e. there exists a unique equilibrium number of firms n^*, which is given by $\tilde{\pi}(n^*;\gamma) = F$. Let horizontal concentration be defined as the one-firm sales concentration ratio $1/n$ (e.g. Sutton, 1991, 1998), denoted R. Thus, equilibrium concentration $R^* = 1/n^*$ is implicitly given by

$$\frac{\left(2\varepsilon\left(R^*/2\right) - \gamma\right) R^*}{1+\gamma} = \frac{F}{w}. \tag{14}$$

Note that F/w are entry costs in units of labor and that equilibrium concentration R^* is positively related to entry costs, as usual. In the case of $F = 0$, R^* is simply given by $2\varepsilon\left(R^*/2\right) = \gamma$.

[9] Remembering that $h(\cdot)$ is strictly convex, it is easy to see that $\varepsilon(\cdot) \leq 1$ is a sufficient condition for Assumption 1 to hold.

Proposition 2 *Under Assumption 1, horizontal concentration R^* increases with γ.*

Proof. Noting that the left-hand side of (14) is strictly increasing in R^*, according to Assumption 1, and applying the implicit function theorem gives the result. ■

As pointed out above, an increase in γ induces firms to increase their amount of marketing labor. Thus, for any given number of firms n, equilibrium output per firm declines and non-production labor costs increase. Both effects induce a fall in profits per firm such that less firms can enter the market, i.e. equilibrium concentration $R^* = 1/n^*$ rises.

4 Revisiting the Skill-bias Hypothesis in a Dual Economy

In this section, the popular skill-bias hypothesis is revisited by proposing a novel mechanism, which focuses on the impact of technological advances in skill-intensive, demand-enhancing activities. For this, the basic model is extended in order to account for two facts. First, marketing and product design can naturally be relevant only in a sector producing non-standardized commodities. Besides this sector, now a second sector is introduced in the model which produces a homogenous good (in a low-skilled intensive way) in which quality-improvements do not play any role. Second, as for instance pointed out by Bresnahan (1999), demand-enhancing activities are more skill-intensive than production-related activities.

4.1 Technology and Labor Market

Regarding the production technology, the following assumptions are made. First, in the differentiated goods sector the production function is linear homogenous as in the basic model, i.e.

$$x(i) = F(h(i), l(i)) \equiv l(i)f(\chi(i)), \tag{15}$$

where $h(i)$ and $l(i)$ denote the amounts of high-skilled and low-skilled production labor employed by firm i, respectively. $f(\cdot)$ is a strictly monotonic increasing and strictly concave function and $\chi(i) \equiv h(i)/l(i)$ is the skill-intensity of production-related activities in firm i. For simplicity, assume that only high-skilled workers can be employed as marketing managers.[10] Second, let output y in the now introduced homogenous goods sector be produced according to

$$y = L_y, \tag{16}$$

[10]The crucial assumption for the results in this section is that non-production activities in the differentiated goods sector are more skill-intensive than production-related activities.

where L_y denotes the amount of low-skilled labor in this sector. The technology specifications (15) and (16) are the simplest way to capture the notion that production-related activities in the homogenous goods sector are less skill-intensive than in the differentiated goods sector, which will play a role later on.

There is a segmented and perfectly competitive labor market for both high-skilled and low-skilled labor. Labor supply is still inelastic, and given by H and L for high-skilled and low-skilled labor, respectively, with $H + L = 1$. Wage rates for high-skilled and low-skilled labor are denoted by w_H and w_L, respectively. Note that full employment of high-skilled labor implies $H_x + M = H$, where $H_x \equiv \sum_i h(i)$ and M denote the aggregate amounts of high-skilled labor assigned to production-related tasks (e.g. engineers and technicans) and quality-improving tasks, respectively. Similarly, full employment of low-skilled labor implies $L_x + L_y = L$, where $L_x \equiv \sum_i l(i)$ denotes the aggregate amount of low-skilled labor in the differentiated goods sector.

4.2 Preferences and Demand

In their role of consumers, preferences of *both* high-skilled and low-skilled workers are uniformly distributed on the circumference of the circle of attributes of the differentiated good. Assume that the utility function of a consumer of type j can be written as $U(X(j), y)$, i.e. utility functions are separable in the two types of goods. (Also note that U is identical for all j.) In order to work out the mechanisms of the model in a simple example, let the function U be Cobb-Douglas (the role of this specification is discussed below), i.e.

$$U(X(j), y) = X(j)^{\alpha} y^{1-\alpha}, \ 0 < \alpha < 1, \tag{17}$$

where $X(j)$ is given by (1). (Also (2) still applies.) It is easy to show from (1) and (17) that expenditure shares for the differentiated and the homogenous good are given by α and $1-\alpha$, respectively. Denote aggregate money income in the economy by I and the price of the homogenous good by q. Then total demand $x^D(i)$ for each variety i in the differentiated goods sector and y^D for the homogenous good are given by $x^D(i) = (\underline{\delta}(i) + \overline{\delta}(i))\alpha I/p(i)$, according to (5) with $E = \alpha I$, and $y^D = (1-\alpha)I/q$, respectively. Thus, in a symmetric equilibrium with $p(i) = p$, $\underline{\delta}(i) + \overline{\delta}(i) = 1/n$ (see lemma 1) and thus $x(i) = x$, the goods market clearing conditions $\sum_i x^D(i) = \alpha I/p = nx$ and $y^D = y$ imply

$$\frac{L_x f(\chi)}{L_y} = \frac{\alpha}{1-\alpha}\frac{q}{p}, \tag{18}$$

according to (15) and (16). Note that $q = w_L$, according to (16).

4.3 Equilibrium

Cost minimization of firms in the differentiated goods sector implies that the relative wage $\omega \equiv w_H/w_L$ of high-skilled labor and the skill-intensity

$$\chi(i) = \chi = \frac{H_x}{L_x} = \frac{H - M}{L_x} \tag{19}$$

of production-related tasks are negatively related by the equation

$$\omega = \frac{f'(\chi)}{f(\chi) - \chi f'(\chi)} \left(= \frac{F_h}{F_l} \right), \tag{20}$$

according to (15). (Note that $h(i) = H_x/n$ and $l(i) = L_x/n$ for all i.) Unit production cost $c_x = \frac{h(i)+w_{L,x}l(i)}{x(i)}$ in the differentiated goods sector is constant and can be written as

$$c_x = \frac{w_H}{f'(\chi)} = \frac{w_L}{f(\chi) - \chi f'(\chi)} \tag{21}$$

according to (15) and (20).

Analogously to (6), gross profits $\pi(i)$ of firm i in the differentiated goods sector are given by

$$\pi(i) = (p(i) - c_x)(\underline{\delta}(i) + \overline{\delta}(i))\frac{\alpha I}{p(i)} - w_H m(i). \tag{22}$$

The first-order conditions with respect to $m(i)$ and $p(i)$ thus read

$$(p(i) - c_x) \left(\frac{\partial \underline{\delta}(i)}{\partial m(i)} + \frac{\partial \overline{\delta}(i)}{\partial m(i)} \right) \frac{\alpha I}{p(i)} = w_H \tag{23}$$

and

$$p(i) = p = (1 + 2\varepsilon\,(R/2))\, c_x, \tag{24}$$

respectively, where (10) has been used to obtain (24). (Remember $R = 1/n$.) Substituting both the goods market clearing condition $\alpha I/p = L_x f(\chi)$ and (24) into (23) yields

$$2\varepsilon\,(R/2)\, L_x f(\chi) \left(\frac{\partial \underline{\delta}(i)}{\partial m(i)} + \frac{\partial \overline{\delta}(i)}{\partial m(i)} \right) c_x = w_H. \tag{25}$$

By substituting (9) and (21) into (25) one obtains $\gamma f(\chi)/f'(\chi) = M/L_x$. Combining the latter expression with (19) one finds

$$\frac{M}{H} = \frac{\gamma}{\rho(\chi) + \gamma}, \tag{26}$$

where $\rho(\chi) \equiv \chi f'(\chi)/f(\chi)$ (note that $\rho(\cdot) < 1$), and

$$L_x = \frac{f'(\chi) H}{\chi f'(\chi) + \gamma f(\chi)}, \tag{27}$$

respectively. (26) gives a relationship between the employment share M/H of high-skilled labor in quality-improving activities and the skill-intensity χ of production-related activities in the differentiated goods sector. (27) gives a relationship between the total employment of low-skilled labor L_x in the differentiated goods sector and χ. Another relationship between L_x and χ can be found by substituting the full employment condition for low-skilled labor $L_y = L - L_x$, $q = w_L$, (21) and (24) into (18). After rearranging terms, this gives

$$L_x = L\left(\frac{1-\alpha}{\alpha}\frac{1+2\varepsilon\left(R/2\right)}{1-\rho(\chi)}+1\right)^{-1}. \tag{28}$$

By combining (27) and (28) one obtains the "market-clearing locus"

$$\Lambda(\chi, R; \gamma) \equiv \frac{\gamma f(\chi)}{\frac{H}{L}\left(\frac{1-\alpha}{\alpha}\frac{1+2\varepsilon(R/2)}{1-\rho(\chi)}+1\right)-\chi} - f'(\chi) = 0. \tag{29}$$

It is straightforward to show that $\partial\Lambda/\partial R \leq 0$ (with strict inequality for some R, according to Assumption 1) and $\partial\Lambda/\partial\chi > 0$ (use the definition of $\rho(\cdot)$). Thus, $\Lambda(\chi, R; \gamma) = 0$ defines an upward-sloping curve in the $\chi - R$ space. (This curve is vertical whenever $\varepsilon'(\cdot) = 0$.) Note that this curve has been derived from market-clearing conditions, for a given concentration $R = 1/n$. Intuitively, the positive relationship between the skill-intensity of production-related tasks χ and concentration R stems from the fact that a higher R induces a higher mark-up factor in the differentiated goods sector if $\varepsilon'(\cdot) > 0$. In turn, this raises the relative price p/q, shifting goods demand and thus the output structure towards the low-skilled intensive homogenous good.

Next, note that gross profits of any firm i in symmetric equilibrium are given by $\pi(i) = (p - c_x)x - w_H m$. Using $M = nm$, $nx = L_x f(\chi)$ and (24) thus yields

$$\pi(i) = \frac{2\varepsilon L_x f(\chi) c_x - w_H M}{n}. \tag{30}$$

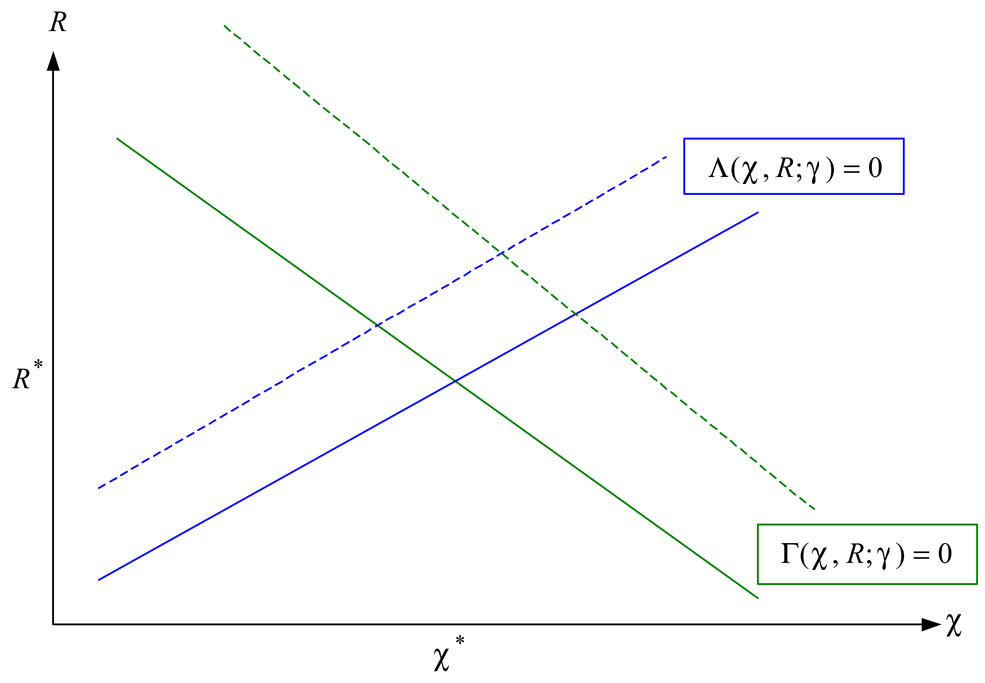
Substituting (21), (26) and (27) into (30), and noting that $\pi(i) = F$ for all i must hold in equilibrium with free entry of firms, one obtains the "zero-profit locus"

$$\Gamma(\chi, R; \gamma) \equiv \frac{H\left(2\varepsilon\left(R/2\right)-\gamma\right)R}{\rho(\chi)+\gamma} - F = 0, \tag{31}$$

with normalization $w_H = 1$. Note that $\partial\Gamma/\partial R > 0$ (use Assumption 1) and $\partial\Gamma/\partial\chi \gtreqless 0$ iff $\rho'(\cdot) \lesseqgtr 0$. (29) and (31) simultaneously define the equilibrium skill-intensity χ^* of production-related tasks and equilibrium concentration R^* in the differentiated goods sector as function of γ.[11] In order to ensure that the equilibrium is unique,

[11] The other parameters are not essential here and are therefore suppressed in both $\Lambda(\cdot)$ and $\Gamma(\cdot)$.

Figure 3: The impact of an increase in γ on the equilibrium in the dual economy.



the following is assumed.[12]

Assumption 2: Let $(\partial\Lambda/\partial\chi)\,\partial\Gamma/\partial R - (\partial\Lambda/\partial R)\,\partial\Gamma/\partial\chi > 0$.

Note that $\rho'(\cdot) \leq 0$ is sufficient for Assumption 2 to hold. For $\varepsilon'(\delta) > 0$ and $\rho'(\chi) < 0$, which imply that in the $\chi - R$ space the locus $\Lambda(\chi, R; \gamma) = 0$ is upward-sloping and the locus $\Gamma(\chi, R; \gamma) = 0$ is downward-sloping, respectively, the equilibrium outcome is depicted in Fig. 3. The dotted lines indicate the impact of an increase in γ in that case. Generally, one can conclude the following.

Proposition 3 *Under Assumptions 1 and 2. If γ increases, then horizontal concentration R^* rises unambiguously. The impact on the relative wage $\omega^* = \frac{f'(\chi^*)}{f(\chi^*)-\chi^* f'(\chi^*)}$ is ambiguous if $\varepsilon'(\cdot) > 0$ and positive if $\varepsilon'(\cdot) = 0$.*

[12] It is easy to show that Assumption 2 is sufficient for uniqueness. First, note that $\Lambda(\chi, R; \gamma) = 0$ defines χ as function of R and γ. Write this function as $\psi(R; \gamma)$ and note that $\partial\psi/\partial R = -(\partial\Lambda/\partial R)\,/\,(\partial\Lambda/\partial\chi) \geq 0$. Substituting $\chi = \psi(R; \gamma)$ into (31) implies that R^* is given by $\Gamma(\psi(R^*; \gamma), R^*; \gamma) = 0$. Note that there exists a $\underline{R}$ such that $\Gamma(\psi(\underline{R}; \gamma), \underline{R}; \gamma) < 0$. Thus, R^* is unique if $\Gamma(\psi(R; \gamma), R; \gamma)$ is strictly increasing in R. This holds under Assumption 2.

Proof. First, note that χ^* and ω^* are negatively related, according to (20). Second, note that Assumption 2 is equivalent to the fact that the locus $\Lambda(\chi, R; \gamma) = 0$ in $\chi - R$ space is steeper than the locus $\Gamma(\chi, R; \gamma) = 0$ even when $\rho'(\chi) > 0$. Third, note that $\partial\Lambda/\partial\gamma > 0$ and $\partial\Gamma/\partial\gamma < 0$, according to (29) and (31), respectively. Thus, in $\chi - R$ space, the locus $\Lambda(\chi, R; \gamma) = 0$ shifts rightward and the locus $\Gamma(\chi, R; \gamma) = 0$ shifts upward when γ increases (remember $\partial\Lambda/\partial\chi > 0$ and $\partial\Gamma/\partial R > 0$). If $\varepsilon'(\cdot) = 0$, then the locus $\Lambda(\chi, R; \gamma) = 0$ is vertical, which implies that the impact of an increase in γ on χ^* is unambiguously negative in this case. However, as can be seen from Fig. 3, generally, this does not hold if $\varepsilon'(\cdot) > 0$. This concludes the proof. ■

Applying the same logic as in section 3, an increased effectiveness of quality improvements provides incentives for firms to reallocate high-skilled labor from production-related to demand-enhancing activities. In turn, this raises concentration R^* in the differentiated goods sector. Moreover, Proposition 3 states that, although an increase in γ makes high-skilled (non-production) labor more effective, the relative equilibrium return to skills ω^* may increase or decrease. The intuition for a potential decline in ω^* is the following. Higher concentration R^* goes along with an increased price mark-up for differentiated goods whenever $\varepsilon'(\cdot) > 0$, which raises relative goods prices p/q, all other things equal. With a Cobb-Douglas utility function, which implies fixed expenditure shares for the two types of goods in the economy, this induces a shift in the demand (and output) structure towards the homogenous good, according to (18). Since the homogenous good is produced in a low-skilled intensive way, the relative wage ω^* may decrease if γ rises.[13]

In contrast, if $\varepsilon'(\cdot) = 0$ in the relevant range, i.e. an increase in R^* does not affect pricing power of firms in the differentiated goods sector, wage dispersion unambiguously rises. Similarly, in absence of a homogenous goods sector (i.e. consider $\alpha = 1$ and thus $L_x = L$) an increase in γ unambiguously lowers the skill-intensity of production-related activities χ^* (through an increase in M^*). In turn, this raises relative wages ω^*.[14] Stated differently, if $\alpha = 1$, an increase in the effectiveness of marketing labor positively affects the relative marginal productivity of high-skilled labor, which, in a one-sector model, is consistent with the usual definition of skill-biased technological change. However, taking into account general equilibrium effects in a two-sector model, this turns out to be a too simplistic notion.

4.4 Product Innovations versus Process Innovations

The present paper has started out with the observation that technological progress has increased the potential for marketing managers to design products and customer services which raise consumers' subjectively perceived quality of (horizontally differ-

[13] However, if preferences would be such that expenditure shares would shift towards differentiated goods after quality-improvements, this result could be overturned.

[14] To see this formally, note that (29) implies that χ^* is given by $\gamma f(\chi^*)/\left(\frac{H}{L} - \chi^*\right) - f'(\chi^*) = 0$ if $\alpha = 1$, where $\chi < H/L$ with $M > 0$ and $L_x = L$, according to (19). Thus, $\partial\chi^*/\partial\gamma < 0$.

entiated) goods. So far, this section has shown that such "skill-biased" technological change does not necessarily raise wage premia for skills in general equilibrium, although it raises relative demand for skilled labor in the differentiated goods sector.

The existing literature on skill-biased technological change has considered *process* innovations (which affect the production function and thus marginal costs), rather than an increased effectiveness of *product* innovations. Besides realism, modelling this latter kind of technological change provides insights into mechanisms which are rather different from process innovations. In order to work out these differences, consider the following simple example.

Example 1: Let the production function (15) in the differentiated goods sector be Cobb-Douglas, i.e. specify

$$f(\chi) = a\chi^{\beta}, \; a > 0, \, 0 < \beta < 1. \tag{32}$$

In this case, changes in a would be skill-neutral and increases in β "skill-biased" technological change in *production-related* activities. Moreover, in order to focus the analysis, suppose entry costs are positive, i.e. $F > 0$.

Using (32), χ^* and R^* are simultaneously given by[15]

$$\widetilde{\Lambda}(\chi, R; \beta, \gamma) \equiv \frac{\gamma}{\frac{H}{L}\left(\frac{1-\alpha}{\alpha}\frac{1+2\varepsilon(R/2)}{1-\beta} + 1\right) - \chi} - \frac{\beta}{\chi} = 0 \tag{33}$$

and

$$\widetilde{\Gamma}(\chi, R; \beta, \gamma) \equiv \frac{H\left(2\varepsilon\left(R/2\right) - \gamma\right) R}{\beta + \gamma} - F = 0, \tag{34}$$

according to (29) and (31), respectively.[16] Thus, as shown in Fig. 4, the market-clearing locus $\widetilde{\Lambda}(\cdot) = 0$ in $\chi - R$ space shifts rightward if β increases, according to (33). Moreover, the zero-profit locus $\widetilde{\Gamma}(\cdot) = 0$ is horizontal, and (since $F > 0$), it shifts upward if β increases, according to (34).[17] This leads to the following results.

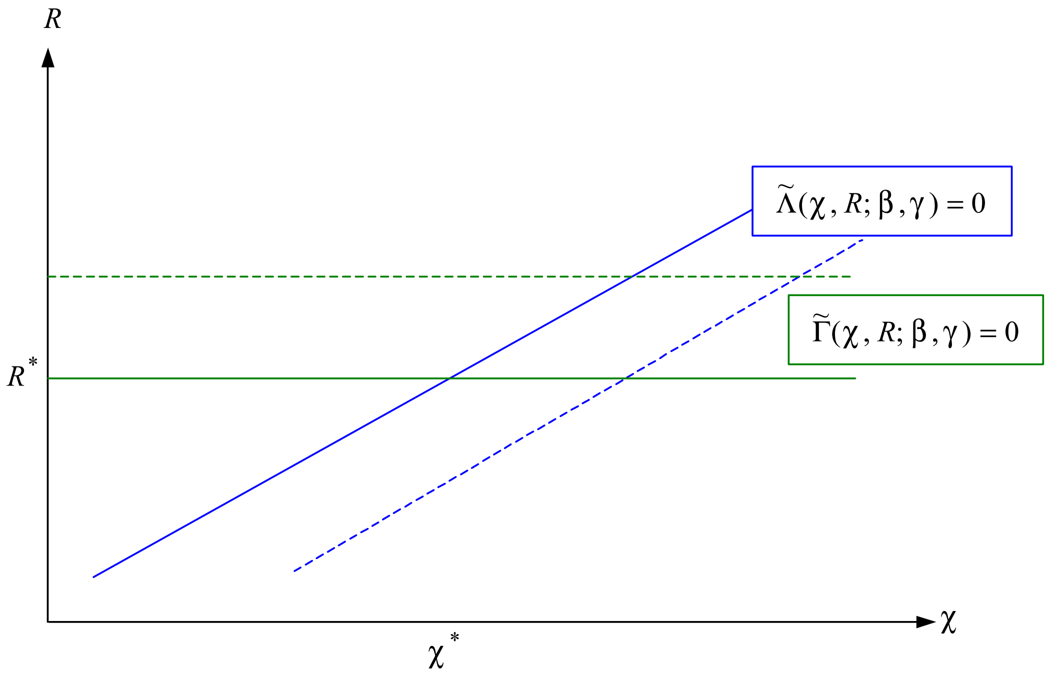
Proposition 4 *In Example 1, under Assumptions 1 and 2. "Skill-biased" process innovations (i.e. an increase in β) in the differentiated goods sector raises both equilibrium concentration R^* and equilibrium skill-intensity of production-related tasks χ^*, leaving the impact on ω^* generally ambiguous.*

[15] Note that $\rho(\cdot) = \beta$, according to (32).

[16] It is easy to see from (33) and (34) that neither χ^* nor R^* depend on a. Note that an increase in a positively affects the level of production in the differentiated goods and negatively affects marginal costs (as well as prices p), all other things equal. In sum, this leaves the equilibrium output structure in the economy unchanged.

[17] If $F = 0$, equilibrium concentration R^* is simply given by $2\varepsilon(R^*/2) = \gamma$, according to (34), and thus is independent of β.

Figure 4: The impact of an increase in β on the equilibrium in the dual economy.



Proof. The impact of an increase in β on R^* can be deducted from Fig. 4. Moreover, note that $\omega^* = \frac{\beta}{(1-\beta)\chi^*}$, according to (20) and (32). ■

Thus, an increase β and an increase in γ have similar effects with respect to concentration and wage dispersion across skills, according to Proposition 3 and 4, respectively. However, the mechanisms and thus the reason for this similarity are quite contrary. Note that, with perfect labor markets, the wage rate for high-skilled labor is the same for both production-related and demand-enhancing activities. Thus, an increase in β implies that non-production labor costs rise (in real terms), implying both an increase in concentration R^* (as stated in Proposition 4) and a reallocation of high-skilled labor towards production-related activities. To see the latter, use (26) and (32) to obtain

$$\frac{M^*}{H} = \frac{\gamma}{\beta + \gamma}. \tag{35}$$

Thus, whereas an increase in γ leads to a reallocation of high-skilled labor towards non-production activities, consistent with the evidence in Fig. 1 and important empirical contributions to the literature on skill-biased technological change,[18] M^*/H

[18] E.g. Berman, Bound and Grichilis (1994), Berman, Bound and Machin (1998), Machin and van Reenen (1998).

decreases if β increases.[19] Moreover, whereas the ambiguity of the impact of an increase in γ on the relative wage ω^* is due to a general equilibrium effect on the goods demand structure, an increase in β potentially reduces wage dispersion even in a one-sector model (i.e. if $\alpha = 1$). This is in stark contrast to other models of skill-biased technological change, and solely stems from analytically distinguishing production-related and non-production activities of skilled labor.[20]

5 Conclusion

This paper has examined an ideal variety model of monopolistic competition in which firms can employ "marketing managers" for quality-improving, demand-enhancing activities. The analysis has focused on the impact of technological progress in the effectiveness of marketing and product design (R&D in a broad sense) on wage inequality and the employment structure. In a first step, it has been shown that such technological change leads to a higher employment share of marketing managers in the economy, in turn raising price mark-up factors for differentiated goods. This is consistent with two stylized facts: the recent increase in horizontal concentration in some key industries on the one hand and an increase in the non-production employment share on the other hand. Moreover, accounting for the fact that demand-enhancing activities are skill-intensive, the model has provided a novel mechanism for the way in which new technologies affect the relative demand for skilled labor in the economy. Although an increased effectiveness of product innovations raises the demand for skilled labor in the differentiated goods sector, its impact on wage inequality is generally ambiguous if, in addition, there is a low-skilled intensive homogenous goods sector. This is because higher mark-ups in the differentiated goods sector may shift the demand structure towards standardized goods.

Finally, these results are compared with the impact of "skill-biased" process innovations. It has been shown that, once analytically distinguishing between production-related and demand-enhancing activities, the impact of such process in-

[19] Moreover, note that $L_x^*/L = \left[(1-\alpha)\left(1+2\varepsilon\left(R^*/2\right)\right)/\left(\alpha\left(1-\beta\right)\right)+1\right]^{-1}$, according to (28) and (32). Thus, an increase in β leads to downsizing of low-skilled labor L_x^* in the differentiated goods sector, for two reasons. First, for a given concentration, relative marginal productivity of skilled labor rises, as in many models in the skill-bias literature. Second, similar to the impact of γ, there is a possible increase the mark-up factor $2\varepsilon(R^*/2)$, in turn shifting goods demand towards the second sector. In sum, since both M^* and L_x^* decrease with β, χ^* unambiguously increases, as stated in Proposition 4.

[20] It should be noted that there are two different notions of skill-biased technological change in the literature, which have been called "intensive" and "extensive" skill-bias (Johnson, 1997). The former means skilled labor-saving technological progress. It is well established that this kind of skill-bias raises wage inequality (in a one-sector model) if and only if the elasticity of substitution between skilled and unskilled labor exceeds unity. In contrast, the change in β considered here represents the latter notion of skill-biased change, which unambiguously raises the skill premium in standard models (e.g. Gregg and Manning, 1997).

novations on wage dispersion is ambiguous even in absence of a homogenous goods sector. This is because "skill-biased" process innovations raise the skill-intensity of production-related employment, i.e. counterfactually reduce the non-production employment share. This suggests to look more carefully for which tasks skill-biased technological change has actually occurred. For instance, in terms of R&D expenditure there seems to be a striking difference between process R&D and product R&D. As pointed out by Lin and Saggi (2002, p.201), "approximately three-fourth of R&D investments by firms in the United States are devoted to product R&D". This suggests that biased changes in the effectiveness quality-improving activities should have empirically relevant effects, providing some justification for the analysis of the present paper.

However, the present paper has not touched the important issue of within-group wage inequality, which has dramatically risen in the industrialized world in the last decades. It may be fruitful to extend the present framework to derive wage inequality within the group of high-skilled workers, say, between managers (i.e. non-production labor) and production-related labor. This could be done by allowing skills to differ in a second dimension besides general education (e.g. managerial skills).

Colophon

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Appendix: Proof of lemma 1

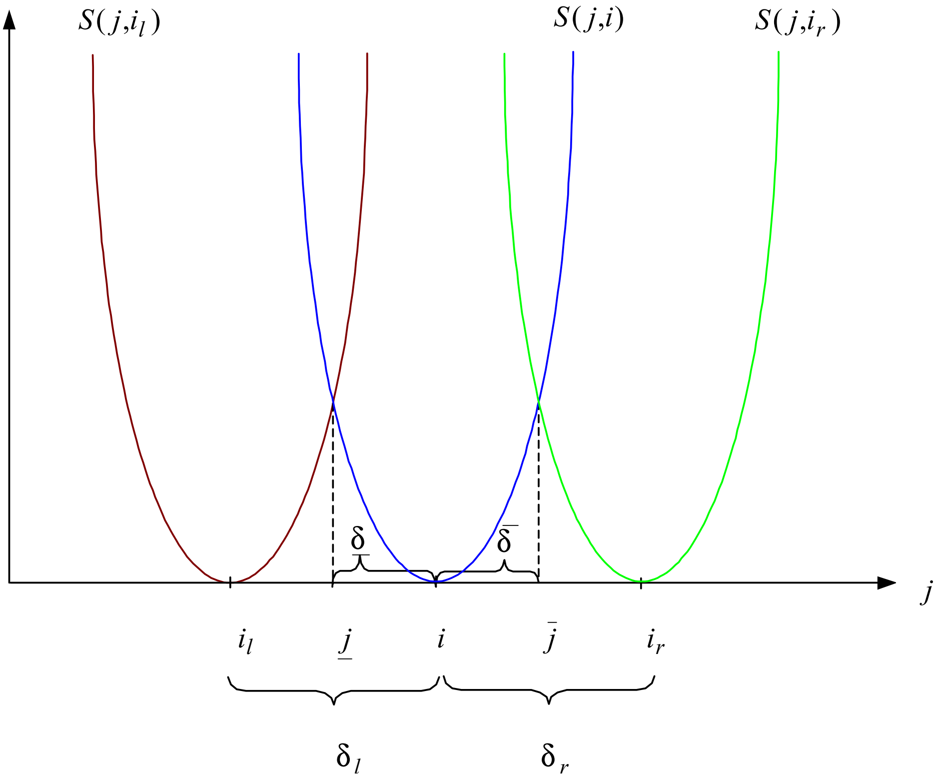
Let the closest neighboring goods on the circumference of the circle of product attributes to the left and right of good i be denoted by i_l and i_r, respectively; that is, the arc distances of good i to i_l and i_r are given by $\delta_l(i) \equiv \delta(i, i_l)$ and $\delta_r(i) \equiv \delta(i, i_r)$, respectively. By maximizing profits with respect to the location on the circumference of the circle of attributes, firm i takes the arc distance $D(i) = \delta_l(i) + \delta_r(i)$ between varieties i_l and i_r as given.

Maximization of profits of firm i with respect to its location is thus equivalent to maximization of (6) with respect to $\delta_l(i)$. The corresponding first-order condition reads

$$(p(i) - w)\left(\frac{\partial\underline{\delta}(i)}{\partial\delta_l(i)} + \frac{\partial\overline{\delta}(i)}{\partial\delta_l(i)}\right) = 0. \qquad \text{(A.1)}$$

(A.1) means that if firm i marginally shifts its location to the right on the circumference of the circle of attributes, the marginal gain of additional consumers

Figure 5: Graphical derivation of $\underline{\delta}$ and $\overline{\delta}$.



rightward must equal the marginal loss of consumers leftward. The first-order conditions (A.1), (7) and (8), $i = 1, ..., n$, give us the equilibrium values of $\delta_l(i)$, $m(i)$ and $p(i)$, $i = 1, ..., n$, respectively. Note that, according to (5), the price elasticity of demand for variety i is given by

$$\eta(i) = 1 - \frac{p(i)\left(\frac{\partial\underline{\delta}(i)}{\partial p(i)} + \frac{\partial\overline{\delta}(i)}{\partial p(i)}\right)}{\underline{\delta}(i) + \overline{\delta}(i)}. \tag{A.2}$$

Remember that all demand by type j goes to the good with the lowest Q-adjusted price she or he perceives. Thus, as can be deducted from Fig. 5 (compare with Wong, 1995, p.262) and (1), $\underline{\delta}(i)$ and $\overline{\delta}(i)$ are given by

$$\underbrace{\frac{p(i)}{Q(\underline{\delta}(i), m(i))}}_{=S(\underline{j}(i),i)} = \underbrace{\frac{p(i_l)}{Q(\delta_l(i) - \underline{\delta}(i), m(i_l))}}_{=S(\underline{j}(i),i_l)} \tag{A.3}$$

and

$$\underbrace{\frac{p(i)}{Q(\overline{\delta}(i), m(i))}}_{=S(\overline{j}(i),i)} = \underbrace{\frac{p(i_r)}{Q(\delta_r(i) - \overline{\delta}(i), m(i_r))}}_{=S(\overline{j}(i),i_r)}, \tag{A.4}$$

respectively. Rewrite (A.3) and (A.4) as

$$p(i)Q(\delta_l(i) - \underline{\delta}(i), m(i_l)) - p(i_l)Q(\underline{\delta}(i), m(i)) = 0 \tag{A.5}$$

and

$$p(i)Q(D(i) - \delta_l(i) - \overline{\delta}(i), m(i_r)) - p(i_r)Q(\overline{\delta}(i), m(i)) = 0, \tag{A.6}$$

respectively, where $\delta_r(i) = D(i) - \delta_l(i)$ has been substituted into (A.4) to obtain (A.6). Applying the implicit function theorem, (A.5) and (A.6) imply

$$\frac{\partial \underline{\delta}(i)}{\partial \delta_l(i)} = \frac{p(i)\frac{\partial Q(\delta_l(i) - \underline{\delta}(i), m(i))}{\partial \delta}}{\Lambda(i, i_l)} \quad \text{and} \quad \frac{\partial \overline{\delta}(i)}{\partial \delta_l(i)} = \frac{-p(i)\frac{\partial Q((\delta_r(i) - \overline{\delta}(i), m(i))}{\partial \delta}}{\Lambda(i, i_r)}, \tag{A.7}$$

$$\frac{\partial \underline{\delta}(i)}{\partial m(i)} = \frac{-p(i_l)\frac{\partial Q(\underline{\delta}(i), m(i))}{\partial m}}{\Lambda(i, i_l)} \quad \text{and} \quad \frac{\partial \overline{\delta}(i)}{\partial m(i)} = \frac{-p(i_r)\frac{\partial Q(\overline{\delta}(i), m(i))}{\partial m}}{\Lambda(i, i_r)}, \tag{A.8}$$

$$\frac{\partial \underline{\delta}(i)}{\partial p(i)} = \frac{Q(\delta_l(i) - \underline{\delta}(i), m(i_l))}{\Lambda(i, i_l)} \quad \text{and} \quad \frac{\partial \overline{\delta}(i)}{\partial p(i)} = \frac{Q(\delta_r(i) - \overline{\delta}(i), m(i_r))}{\Lambda(i, i_r)}, \tag{A.9}$$

where

$$\Lambda(i, i_l) \equiv p(i)\frac{\partial Q(\delta_l(i) - \underline{\delta}(i), m(i_l))}{\partial \delta} + p(i_l)\frac{\partial Q(\underline{\delta}(i), m(i))}{\partial \delta} \tag{A.10}$$

and

$$\Lambda(i, i_r) \equiv p(i)\frac{\partial Q(\delta_r(i) - \overline{\delta}(i), m(i_l))}{\partial \delta} + p(i_r)\frac{\partial Q(\overline{\delta}(i), m(i))}{\partial \delta}, \tag{A.11}$$

respectively.

First, it is shown that a symmetric Nash equilibrium exists. Imposing $\delta_l(i) = \delta_r(i) = \frac{1}{n}$, $\underline{\delta}(i) = \overline{\delta}(i) = \frac{1}{2n}$, $p(i) = p$ and $m(i) = m$ for all $i = 1, ..., n$, one finds that $\Lambda(i, i_l) = \Lambda(i, i_r)$ and thus $\frac{\partial \underline{\delta}(i)}{\partial \delta_l(i)} + \frac{\partial \overline{\delta}(i)}{\partial \delta_l(i)} = 0$, according to (A.7). Hence, for all i, the first-order condition (A.1) is fulfilled, which proves existence. (See Helpman, 1981, for a similar proof.) Evaluated at the symmetric equilibrium, the first equation in (9) follows from (A.8), (A.10) and (A.11) and the first equation in (10) follows from (A.2) and (A.9)-(A.11). Finally, to confirm the second equations in (9) and (10), respectively, use (2). This concludes the proof. □

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