Superstar knowledge-products in a model of growth

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Danny Quah*
LSE Economics Department
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ABSTRACT

This paper develops a hedonic-price growth model where Superstar rewards induce patterns of innovation, learning, and income mobility and inequality. The model provides one formalization of how consumer attitudes towards knowledge-like goods (e.g., computer software) influence the latter's creation and dissemination, and thereby economic growth and income distribution dynamics. The model can be viewed as applying: (i) across producers and consumers within developed or developing economies; or (ii) to the process of knowledge dissemination from developed to developing countries. The model generates dynamics consistent with particular features of actual cross-country income distribution dynamics.

Keywords: income distribution, innovation, knowledge creation, knowledge dissemination, learning, software

JEL Classification: O33, O41

Communications to: D. Quah, LSE, Houghton Street, London WC2A 2AE. [Tel: +44 (171) 955-7535, Email: `D.Quah@lse.ac.uk`] [(URL) `http://econ.lse.ac.uk/~dquah/`]

1 Introduction

This paper develops a hedonic-price growth model where Superstar rewards (in the sense of Rosen [33]) induce patterns of innovation, learning, and income mobility and inequality.

In the model, consumer attitudes towards knowledge-like goods (such as computer software) form a key driving force for technical change. By knowledge-like goods, I mean consumer goods with characteristics similar to those properties of knowledge—initial "unknownness", infinite expansibility, and priority-significance[1]—noted in Arrow [2]. This paper calls such goods *knowledge-products* to distinguish its focus from studies where knowledge forms not a final consumption good but instead an intermediate input into some production process.

On the surface, the model can be viewed as dealing narrowly with the computer software industry and its customers. However, in modern economies many other fast-growing industries produce goods with similar features: New media, massive information databases, entertainment, and modern telecommunications are examples. The consumption products from these industries all show, to some degree, initial unknownness, infinite expansibility, and priority-significance.

More broadly, the model can also be taken to describe aspects of the process of knowledge creation and dissemination, where producers create knowledge and consumers absorb knowledge. Producers and consumers in the model then have interpretations as advanced and developing economies, respectively, in a scheme of technology transfer.

The remainder of this paper is organized as follows. Section 2 briefly describes some related literature. Section 3 presents the model,

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[1] The last two of these properties have been studied further in Dasgupta [9], Dasgupta and David [10], Dasgupta and Maskin [11], and David [15, 16] among others. Sociologists such as Merton [27] have also contributed to that development.

describes the economic agents, and works out alternative equilibria. Section 4 concludes.

2 Related work

Because this paper analyzes knowledge-products in a growth model, it naturally relates to the large literature on ideas, knowledge, and R&D forming the engine of growth (e.g., Aghion and Howitt [1], Grossman and Helpman [19], Jones [20], Jones and Williams [21], Romer [31, 32], and Weitzman [35]). Where this paper differs is its focus on knowledge-products for consumption, not as an intermediate input in production. The production side of the model below therefore is comparatively simple, with the analysis emphasizing instead consumer attitudes towards knowledge-products.

This same distinction differentiates the current paper from that industrial organization literature that has built upon Arrow's [2] insights. Examples of such work include Dasgupta [9], Dasgupta and Stiglitz [12, 13], d'Aspremont, Bhattacharya, and Gérard-Varet [14], and Kortum [24]. Again, that literature has focused on producer behavior (e.g., patent races) with the consumer side kept relatively simple. This paper reverses that ordering of emphasis.

What Arrow [2] identified as infinite expansibility in knowledge is, of course, a special case of increasing returns or nonconvexity more generally.[2] Models focused explicitly on increasing returns have already produced interesting insights on knowledge-intensive industries like computer software (see, e.g., Arthur [3] and Krugman [25]). Such models predict the positive feedback, path-dependence, and first-mover advantage properties that many observers have noted of the

[2] I say "infinite expansibility" rather than "nonrivalry"—they have the same meaning—because the positive term seems to me more descriptive and thus more useful than a negation (which just means everything else). To my knowledge the first usage of "infinite expansibility" to describe the economic properties of knowledge is in a 13 August 1813 letter of Thomas Jefferson (Koch and Peden [23]) to I. McPherson.

computer software industry in particular and knowledge-based industries more generally (see, e.g., David [15, 16]).

In this paper, by contrast, the production side shows no increasing returns. The novelty appears instead on the consumer side through a hedonic price for consuming knowledge-products. The paper emphasizes yet another of Arrow's [2] observations about knowledge, that knowledge is by definition initially unknown, except to its discoverer or creator. Outside of the knowledge-creator, using and consuming knowledge entails a setup cost. Admittedly, that cost is usually lower than the original discovery cost. More important to this paper, however, is that that cost varies across economic agents, either because some agents adapt more easily than others to knowledge-products, or because the opportunity cost of time spent learning to access, enjoy, and use knowledge-products differs across people.[3]

The hedonic-price structure I use below draws on the Superstars specification of MacDonald [26] and Rosen [33], where the focus is on the market behavior of yet a different commodity, namely the performance of opera, music, and athletics. Those goods also show the properties of infinite-expansibility and priority-significance (now not in time as with knowledge discoveries, but instead in cross-section ranking across performers). As Rosen [33] makes clear, such markets differ from more standard anonymous markets in that equilibrium in them entails solving an assignment problem: a particular group of consumers gets assigned to a particular producer. This non-anonymity property will appear in the current study as well.

To summarize, the model developed below applies naturally to

[3] The model below will not display a first-mover advantage property. Thus, unlike the standard increasing-returns model, it is potentially consistent with observations such as Microsoft Internet Explorer's overtaking Netscape Navigator in market share, even though the latter product was initially better established and more widely distributed. In the model below the interpretation given to such an outcome would be that new consumers coming online have been persuaded by Microsoft to adopt its own product in place of Netscape's already-established Navigator.

the study of markets for computer software or other sophisticated modern goods (for instance, large information databases, new media, telecommunications services).[4] A second natural application is to markets for entertainment—opera, music, or athletics—that display Superstar behavior.

Additionally, the model might be used to consider the problem of knowledge dissemination across rich and poor countries in the world. The question here is, If technology levels explain why some countries are rich and others poor, why don't all countries go to the same highest technology levels immediately? After all, technology in the sense of blueprints is, in the large, widely available to everyone. The model below emphasizes the often-made observation that using the best available knowledge entails a cost of learning and adaptation. Understanding the deliberate choice made in this setting then gives some insight into the dynamics of knowledge creation, dissemination, and absorption, and thus potentially helps explain patterns of cross-country growth and convergence.[5]

There are two clear points of contact between the Superstars theoretical model studied below and empirical work on cross-country convergence more generally. First, already stated above, the model emphasizes non-anonymous interactions between economic participants. Second, common to all Superstars structures, the model produces as an equilibrium outcome increased inequality—increased beyond that in some well-defined set of underlying characteristics. Both of these can be used to shed light on the 'emerging twin peaks' and 'clustering/convergence clubs' behavior that Quah [28] empirically documents and claims is explained by spatial and trading-partner interactions.[6]

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[4] An empirical analysis of such goods is in Quah [29], where they are called elements of the *weightless economy*. This list of goods potentially includes intellectual property rights as well (e.g., Scotchmer [34] or Wright [36]).

[5] Ferreira and Quah [18] study that deliberate choice by distinguishing tacit and codifiable knowledge.

[6] Empirical studies on technology transfer are, of course, also con-

3 The model

Assume an economy having distinct populations of producers and consumers, and proceeding in discrete time $t = 0, 1, 2, \ldots, \infty$.

3.1 Producers

Producers are drawn from two-period lived overlapping generations that are born ex-ante identical. Every generation contains P potential producers, each seeking to maximize over choice of occupation and output supplied the present discounted value of expected profits, with discount factor $\beta \in (0, 1)$.

Fig. 1 shows the demography and timing of decisions. When members of generation t are born at the beginning of period t, they decide whether to become regular workers or to develop ideas for the knowledge or θ industry. If they choose to be regular workers, they earn the outside option $w(t)$ at time t. If, however, a member of generation t becomes an idea-developer at time t, she produces a knowledge-product with quality $\theta_x(t) \in (0, \infty)$. (Ideas and knowledge-products are synonymous in the model.) The x subscript denotes *experimental*, and θ_x is the same across all active experimenting idea-developers—young and old—in a given time period. Quantity θ_x evolves across time periods; its dynamics are described below.

When old, those in generation t who were previously regular workers can either continue to be regular workers—now at the outside option wage $w(t + 1)$—or they can start to be idea-developers. If the latter, because they are new at idea-developing, the old of generation t produce $\theta_x(t + 1)$, as do the young of generation $t + 1$.

Those in generation t who were in the knowledge-products busi-

cerned with cross-country interaction. Examples of such analyses, using quite different modelling techniques and motivations, include Ben-David and Rahman [4], Bernard and Jones [5], Cameron, Proudman, and Redding [6], and Coe and Helpman [8]. In related work, Keely [22] and Quah [30] attempt to model the economic decisions underlying those patterns of clustering and convergence clubs that are observed in cross-country data.

ness when young are seasoned developers by time $t+1$. If such an agent continues to develop knowledge-products when old, she produces an idea that is a random variable realizing as either $\theta_s(t+1)$ (success) with probability π or $\theta_f(t+1)$ (failure) with complementary probability $1-\pi$. These outcomes are distinguished by

$$\forall\ t: \qquad \theta_f(t+1) < \theta_s(t+1),$$

and distributed independently across seasoned idea-producers. The (θ_s, θ_f) pair can be attained only by those who have undergone the experimental stage, i.e., an initial release is necessary before a knowledge-product matures to become a success or a failure.[7]

At t the experimental knowledge-product has quality $\theta_x(t)$ borrowing from the current state of acknowledged successes $\theta_s(t)$, i.e.,

$$\theta_x(t) = \lambda_x \theta_s(t), \quad \text{with } 0 < \lambda_x < 1. \tag{1}$$

Let $\mathsf{P}_x(t) \in [0, \mathsf{P}]$ denote the number of young in period t working as idea-producers. I will assume that when P_x differs from zero, both it and P are sufficiently large to allow a law of large numbers across producers.

Assume that success quality evolves as:

$$\forall\ t \geq 0: \qquad \theta_s(t+1) = \begin{cases} \lambda_0 \theta_s(t) & \text{if } \mathsf{P}_x(t) = 0, \\ \lambda_s \theta_s(t) & \text{otherwise,} \end{cases} \tag{2}$$

with $\lambda_s \geq 1 > \lambda_0 > 0$ and $\theta_s(0) > 0$ given. Equation (2) specifies, as a simplification, that growth in θ_s does not vary smoothly in P_x, but depends only on whether *some* young are working as idea-producers. When those exist, growth is at rate λ_s; otherwise, growth is lower at rate λ_0. Indeed, since $\lambda_0 < 1$ the economy actually regresses when there are no young idea-producers.

7 We might think of this in the vernacular as requiring a beta version or a version 1.0 before a knowledge-product becomes established.

A different and perhaps more natural specification might have growth rates continue to increase as P_x rises. Equation (2), appropriately monotone increasing in P_x, simplifies the analysis without giving up that intuition. The constant proportionality in (1) means that with a lag the growth rate in experimental quality equals that in success quality, regardless of which branch of (2) is active.

Because $\lambda_0 < 1$ technical regress occurs in the absence of experimental activity. This, however, is inessential: what matters is only that $\lambda_s > \lambda_0$ so that we could have, for instance, $\lambda_0 = 1$. Then, no technical regress occurs even when idea-producers are inactive for several periods: Progress simply picks up where it had earlier left off.

Assume that experimental idea-products have quality intermediate between that of failures and successes, $\theta_x(t) \in [\theta_f(t), \theta_s(t))$, and that there is free entry into the knowledge-product industry.

Turn next to the costs of producing knowledge-products in quantity. From Arrow [2] and following Arthur [3], Krugman [25], and Romer [31], it is natural to suppose that such marginal costs are either zero or falling. However, to focus on the effects that are novel here, assume not the standard increasing returns, but that it costs an idea-producer $\phi_t(G)$ at time t to supply G units of her knowledge-product, with $\phi_t(0) = 0$, $\phi_t' > 0$, and $\phi_t'' > 0$. Costs ϕ_t are, therefore, taken to be identical across θ, although varying through time. Invariance of marginal costs with respect to θ gives then increasing returns in the θ direction, although there is no increasing returns in the quantity G direction.

At any time t three kinds of knowledge-products, $\theta_f(t)$, $\theta_x(t)$, and $\theta_s(t)$, are potentially traded. Denote their corresponding spot prices $p_f(t)$, $p_x(t)$, and $p_s(t)$. This notation imposes that knowledge-products in the same class command the same price. In a given time period an idea-producer with knowledge-product θ receives profit

$$R = \max_{G \geq 0} pG - \phi(G), \tag{3}$$

so that optimal G and R increase in p. (Indeed, from the envelope theorem, the rate at which R increases in p is itself increasing.) Because $\phi(0) = 0$, we must have R nonnegative. Label R_f, R_x, and

R_s the profits corresponding to the different classes of knowledge-products, and let the associated supply decisions be G_f, G_x, and G_s. If $p_f < p_x < p_s$, then so too $R_f < R_x < R_s$ with absolute differences magnified from those in p.

Finally, assume that the outside option $w(t)$ and the cost structure ϕ_t evolve exogenously. For existence of equilibrium, it will be convenient to assume that w in each period falls in an appropriate intermediate range. The conditions determining that range don't have a directly interesting economic interpretation; so I assume here only that the outside option w is neither too large or too small.

To summarize the essential elements above, write the producer's problem as the value equation:

$$R_x + \beta \left[\pi \max\{\widetilde{R}_s, \widetilde{w}\} + (1-\pi) \max\{\widetilde{R}_f, \widetilde{R}_x, \widetilde{w}\}\right] = w + \beta \max\{\widetilde{R}_x, \widetilde{w}\}, \quad (4)$$

where $\tilde{}$ denotes values in the second period of life. When (4) is satisfied, producers are indifferent across occupations. The demand side then determines P_x.

3.2 Consumers

Consumers live for one period, at the beginning of which each receives exogenous income Y. The number of consumers is C constant through time. Heterogeneity across consumers is indexed by $\nu \in (-\infty, \infty)$ distributed following cdf $\mathbb{F}$. Population heterogeneity and incomes evolve exogenously so that at t they are $\mathbb{F}_t$ and $Y(t)$ respectively.

Two kinds of goods can be consumed: knowledge-products and a numeraire composite commodity. Consumption of the first is time-consuming, so that in a lifetime at most one knowledge-product from a single class can be consumed.

Consumer type ν solves the problem:

$$\max_{\substack{c \geq 0 \\ \theta \in \{\theta_f, \theta_x, \theta_s\} \bigcup \emptyset}} U(c, \theta \mathbf{1}_\theta) \quad \text{s.t. } c + (p_\theta + \nu)\mathbf{1}_\theta \leq Y \quad (5)$$

with

$$U_c > 0,\ U_\theta > 0 \quad \text{and} \quad \lim_{c\to 0} U(c,\theta) = 0 \text{ for fixed } \theta, \tag{6}$$

and $\mathbf{1}_\theta$ denoting the indicator function on $\{\theta_f, \theta_x, \theta_s\}$.

The budget constraint in (5) says that consuming θ entails payment on top of the sticker price p_θ a further cost ν. Condition (6) says that consumers value both the composite commodity and the knowledge-product θ but leaves unrestricted the substitution propensities across the two kinds of goods.

The higher is type ν, the more costly is consuming the knowledge-product. Although ν differs across consumers, it is invariant to quality θ. This has two interpretations. First, following Rosen [33], ν can be viewed as measuring the opportunity cost of time. The act of consuming knowledge-products—like enjoying opera or athletic performances—takes time. The opportunity cost of that time does not depend on whether the opera performance or knowledge-product is high- or low-quality, only on whether or not the consumer attends the performance. High-ν consumers would then, other things equal, have a further reason for selecting high-quality knowledge-products.

Second, ν can be viewed as parameterizing the cost of learning. The higher is ν, the less easily the consumer learns to access and appreciate a particular knowledge-product.[8] In this second interpretation, negative ν can be interpreted as a subsidy to learning.[9]

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[8] For knowledge-products that are computer software, there might be a specific set of conventions—keyboard and mouse actions, menu configurations, and so on—one has to learn that is common to all software, but the quality of screen presentations and metaphor developments in the product differ across θ's. For knowledge-products that are ideas, one might have to learn the technical language in which such ideas are expressed, but that language is invariant to the quality of the ideas themselves.

[9] Sufficiently negative ν's might lead to a negative total price $p_\theta + \nu$. This is not necessarily inconsistent with a sensible economic equilibrium. In models of clubs, e.g., Ellickson, Grodal, Scotchmer,

In either interpretation, ν invariant over θ means that consumers find it no easier or harder to appreciate an experimental θ_x than they do an established success θ_s. Thus, in the model the inherent quality of the knowledge-product is fully described by θ in the utility function, not by its potentially affecting the budget constraint in (5). Type ν describes consumer attitudes towards knowledge-products altogether, not towards any one of them.

Consumer type ν can always choose to consume no knowledge-product at all in which case ν is irrelevant and all income is spent on the composite commodity c. Otherwise, composite commodity consumption $c = Y - p_\theta - \nu$, whereupon utility is $U(Y - p_\theta - \nu, \theta)$.

Call C_x the number of consumers choosing θ_x. Similarly, let C_f and C_s be the number of consumers choosing θ_f and θ_s respectively.

3.3 Equilibrium

Producers and consumers understand the laws of motion of the different variables in the economy, and in particular those (unspecified in the discussion thus far) in the exogenous quantities w, ϕ, $\mathbb{F}$, and Y.

An equilibrium is a sequence of spot prices and occupation and supply decisions such that all consumers maximize utility and all members of the producer populations maximize expected present discounted value of profits. Formally, we seek sequences

$$\{p_f(t), p_x(t), p_s(t), \mathsf{P}_x(t), G_f(t), G_x(t), G_s(t) : t = 0, 1, \ldots, T\}$$

satisfying (3), (4), and (5), given the exogenous evolution of outside options $w(t)$, cost structure ϕ_t, consumer attitudes $\mathbb{F}_t$, and incomes $Y(t)$.

The discussion is considerably simplified if we focus on equilibria bearing a stationarity property. It is convenient for this to take $\lambda_s = 1$, i.e., the economy even with ongoing successful innovation shows zero growth (without ongoing innovation, on the other hand, the

and Zame [17], negative prices can be an essential part of an otherwise standard price-taking equilibrium.

economy decays at rate λ_0). Define a *stationary equilibrium* to be an equilibrium where for all t

$$p_f(t+1) = p_f(t), \quad p_x(t+1) = p_x(t), \quad p_s(t+1) = p_s(t),$$
$$\mathsf{P}_x(t+1) = \mathsf{P}_x(t),$$

and

$$G_f(t+1) = G_f(t), \quad G_x(t+1) = G_x(t), \quad G_s(t+1) = G_s(t).$$

Assume that the exogenous quantities are, similarly, time-invariant, i.e.,

$$w(t+1) = w(t),\ \phi_{t+1} = \phi_t,\ \mathbb{F}_{t+1} = \mathbb{F}_t,\ Y(t+1) = Y(t).$$

Hereafter, we study only such stationary equilibria.

Free entry implies that in each period $R_x \leq w$. Moreover, since $\theta_f < \theta_x < \theta_s$ and utility is increasing in θ, we must have $p_f < p_x < p_s$, and therefore $R_f < R_x < R_s$. The producer's value equation (4) then becomes

$$R_x + \beta\pi \max\{\widetilde{R}_s, \widetilde{w}\} = w + \beta\pi\widetilde{w} = (1+\beta\pi)w. \tag{7}$$

However, if $\widetilde{R}_s \leq \widetilde{w}$ then $R_x = w \geq R_s$, which is a contradiction. Thus, in each period $R_f < R_x < w < R_s$. New idea-developers accept low earnings temporarily so that they can later potentially become high-earning Superstar successes. Those idea-developers whose experiments turned out to be failures exit the market and work the outside option.

In equilibrium, therefore, no θ_f's are produced. Call ζ_s the state of consuming θ_s while paying price p_s; similarly define ζ_x. The consumer's problem (5) reduces to:

$$\max_{\theta \in \{\theta_x, \theta_s\} \bigcup \emptyset} \{U(Y - p_s - \nu, \theta_s),\ U(Y - p_x - \nu, \theta_x),\ U(Y, 0)\}. \tag{8}$$

For fixed Y and (p, θ), the function $U(Y - p - \nu, \theta)$ decreases with ν. Taking variation in type ν, the three functions $U(Y - p_s - \nu, \theta_s)$, $U(Y - p_x - \nu, \theta_x)$, and $U(Y, 0)$ can be graphed as in Figs. 2–4. In all cases, the solution to (8) traces out the upper envelope of the three schedules in U.

Figs. 2–4 show that exactly three outcomes are possible: the graphs of $U(Y - p_s - \nu, \theta_s)$ and $U(Y - p_x - \nu, \theta_x)$ might intersect, or they might not (Fig. 2). If the former, the intersection might occur below $U(Y, 0)$ (Fig. 3) or above (Fig. 4). (In principle, multiple intersections might occur. Conditions on U that rule out such multiplicity are available, but don't seem to add much insight. Thus I simply take the single intersection possibility as primitive.)

Taking (Y, p_s, p_x) as given define ν_{int} to be the intersection in ν of $U(Y - p_s - \nu, \theta_s)$ and $U(Y - p_x - \nu, \theta_x)$, i.e.,

$$\nu_{int} \stackrel{\text{def}}{=} \{\nu \ni U(Y - p_s - \nu, \theta_s) = U(Y - p_x - \nu, \theta_x)\}\,.$$

Let ν_{max} be the larger of the intersections of $U(Y - p_s - \nu, \theta_s)$ and $U(Y - p_x - \nu, \theta_x)$, respectively, with $U(Y, 0)$, i.e.,

$$\begin{aligned}\nu_{max} \stackrel{\text{def}}{=} \max(&\{\nu \ni U(Y - p_x - \nu, \theta_x) = U(Y, 0)\},\\ &\{\nu \ni U(Y - p_s - \nu, \theta_s) = U(Y, 0)\}).\end{aligned}$$

From (6), threshold ν_{max} always exists, even if ν_{int} might not.

The cases depicted in Fig. 2 and Fig. 3 are, in effect, the same. In either Figure, only two types of consumption behavior occur: one or the other of θ_x and θ_s (but not both), or no knowledge-product at all. However, neither situation in Fig. 2 and Fig. 3 is sustainable. To see this, note that no idea-producer works at θ_x for $R_x < w$ when in the next period θ_s experiences zero demand. Conversely, no idea-producer achieves the maturity to produce θ_s if no demand is expressed for θ_x when she is young. Thus, the only case of interest is Fig. 4.

Here, again, there are two cases: $U(Y - p_s - \nu, \theta_s)$ can intersect $U(Y - p_x - \nu, \theta_x)$ from above (Fig. 5) or from below (Fig. 6). Which obtains depends on the interaction between possibilities of substitution across c and θ and on the configuration of quality θ and equilibrium price p. (For instance, CES functional forms for U can give either Fig. 5 or Fig. 6, depending on whether the elasticity of substition exceeds 1. The standard Cobb-Douglas special case gives Fig. 5.)

I have labelled Fig. 5 the *Learning Society* because in it the middle class—as measured by their type ν falling in a range intermediate between the very low and very high—choose to consume the experimental θ_x. It is this middle group of consumers that supports innovation and experimentation in the knowledge-products industry.

By contrast in the *Conservative Society* of Fig. 6 the middle class chooses only established successes. It is now those with low ν's who demand experimental knowledge-products.

The distinction between the two societies in Figs. 5–6 is substantive. If, for example, governments seek to subsidize learning by reducing consumers' opportunity costs (induce negative ν) they will end up only subsidizing consumption of established successes in Fig. 6, not of the experimental knowledge-products, as would happen in Fig. 5. (Of course, increasing the demand for θ_s does have, in general, positive knock-on effects for θ_x since dynamic rewards then increase for those in the knowledge-products industry.)

To see that a stationary equilibrium exists for both the Learing and Conservative Societies, we proceed in steps. In either society, no θ_f is produced and we can set $\mathsf{C}_f = 0$. In the Learning Society, demand for successful knowledge-products is $\mathsf{C}_s = F(\nu_{int})$ while supply is $\pi \mathsf{P}_x G(p_s)$; demand for experimental knowledge-products is $\mathsf{C}_x = F(\nu_{\max}) - F(\nu_{int})$ while supply is $\mathsf{P}_x G(p_x)$. Holding fixed the number of experimenting idea-developers P_x, an increase in p_s reduces $F(\nu_{int})$ and increases $G(p_s)$; an increase in p_x reduces $F(\nu_{\max}) - F(\nu_{int})$ and increases $G(p_x)$. Thus, for fixed P_x, a price pair (p_x, p_s) clearing the knowledge-product markets always exists. The same conclusion holds for the Conservative Society, remembering to reverse both the interpretations and the supplies that correspond to the different demands $F(\nu_{int})$ and $F(\nu_{\max}) - F(\nu_{int})$.

Of course, for arbitrary P_x the (p_x, p_s) pair that clears knowledge-product markets need not satisfy the producer value equation (7). But the left-hand side of (7) varies continuously in P_x so that provided w falls in an appropriate intermediate range (as discussed above), then there always exists an equilibrium sub-population P_x of idea-producers in $(0, \mathsf{P})$ such that the knowledge-product market-clearing prices then also imply revenues (R_x, R_s) satisfying (7).

Summarizing, a stationary equilibrium always exists and has the properties described in Figs. 5–6.

3.4 Income mobility and inequality: Distribution dynamics

Equilibrium, regardless of whether it is in the Learning or Conservative Societies, displays certain properties common to all Superstars models. Other features, however, are a little surprising.

The central Superstars result holds in the model. From consumers' optimization, price p is increasing in quality θ. Since production costs ϕ are invariant to θ, high-quality idea-producers optimally produce more than low-quality ones. The reasoning surrounding (3) then gives that profits are a convex function of quality, so that there is the usual skewed income distribution, already familiar from MacDonald [26] and Rosen [33].

Only a few Superstars ($\pi \mathsf{P}_x$) survive to earn very high rewards. At the same time, many more experimenters (P_x) enter the industry at low immediate earnings, anticipating that they too might become Superstar producers in the future. Many of them fail, however, and exit the industry.

Finally, since $R_x < w$, no producer begins a career as an idea-developer in midlife. A regular worker when young remains a regular worker throughout.

On the consumer side, as expected from the standard Superstars reasoning, those with high opportunity or learning costs ν—on the extreme right of Figs. 5–6—spend none of their resources on the knowledge-product. But then, however, unlike in MacDonald [26] and Rosen [33], there is no necessary monotonicity in consumption patterns.

To be clear on this, recall the discussion of opera consumption in MacDonald [26] and Rosen [33]. High ν consumers find their time opportunity costs too high and consume no opera at all. Slightly lower ν consumers never find it worthwhile to try out experimental (potentially) low-quality opera, and instead always consume just the established successes. Finally, the least discriminating consumers, with lowest ν's, only go to cheaper experimental, low-quality opera.

Here, by contrast, intermediate consumers with $\nu \in (\nu_{int}, \nu_{max})$ do not always consume just the high-quality knowledge-product. In the Learning Society of Fig. 5, those middle-ν consumers experiment—the equilibrium price p_x turns out to be sufficiently low to induce them to do so. It is only in the Conservative Society of Fig. 6 that the middle-ν consumers choose to consume high-quality established successes θ_s.

Although somewhat outside the model, a leapfrogging interpretation is also available. In the Learning Society Fig. 5, those with smallest ν's—who have the lowest opportunity cost of time—bypass the lower-quality experimental products and latch right on to the high-quality ones. If we identified such consumers as the least-developed economies (ignoring the assumption that, in the model, Y is the same across all consumers) Fig. 5 says that they immediately jump to the knowledge frontier. At the same time, however, those economies already relatively developed, with ν's in an intermediate range, choose to learn and use only experimental technologies (because the price on those is relatively low in equilibrium). In the Conservative Society Fig. 6 the situation is reversed. The least-developed economies only use lower-quality experimental knowledge-products, while the relatively more-developed ones, only the established high-quality successes.

4 Conclusions and extensions

This paper has developed a simple hedonic-price growth model with a Superstars reward structure inducing patterns of innovation, learning, and income mobility and inequality.

The model has two natural interpretations. First, it can be taken to be an industry model of software producers and consumers. Second, it can be viewed as a model of knowledge creation and dissemination, and thus is a model potentially useful for shedding light on observed patterns of cross-country growth and convergence.

The model addresses a number of empirical regularities in observed patterns of cross-country growth and convergence. First, there is the importance of non-anonymous interaction across producers and consumers (knowledge creators and knowledge absorbers). Second, there is a dynamic increasing inequality towards clusterings at top and bottom of the cross-section distribution.

The limitations of the preceding analysis naturally suggests extensions. The types distribution $\mathbb{F}$ is exogenous in the model above; more natural and interesting would be where $\mathbb{F}$ adapts endogenously over time to historical consumption patterns. Second, although the model above can display two different aggregate growth rates in equilibrium, it cannot be viewed as a model of endogenous growth. As an extension, therefore, the aggregate growth rate of the economy might be made to depend on the intensity of innovation, not just whether or not innovation occurs at all.

The knowledge-products in the model share the standard properties of knowledge that different branches of the economics literature (significantly, industrial organization on the one hand and endogenous growth on the other) have previously studied. The novelty in this paper is its focus on consumer attitudes towards those knowledge-products as a key factor determining their development, in contrast to the usual increasing returns or infinite expansibility on the producer side.

Turn finally to some broader issues. Although unnecessary to note for the formal analysis, one question motivating the model is, Does growth in economies now—where relatively important are consumer software, new media, information databases, and other elements of the "weightless economy"—differ from growth in economies during, say, the Industrial Revolution of the 19th century? The intuition motivating the model is that the answer is Yes. While software is like knowledge in the Arrow sense, its role in modern economies differs from the functions of the kind of knowledge involved in, say, building better machines.

This distinction is similar to that expressed by some sociologists, e.g., Castells [7], that modern economic development profoundly differs from that of earlier times.[10] It is now relatively uncontroversial

[10] Castells [7] articulates this as follows: 'To be sure, knowledge and information are critical elements in all modes of development,

to observe that (a) progress in knowledge is an important factor in all economic growth, and that (b) modern economies increasingly emphasize knowledge-intensive goods. Underlying this paper's analysis is the hunch that observations (a) and (b) are distinct in economically important ways.

since the process of production is always based on some level of knowledge and in the processing of information. ... What is specific to the informational mode of development is the action of knowledge upon knowledge itself as the main source of productivity.'

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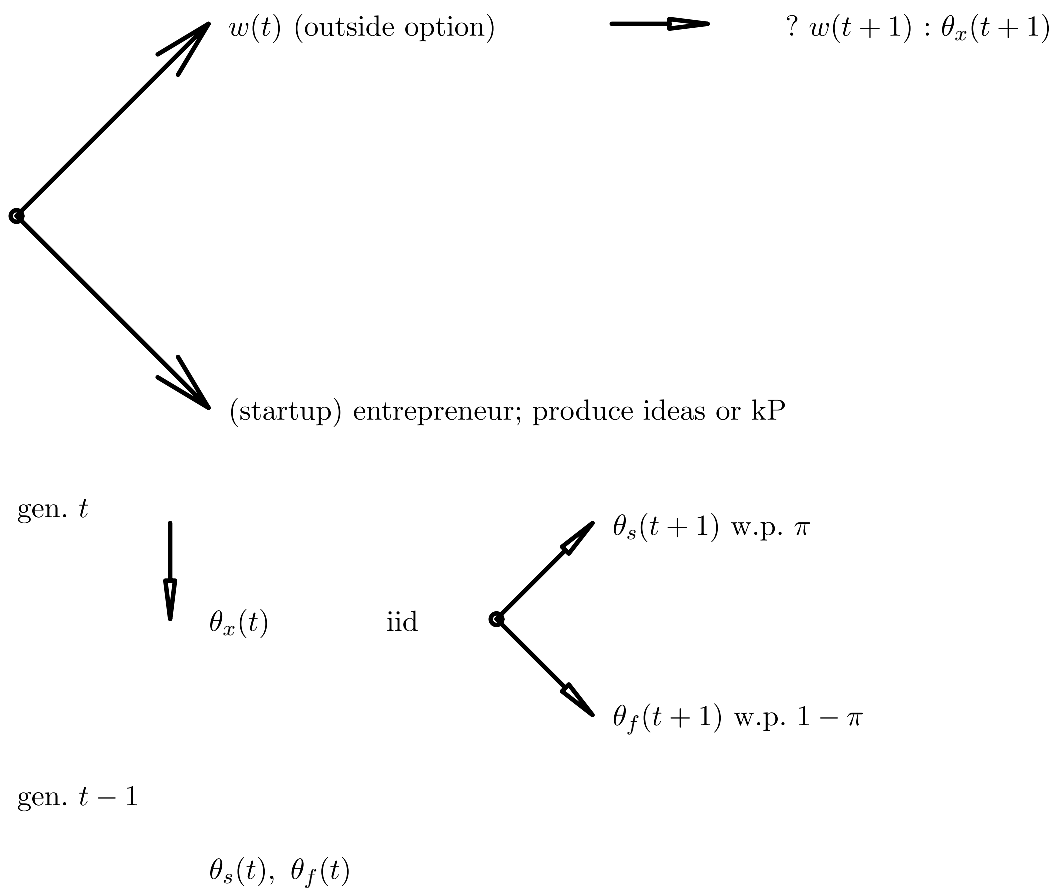

Fig. 1: Producer Demography and Decisions

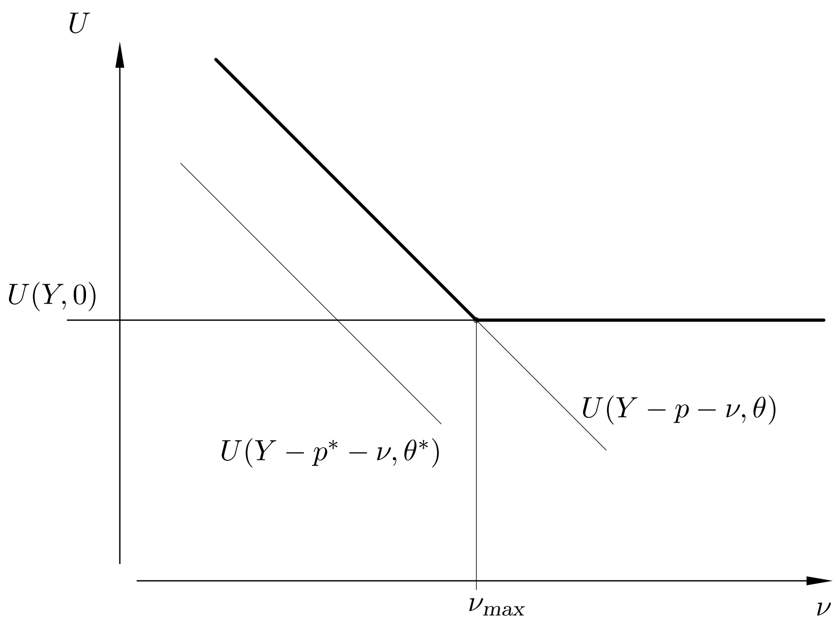

Fig. 2: Non-existent ν_{int} Only 2 kinds of consumption activity occur: One or the other kP (but not both) and no kP.

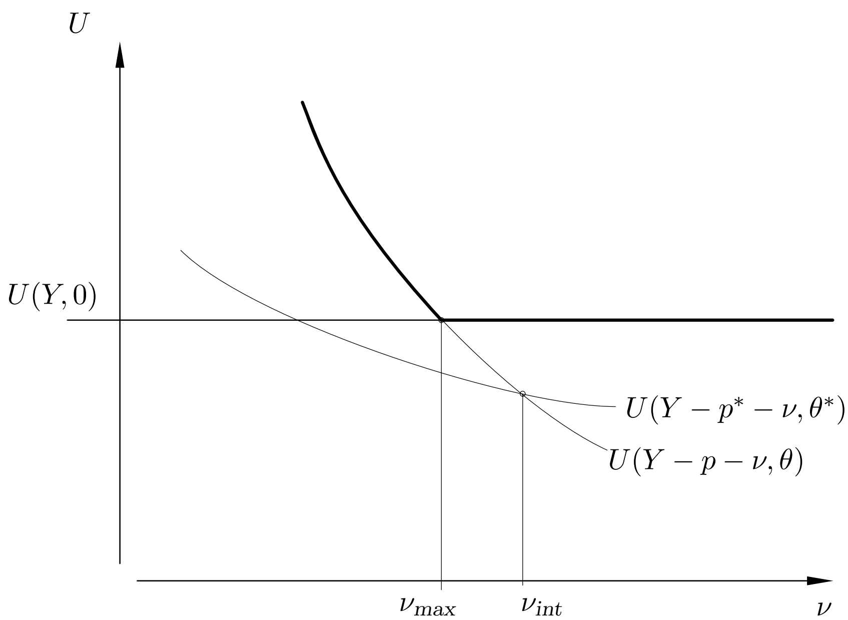

Fig. 3: Both intersections exist with $\nu_{max} < \nu_{int}$ Again, only 2 kinds of consumption activity occurring: One or the other kP (but not both) and no kP.

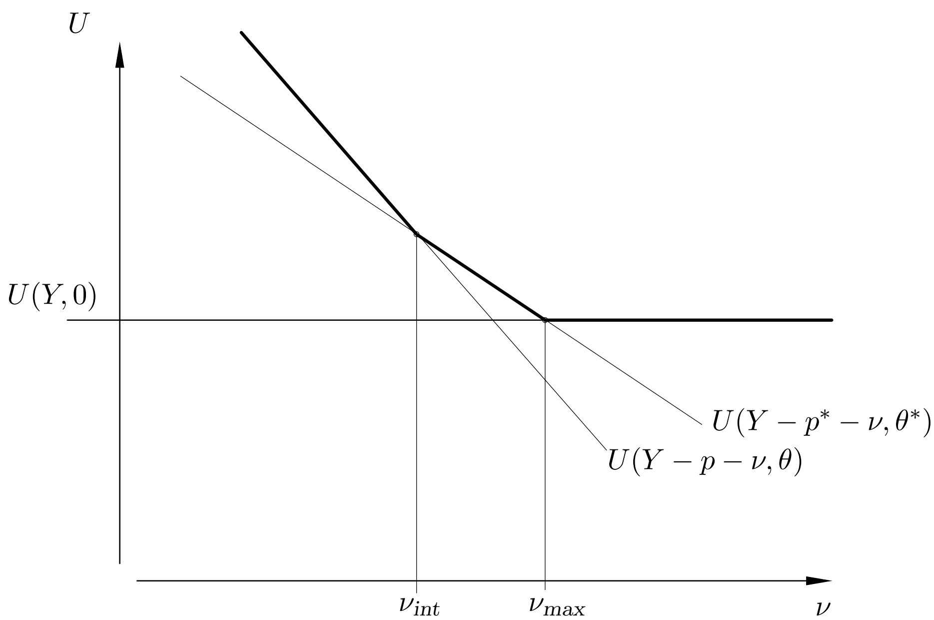

Fig. 4: Dispersed case with $\nu_{int} < \nu_{max}$ All 3 kinds of consumption activity occur.

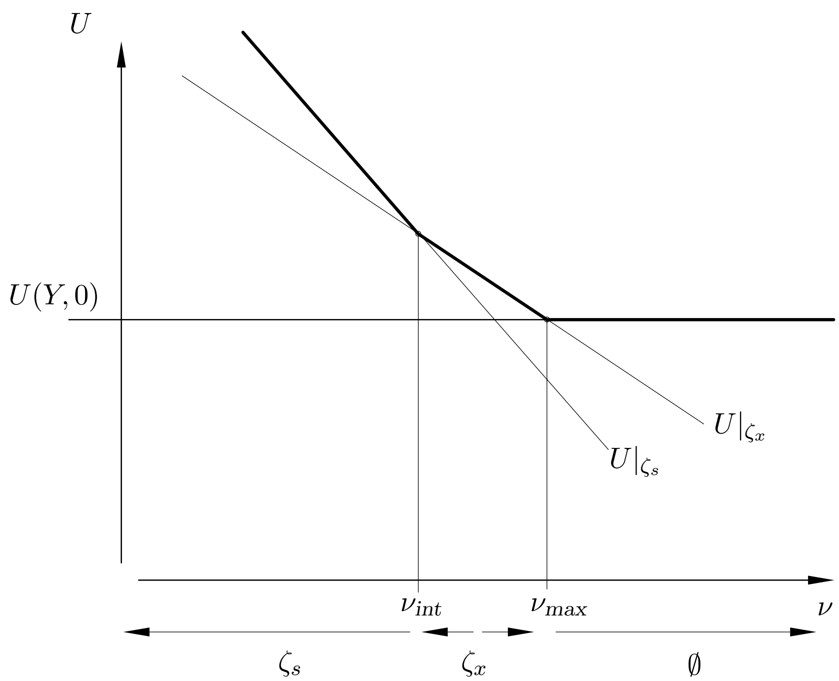

Fig. 5: The learning society Intermediate ν's consume experimentation.

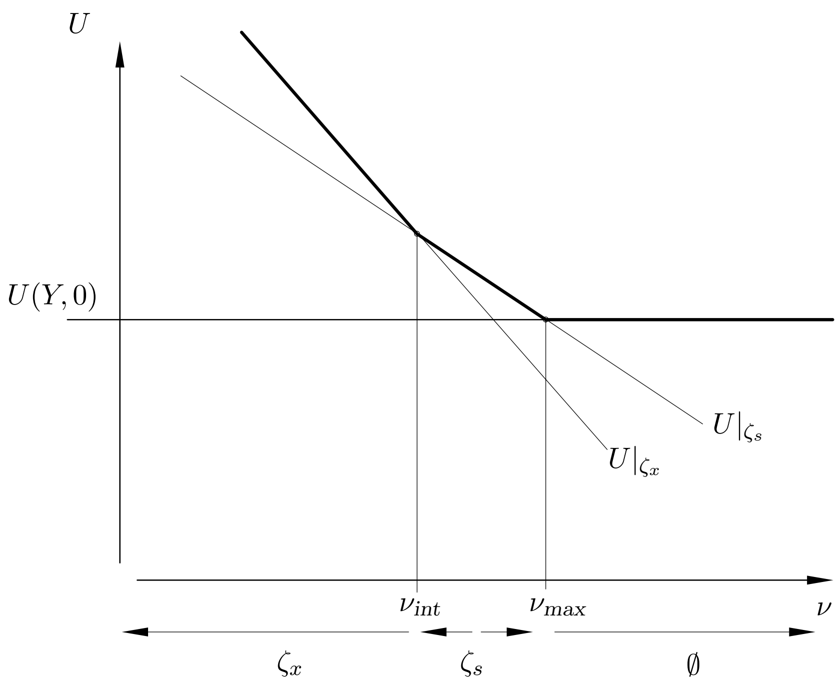

Fig. 6: The conservative society Intermediate ν's consume established successes.