A theoretical account for the rise of mass production

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Abstract

Despite being widely used and studied in various different disciplines, mass production has not been analyzed rigorously from an economic theory point of view. This paper is an attempt to fill that gap. Defining mass production as a new system in which goods can be produced cheaper but which requires higher fixed costs, I derive the conditions under which the economy switches to mass production by analyzing a general equilibrium model with technology choice. It is then found that once the transition to mass production takes place, there is no reversal to the old way of production unless preferences change. I show that such a transition of the economy to mass production, driven by profit-seeking firms' decisions to adopt new mass production technologies, always improves welfare. These findings may increase our understanding of some of the underlying forces that drove the diffusion of mass production in the twentieth century.

Keywords: mass production, monopolistic competition, technological choice
JEL classifications: D21, D43, L23, N60, O33

1. Introduction

Mass production has been intensively studied in the business world. The term mass production is used frequently, but it is usually associated with Ford Motor Company's automobile production in the early twentieth century, sometimes called Fordism. Introducing revolutionary ways of production must have affected people's economic life in many ways, both in their workplaces and in their consumption. The way people work changed drastically and consumer goods became standardized and cheaper.

While these production methods faced various kinds of opposition, including that from popular figures such as Charlie Chaplin in his critical film "Modern Times," mass production eventually diffused throughout the industrialized world during the twentieth century. Other automobile manufacturers adopted Ford's assembly line production style. The techniques have also been applied to many other products, including "white goods" such as refrigerators and washing machines. Mass production became, in the words of Sabel and Zeitlin (1985, p133), "the undisputed emblem of industrial efficiency." It should be noted, however, that mass production did not work in all industries. According to Hounshell (1984) early application of mass production to housing, furniture, and agricultural goods production turned out to be unsuccessful.

Ford's famous Model T automobile displayed drastic price drops and rapid production increases. When the car was introduced in the market in 1908, its retail price was 850 dollars. Ford sold 5,986 units. After introducing its revolutionary assembly line in 1913, the Model T cost 360 dollars, and 577,036 units were sold in 1916.[1]

The mass production system is characterized by its assembly line, which was made possible by the introduction of interchangeable parts made by steel punches and presses. Its rise seems inevitable today, but it was revolutionary in the early twentieth century when Ford started mass producing Model Ts. Prior to mass production, when there were no assembly lines, manufacturing relied on the "fitting" done by many skilled workers. Some departures from this pattern were seen in the United States in its small arms production, sewing machine production by Singer, agricultural machinery (such as reapers and mowers) by McCormick, and bicycle

[1] These figures are complied and provided by Hounshell (1984, Table 6.1.).

production.[2] But it was Ford that combined the two elements of mass production, interchangeable parts and minute division of labor, to make moving assembly line production a reality.

Running the assembly line also required organizational changes. Freeman and Soete (1997, p.144) describe "[T]he need for skilled workers was reduced to a minimum and the plant was controlled and co-ordinated by the new profession of industrial (production) engineers and an army of foremen and indirect workers responding to their orders." This suggests that as firms introduced assembly lines they needed to hire more people to manage the system, which is likely to have increased their fixed costs.

In business studies, interest shifted long ago from mass production to new concepts such as lean production, flexible/agile production, and mass customization, etc.[3] This shift, to some extent, was triggered by the rise of Japanese manufacturing in the post-war era. Japan's production system has gone beyond mass production.[4] Womack et al. (1990) studied it to come up with the concept of lean production. Pine (1993) addressed the management issues of how to mass-produce and individually customize goods and services.

Within the literature, however, mass production has not been addressed and rigorously studied from the viewpoint of economic theory. This paper is an attempt to fill that gap. I aim to construct a formal model of mass production then analyze the transition from traditional, small-scale production to mass production. The model must be capable of capturing changes in firms' production scales as well as the welfare implications of the resulting standardization of consumer goods. To this aim I propose using monopolistic competition, because it is useful in capturing such supply and demand side changes. Specifically, I use the simplest possible general equilibrium model of monopolistic competition with technological choice. All firms initially produce using traditional technology. They are then given a new technology, mass production, and choose the more profitable one. I show that, consistent with intuition, transition to mass production occurs if the expected gains in operating profits exceed the required increase in fixed costs for the new production system. Once the transition to mass production takes place, there is no reversal to traditional, small-scale production unless preferences change. I also show that such

[2] See, for example, Bo (1984) on the development of machine tools that preceded the rise of mass production. See also Hounsell (1984) on the rise and transition to mass production in the United States.

[3] See, for exmaple, Duguay et al. (1997) on flexible/agile production.

a transition of the economy to mass production, driven by profit-seeking firms' decisions to adopt new mass production technologies, always improves welfare. These findings may increase our understanding of some of the underlying forces that drove the diffusion of mass production in the twentieth century.

The rest of the paper is organized as follows. After setting the technological assumptions in Section 2, the initial equilibrium is derived in Section 3. Section 4 explains the conditions under which firms adopt mass production technology, and a new mass production equilibrium is derived and analyzed. Welfare implications of the transition to mass production are presented in Section 5. The effects of the change in preferences after the transition to mass production is analyzed in Section 6, followed by a conclusion section that contains a brief summary and limitations of the analysis.

2. Technology choices

In the business literature, mass production is seen as a production system using assembly lines coupled with organizational changes that require more indirect workers to manage production. To formalize mass production I interpret it as an investment that requires larger fixed costs but reduces the marginal costs of production, compared to existing or traditional technology. Mass production would then require a variety of resources that differ from traditional production technology. For simplicity, this model assumes labor as the only factor of production. (Therefore, labor should not be interpreted literally, but should be interpreted as a composite of various production factors including labor.) Assuming fixed costs implies that the production technology exhibits increasing returns to scale. Specifically, as shown in Table 1, I assume that traditional technology requires F units of labor and c units of labor per unit output. Then denoting a firm's output as q, its cost function under traditional technology is $C(q) = F + cq$. On the other hand, mass production technology requires αF units of labor and βc units of labor per unit output, where importantly $\alpha > 1$ and $0 < \beta < 1$. This implies that switching to mass production reduces the marginal cost from c to βc, but requires an increase

[4] See, for example, Kenny and Florida (1988) on mass production in Japan and the society.

in fixed cost from F to αF. The cost function under mass production technology is $C(q) = \alpha F + \beta cq$.

Table 1. Technology choices

	fixed cost	marginal cost
traditional production	F	c
mass production	αF $(\alpha > 1)$	βc $(0 < \beta < 1)$

3. Initial equilibrium with traditional technology

The population of the economy, or the total amount of production factors, is denoted as L. All members of the economy work and consume. Firms are assumed to be monopolistically competitive. Each firm produces a particular variety of goods, but there is some degree of competition because other rival firms produce similar goods. We use a standard assumption for consumer behavior originally developed by Dixit and Stiglitz (1977). All consumers have the same preferences, which are defined as

$$U = \left[\int_0^n m(i)^\rho \, di \right]^{\frac{1}{\rho}},$$

where U is the composite of all the differentiated varieties, n is the mass of varieties, $m(i)$ is the consumption of variety i, and ρ is the substitution parameter. I assume that $0 < \rho < 1$ to ensure that the varieties are imperfect substitutes. $\sigma \equiv 1/(1-\rho) > 1$ represents the elasticity of substitution between any two varieties. σ increases as desire for variety decreases. Denoting the price of a variety as $p(i)$, a price index

$$G \equiv \left[\int_0^n p(i)^{1-\sigma} \, di \right]^{\frac{1}{1-\sigma}} \tag{1}$$

is introduced such that total expenditure is GU. G is the overall level of prices that each firm takes as given.

In the above setting, consumers' utility maximization leads to demand for each variety being $p(i)^{-\sigma} G^{\sigma-1} Y$, where Y is aggregate income. Demand therefore depends not only on $p(i)$ and Y but also on G. Y is equal to the total earnings of the workers. Setting the wage (or the returns on the factors of production) equal to 1, then

$$Y = L. \tag{2}$$

On the supply side, a typical monopolistically competitive firm will set its price so that marginal revenue equals marginal cost (c), that is,

$$p_T(1 - 1/\sigma) = c, \tag{3}$$

which is known as mark-up pricing, where firms always set their prices above their marginal costs. (Hereafter, i will be omitted, and subscripts T and M will be used to denote traditional technology and mass production technology, respectively.) Since rival firms are producing more or less substitutable varieties, the mark-up depends on σ: when the varieties are close substitutes (or the consumers' love of variety is weak), i.e., when σ is high, then the consumers are sensitive to price and they come closer to c. By substituting Eq. (3) into Eq. (1), we find that mark-up pricing by each firm leads to the price index being

$$G_T = (n_T)^{\frac{1}{1-\sigma}} \frac{\sigma c}{\sigma - 1}. \tag{4}$$

We can now consider the equilibrium with traditional technology. It is defined as a situation in which, allowing free entry, the goods and factor markets clear (i.e., supply equals demand). The profit of a typical firm (π_T) is

$$\pi_T = p_T q_T - F - c q_T. \tag{5}$$

Free entry, however, drives π_T down to zero. Substituting Eq. (3) into Eq. (5) and setting it equal to zero, we have

$$q_T = \frac{F(\sigma - 1)}{c}. \tag{6}$$

The goods market clearing condition is

$$q_T = {p_T}^{-\sigma} {G_T}^{\sigma-1} Y, \tag{7}$$

and the factor market clearing condition is

$$L = n_T F + n_T c q_T, \tag{8}$$

which means that the population (L) needs to be fully employed. Substituting Eq. (6) into Eq. (8), we have

$$n_T = \frac{L}{F\sigma}. \tag{9}$$

Substituting Eq. (9) into Eq. (7) can be confirmed to lead to the same result as Eq. (6).

4. Transition to mass production

The equilibrium derived above is the standard result of monopolistic competition in general equilibrium. We move on to consider the behavior of firms when they can choose mass production technology as given in Table 1. Given mass production technology, a typical firm calculates its hypothetical profit ($\tilde{\pi}_M$), which is its expected profit if it adopts mass production technology. Denoting the hypothetical price and output as $\tilde{p}_M$ and $\tilde{q}_M$, respectively,

$$\tilde{\pi}_M = \tilde{p}_M \tilde{q}_M - \alpha F - \beta c \tilde{q}_M, \tag{10}$$

where

$$\tilde{p}_M = \frac{\sigma \beta c}{\sigma - 1} \tag{11}$$

and

$$\tilde{q}_M = \tilde{p}_M{}^{-\sigma} G_T{}^{\sigma-1} Y. \tag{12}$$

(Note in Eq. (12) that the price index is G_T. This is because firms can only set the prices of their own varieties and take the price index, which is the overall price level including rival firms' prices, as given.) Substituting Eqs. (11) and (12) into Eq. (10) and rearranging we have

$$\tilde{\pi}_M = F\left(\beta^{1-\sigma} - \alpha\right). \tag{13}$$

Profit-seeking firms compare π_T (which is zero) and $\tilde{\pi}_M$, and switch to mass production if $\tilde{\pi}_M > \pi_T (= 0)$. That is, firms' profitable deviation from the traditional to mass production occur if $F\left(\beta^{1-\sigma} - \alpha\right) > 0$ or

$$\alpha < \beta^{1-\sigma}. \tag{14}$$

Result 1. Given the mass production technology parameters α and β, the transition to mass production takes place when $\alpha < \beta^{1-\sigma}$.

Interpreting condition (14) requires inspection of the hypothetical profit ($\tilde{\pi}_M$) shown in Eq. (10). $\tilde{\pi}_M$ can be rearranged as $\tilde{\pi}_M = (\tilde{p}_M - \beta c)\tilde{q}_M - \alpha F$, where $(\tilde{p}_M - \beta c)\tilde{q}_M$ is the expected operating profit (i.e., sales minus variable cost), and αF is the fixed cost. The expected operating profit is the product of the expected operating profit per unit ($\tilde{p}_M - \beta c$) and hypothetical demand ($\tilde{q}_M$). On the one hand, because the new technology is defined to reduce the marginal cost (c) by a factor of β, the profit-maximizing price ($\tilde{p}_M$) will also be reduced by a factor of β as shown in Eq. (11). Hence, the expected operating profit per unit ($\tilde{p}_M - \beta c$) is reduced by a factor of β. On the other hand, however, the price reduction is expected to increase demand by a factor of $\beta^{-\sigma}$, which can be confirmed by comparing q_T in Eq. (7) and $\tilde{q}_M$ in Eq. (12). (A higher σ corresponds to a larger expected demand increase because higher σ implies that the consumers' love of variety is weaker and that they are more sensitive to prices.) Therefore, the net effect is that the operating profit is expected to increase by a factor of $\beta \cdot \beta^{-\sigma}$, i.e., $\beta^{1-\sigma}$ (>1). Then condition (14) can be interpreted as meaning that in order for the transition to mass production to take place, the new technology must be such that the firms' expected rate of increase in operating profits ($\beta^{1-\sigma}$) exceeds the rate of increase in fixed costs (α).

Result 1 means, consistent with intuition, that the lower α and/or the lower β is, the more likely the economy will be to switch to mass production. Also, other things being equal, a higher σ means a greater likelihood of the transition to mass production. That is, economies with firms producing relatively homogeneous goods are more likely to switch to mass production. With the present model, therefore, the reasons why mass production was more successfully applied in some industries (like in "white goods" such as refrigerators and washing machines) than in others (like in housing, furniture, and agricultural goods) are both technological and demand-side related. Mass production did not work in housing, furniture, and agricultural goods because the technology was not profitable enough for firms and/or consumers had a stronger love of variety (i.e., lower σ) in these goods than in refrigerators and washing machines.

Condition (14) is illustrated in Figure 1. Differentiating $\beta^{1-\sigma}$ with respect to β gives $(1-\sigma)\beta^{-\sigma} < 0$, so $\beta^{1-\sigma}$ is decreasing in β. Thus, plotting $\beta^{1-\sigma}$ against β gives a downward-sloping curve. At a given level of α, the range of β that satisfies condition (14)

and leads to the transition to mass production is shown by the thick solid line. Lowering the level of α will expand the range of β that satisfies condition (14), which makes the transition to mass production more likely. Note that a higher σ essentially rotates the $\beta^{1-\sigma}$ curve clockwise as shown by the dotted lines, which will extend the thick solid line, also making the transition to mass production more likely.

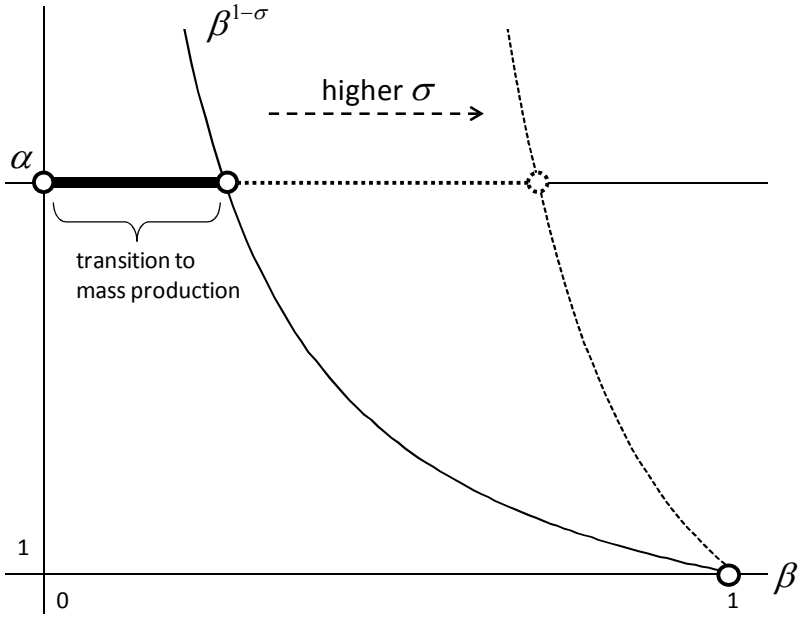

Figure 1. Transition to mass production

The new equilibrium with mass production is obtained as follows, similar to the way the initial equilibrium was found. A typical profit-maximizing firm sets the price of the variety it produces as

$$p_M = \frac{\sigma\beta c}{\sigma - 1}. \tag{15}$$

So the price index is

$$G_M = \left(n_M\right)^{\frac{1}{1-\sigma}} \frac{\sigma\beta c}{\sigma - 1}. \tag{16}$$

The profit of a typical firm (π_M) is

$$\pi_M = p_M q_M - \alpha F - \beta c q_M, \tag{17}$$

but free entry drives π_M down to zero. Hence, substituting Eq. (15) into Eq. (17) and setting it equal to zero, we have

$$q_M = \frac{\alpha F(\sigma - 1)}{\beta c}. \tag{18}$$

The goods market clearing condition is

$$q_M = {p_M}^{-\sigma} {G_M}^{\sigma - 1} Y, \tag{19}$$

and the factor market clearing condition is

$$L = n_M \alpha F + n_M \beta c q_M. \tag{20}$$

Substituting Eq. (18) into Eq. (20) and solving, we have

$$n_M = \frac{L}{\alpha F \sigma}, \tag{21}$$

and we can confirm that substituting Eq. (21) into Eq. (19) leads to the same result as Eq. (18).

The endogenous variables in the two equilibria derived so far are summarized in Table 2. Comparing the two, it is found that the prices are lower ($p_T > p_M$), and each firm is larger ($q_T < q_M$) but there are fewer firms ($n_T > n_M$) in the mass production equilibrium. So it can be said that the result captures some of the features of mass production: products are "standardized" in the sense that fewer varieties are produced in larger quantities by bigger firms. Since the prices are lowered (which lowers G) but the number of firms and varieties drop (which raises G), the net effect on the price index (G) is ambiguous. (This will be addressed in the welfare analysis in Section 5.)

Table 2. Comparison of the two equilibria

	traditional production (initial)	mass production
p	$p_T = \frac{\sigma c}{\sigma - 1}$	$p_M = \frac{\sigma \beta c}{\sigma - 1}$
G	$G_T = \left(\frac{L}{\sigma F}\right)^{\frac{1}{1-\sigma}} \frac{\sigma c}{\sigma - 1}$	$G_M = \left(\frac{L}{\sigma \alpha F}\right)^{\frac{1}{1-\sigma}} \frac{\sigma \beta c}{\sigma - 1}$
q	$q_T = \frac{F(\sigma - 1)}{c}$	$q_M = \frac{\alpha F(\sigma - 1)}{\beta c}$
n	$n_T = \frac{L}{F\sigma}$	$n_M = \frac{L}{\alpha F \sigma}$

Is the mass production equilibrium stable? Assume that condition (14) is satisfied, i.e., $\alpha < \beta^{1-\sigma}$, and the transition to mass production took place. But the firms are still free to choose the traditional technology. If a typical firm switches back to the traditional technology (when all the rest of the firms are producing with mass production technology), its hypothetical profit ($\tilde{\pi}_T$) is

$$\tilde{\pi}_T = (\tilde{p}_T - c)\tilde{q}_T - F . \tag{22}$$

where

$$\tilde{p}_T = \frac{\sigma c}{\sigma - 1} \tag{23}$$

and

$$\tilde{q}_T = \tilde{p}_T^{\,-\sigma} G_M^{\,\sigma-1} Y . \tag{24}$$

Inspecting Eqs. (22) to (24), it is seen that $\tilde{\pi}_T$ cannot be positive: Adopting traditional technology implies that the marginal cost (c) and, correspondingly, the profit maximizing price ($\tilde{p}_T$) will increase by a factor of $1/\beta$ (obtained by comparing $\tilde{p}_T$ in Eq. (23) and p_M in Eq. (15)). Hence, the operating profit per unit ($\tilde{p}_T - c$) is expected to increase by a factor of $1/\beta$. However, because of the price increase, demand is expected to decrease by a factor of $1/\beta^{-\sigma}$ (obtained by comparing $\tilde{q}_T$ in Eq. (24) and q_M in Eq. (19)). The net effect is that operating profit $(\tilde{p}_T - c)\tilde{q}_T$ is expected to decrease by a factor of $(1/\beta)\cdot(1/\beta^{-\sigma})$, i.e., $1/\beta^{1-\sigma}$. Fixed cost drops by a factor of $1/\alpha$ when a firm re-adopts the traditional technology. A firm can profitably depart from mass production and re-adopt the traditional technology if the rate of loss of operating profits ($1/\beta^{1-\sigma}$) is more than compensated for by the rate of reduction in fixed costs ($1/\alpha$). That is, $1/\beta^{1-\sigma} > 1/\alpha$, i.e., $\alpha > \beta^{1-\sigma}$. This is not possible, because we assumed $\alpha < \beta^{1-\sigma}$.

Result 2. The mass production equilibrium is stable.

Result 2 implies that once the transition from traditional technology to mass production has taken place, it is not in the interest of firms to go back; there is no reversal to the traditional equilibrium.

5. Mass production for consumers

Suppose that condition (14) is satisfied, and that firms adopt the mass production technology, driving the economy's transition to mass production. Is this good for consumers? The transition to mass production always reduces prices, which itself is welfare improving. At the same time, however, since mass production technology requires larger fixed costs, meaning that more resources are now needed to set up a firm, there will be fewer firms in the economy, which implies there will be less variety for consumers. (Thus, some degree of "standardization" is inevitable.) From the consumers' point of view, therefore, there is a tradeoff between lower prices and less variety. We need, then to compare welfare under traditional production and mass production equilibria.

In the initial equilibrium with the traditional technology, indirect utility was $1/G_T$. After the transition to mass production it became $1/G_M$. These two expressions are the measures of welfare in this model. Consumers enjoy increased welfare as long as $1/G_M > 1/G_T$, i.e., $G_M < G_T$. Using the expressions for G_T and G_M given in Table 2, consumers' condition for welfare improvement is found to be

$$\alpha < \beta^{1-\sigma}, \tag{25}$$

which is exactly the same as condition (14). This implies that the transition to mass production, when it takes place, is always welfare improving.

Result 3. The condition for the transition to mass production (Result 1) is equivalent to the condition for consumers' welfare improvement.

Condition (25) appears to be the same as condition (14), but has a different meaning. Inspecting the price indices G_T and G_M reveals that a transition to mass production implies that, on one hand, the numbers of firms and varieties are reduced by a factor of $1/\alpha$, which increases the price index by a factor of

$$\left(\frac{1}{\alpha}\right)^{\frac{1}{1-\sigma}}.$$

On the other hand, the prices of individual varieties are reduced by a factor of β, which reduces the price index by a factor of β. Then, for consumers to gain, welfare gained from the drop in prices must outweigh the negative effect of the loss of variety so that

$$\left(\frac{1}{\alpha}\right)^{\frac{1}{1-\sigma}}\beta<1,$$

that is, $\alpha<\beta^{1-\sigma}$. Condition (25), therefore, means that for consumers to gain from the transition to mass production, losses from decreased overall variety must be more than compensated for by gains from reductions in the prices of the individual varieties.

6. Changes in preferences and mass production

The results so far have been obtained focusing on technological change and choice. It is also possible, however, for consumers' preferences to change. Specifically, the effect of a change in the elasticity of substitution (σ) on the choice of technology can be analyzed. This is relevant to the successful challenge by General Motors (GM) against Ford in the 1920s. When the market became flooded with low price/standardized Model T Fords, GM succeeded by introducing a wide range of different types of cars that attracted customers. It may be that consumers at the time got bored with the much cheaper but standardized cars that Ford produced, and GM took advantage of that. The so-called quartz shock in the wristwatch industry in the 1970s offers another example. Japanese watchmakers came up with a way to mass-produce quartz watches which were much cheaper and more accurate than traditional mechanical watches. The shock hit the traditional mechanical watchmakers hard, including those in Switzerland, but later a revival of mechanical watch production was seen. Again, it may be said that consumers got bored with the cheap but standardized watches. In the present model, some of this can be captured by assuming that consumers' preferences changed, with their desire for variety getting stronger, i.e., as a decrease in σ.

Suppose that the transition to mass production has taken place, so that condition (14), i.e., $\alpha<\beta^{1-\sigma}$, is satisfied. Consider then that the consumers' desire for variety becomes stronger (because they become bored with the cheap standardized goods). σ thus decreases from σ to

σ^* ($\sigma > \sigma^*$). As already derived in Result 2, firms can profitably return to traditional production if $\alpha > \beta^{1-\sigma^*}$. Therefore, a return to traditional production occurs if both $\alpha < \beta^{1-\sigma}$ and $\alpha > \beta^{1-\sigma^*}$ are satisfied. That is,

$$\beta^{1-\sigma^*} < \alpha < \beta^{1-\sigma}. \tag{26}$$

Result 4. Return to traditional production can occur when consumers' love of variety increases.

Condition (26) is diagrammatically shown in Figure 2. The return from mass production to traditional production occurs if σ decreases from σ to σ^* and β is within the range illustrated by the thick solid line. If β is lower than that range, returning to traditional production is not profitable for firms, and they choose to carry on with mass production. This is because the expected loss in operating profits is too large to be compensated for by the reduction in fixed costs obtained by returning to traditional production.

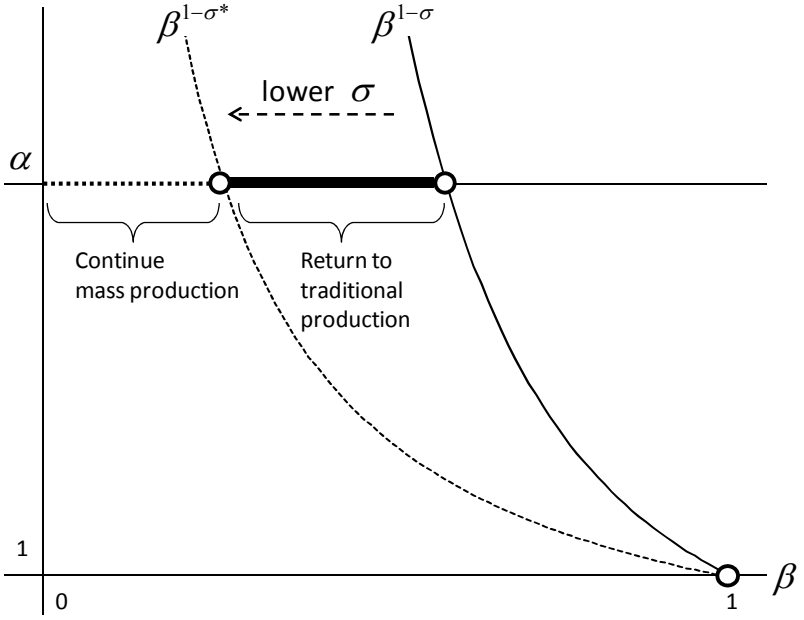

Figure 2. Return to traditional production

7. Conclusion

This paper used monopolistic competition to study mass production from an economic theory perspective. The first result was quite intuitive. The transition to mass production occurs if the expected gains in operating profits exceed the necessary increase in fixed costs. Also, other things being equal, mass production is more likely to be adopted when firms are producing relatively homogeneous goods (Result 1). Second, it was also found that once such a transition to mass production has taken place there will be no going back to traditional technology (Result 2). The third result was that the adoption of mass production driven by profit-seeking firms is always welfare improving (Result 3). Finally, the analysis showed that an increase in the consumers' love of variety can lead to a return from mass production to traditional production (Result 4).

The second result implies that once a profitable, large-scale method of production is invented, all firms will adopt it and the old technology will be left behind; it is in no firm's interest to go back to the old technology. This suggests that workers had to go through various changes and experience costly adjustments. But the third result, that mass production is always welfare improving, suggests that there was something that may have more or less compensated for their hardship. It may also suggest that viewing mass production in only a negative manner, as if the resulting "standardization" deprives people of choice/variety is one-sided and not correct. A combination of the second and third results may help our understanding of why mass production diffused worldwide during the twentieth century despite workers' opposition. Mass production had various negative impacts on workplaces, but there were also compensating positive impacts on consumers that could have outweighed the negative impacts.

There are a number of limitations to the present model due to its simplicity. First, technology is given, so the model does not explain what brings the mass production technology. Second, by using a single-factor model, I have omitted potential disutilities or adjustment costs for workers who had to move to different workplaces and/or change the work that they performed. Third, the model is that of a single industry, and richer results may well be obtained from a multi-industry model. Fourth, new investment required for mass production is only modeled as an increase in fixed costs, so the sectors that supplied the assembly lines and machines needed to produce interchangeable parts are not explicitly modeled.

References

Carlsson, Bo (1984) "The development and use of machine tools in historical perspective" *Journal of Economic Behavior and Organizations* **5**, 91-114.

Dixit, Avinash K. and Joseph E. Stiglitz (1977) "Monopolistic competition and optimum product diversity" *American Economic Review* **67**, 297-308.

Duguay, Claude R., Sylvain Landry and Federico Pasin (1997) "From mass production to flexible/agile production" *International Journal of Operations & Production Management* **17**, 1183-1195.

Freeman, Chris and Luc Soete (1997) *The economics of industrial innovation,* third ed., Cambridge: MIT Press.

Hounshell, David A. (1984) *From the American System to Mass Production, 1800-1932: Development of Manufacturing Technology in the United States*, Baltimore and London: Johns Hopkins University Press.

Kenney, Martin and Richard Florida (1988) "Beyond Mass Production: Production and the Labor Process in Japan" *Politics & Society* **16**, 121-158.

Pine, B. Joseph (1993) *Mass Customization: The New Frontier in Business Competition*, Boston: Harvard Business School Press.

Sabel, Charles and Jonathan Zeitlin (1985) "Historical alternatives to mass production: politics, markets and technology in nineteenth-century industrialization" *Past and Present* **108**, 102-176.

Womack, J. P., D. T. Jones, and D. Ross (1990) *The Machine that Changed the World*, New York: Macmillan.