科技部補助專題研究計畫成果報告
期末報告

高科技廠商的最適生產結構調整：以台灣的晶圓代工產業之生產靈活性對公司表現指標之影響為例

計 畫 類 別 ： 個別型計畫
計 畫 編 號 ： MOST 103-2410-H-004-022-
執 行 期 間 ： 103年08月01日至104年10月31日
執 行 單 位 ： 國立政治大學經濟學系

計畫主持人： 李文傑
共同主持人： 王信實
計畫參與人員： 此計畫無其他參與人員

報 告 附 件 ： 移地研究心得報告

處 理 方 式 ：
1.公開資訊：本計畫可公開查詢
2.「本研究」是否已有嚴重損及公共利益之發現：否
3.「本報告」是否建議提供政府單位施政參考：是，經濟部

中 華 民 國 105 年 02 月 01 日

中 文 摘 要 ： 目前既有的文獻在探討高科技廠商的生產靈活性 (production flexibility)時，完全忽略了對廠商的個別生產績效指標，如生產力，要素投入調整，不同生產技術調整運用的影響。縱使仍有為數不少的經濟學或是商學研究雖已考慮生產靈活性對生產成本及廠商競爭力的改善效果，然而由於一般理論模型設定皆失於簡略及未能精確描述生產靈活性的理論涵義，以及個別公司之營運資料難以取得。此二原因造成探討不同程度的廠商生產靈活性對廠商生產績效指標的影響之研究仍付諸闕如。針對這個缺失，本研究計畫從新理論模型的設定及建構個人廠商營運表現的資料庫著手改善，如:(1)由一個明確定義的固定替代彈性 (CES)的理論模型以及可以自由調整生產替代性技術的理論模型來具體描述生產靈活性的重要角色(2)本計畫也對台灣晶圓代工產業，建構細步的營運表現的資料庫。如此，採用模型校正(Parameter Calibration)刻化理論模型參數以計算出公司層級的生產靈活性程度。運算結果顯示，晶圓代工的兩家主要廠商其關鍵勝出條件為產品品質，及由技術累積形成的關鍵技術力，以及生產彈性。台積電席捲市場的原因為其技術領先而聯電能繼續生存的主要理由為其具有相當高的生產彈性。後續，並可藉由擬真分析 (Counterfactual Analysis) 計算廠商的生產靈活性改善是如何影響 (1) 生產要素配置 (2)生產技術調整的程度，並以之做各項產業政策分析。

中 文 關 鍵 詞 ： 生產靈活性、生產技術調整、模型校正、晶圓代工產業

英 文 摘 要 ： What is the relationship between the production flexibility and the observed firm-level performance such as productivities, development of production techniques and ease of adjustment in factor allocations within an high-technology sector? This question is left unexplored though a vast Business literature on manufacturing flexibility and production efficiency. This is because the concept of production flexibility has not been formalized or rigorously studied theoretically in the existing studies and the lack of disaggregated firm-level data of operational details in the interested IT manufacturing sectors. To remedy these two problems, this proposal formalizes the concept of “production flexibility ‘ ‘ using a constant elasticity of substitution (CES) production function. This specification in turn allows us to calibrate industry and firm-level production function parameters, using an constructed data set of the foundry industry with giant duopolists producing over 70 percent of the world products. We found that the giant TSMC has dominated the market by its reputed quality and accumulated techniques while UMS remains surviving in the market by its flexibility. This enables us to gain better insight toward understanding the duopolists ‘s technology flexibility choice and their consequences for factor allocation and production efficiency. Such an endeavor also permits future counterfactual policy experiments using a structural model consistent with the empirically observed industry framework.

英文關鍵詞： Production Flexibility, Productivity, Adjustment Cost, Counterfactual Analysis, Semi-conductor Foundry Industry.

行政院國家科學委員會補助專題研究計畫 **□期中進度報告**
■期末報告

高科技廠商的最適生產結構調整:
以台灣的晶圓代工產業之生產靈活性對公司表現指標影響為例

計畫類別：■個別型計畫　□整合型計畫
計畫編號：NSC -103-2410-H-004 -022
執行期間：103 年 8 月 1 日至 104 年 10 月 31 日

執行機構及系所：國立政治大學經濟系

計畫主持人：李文傑
共同主持人：王信實
計畫參與人員：王平

本計畫除繳交成果報告外，另含下列出國報告，共 1 份：
■移地研究心得報告
□出席國際學術會議心得報告
□國際合作研究計畫國外研究報告

處理方式：除列管計畫及下列情形者外，得立即公開查詢
　　　　　□涉及專利或其他智慧財產權，□一年□二年後可公開查詢

中　華　民　國 105 年 1 月 31 日

目　　錄

高科技廠商的最適生產結構調整：以台灣的晶圓代工產業之生產靈活性對公司表現指標之影響為例

摘要

目前既有的文獻在探討高科技廠商的生產靈活性 (production flexibility)時，完全忽略了對廠商的個別生產績效指標，如生產力，要素投入調整，不同生產技術調整運用的影響。縱使仍有為數不少的經濟學或是商學研究雖已考慮生產靈活性對生產成本及廠商競爭力的改善效果，然而由於一般理論模型設定皆失於簡略及未能精確描述生產靈活性的理論涵義，以及個別公司之營運資料難以取得。此二原因造成探討不同程度的廠商生產靈活性對廠商生產績效指標的影響之研究仍付諸闕如。針對這個缺失，本研究計畫從新理論模型的設定及建構個人廠商營運表現的資料庫著手改善，如:(1)由一個明確定義的固定替代彈性 (CES)的理論模型以及可以自由調整生產替代性技術的理論模型來具體描述生產靈活性的重要角色(2)本計畫也對台灣晶圓代工產業,建構細步的營運表現的資料庫。如此，採用模型校正(Parameter Calibration)刻化理論模型參數以計算出公司層級的生產靈活性程度。運算結果顯示，晶圓代工的兩家主要廠商其關鍵勝出條件為產品品質，及由技術累積形成的關鍵技術力，以及生產彈性。台積電席捲市場的原因為其技術領先而聯電能繼續生存的主要理由為其具有相當高的生產彈性。後續，並可藉由擬真分析 (Counterfactual Analysis)計算廠商的生產靈活性改善是如何影響 (1) 生產要素配置 (2)生產技術調整的程度，並以之做各項產業政策分析。

關鍵詞：生產靈活性、生產技術調整、模型校正、晶圓代工產業

Designing Manufacturability in an IT Industry : the Case of the Semi-conductor Foundry Industry in Taiwan

Abstract

What is the relationship between the production flexibility and the observed firm-level performance such as productivities, development of production techniques and ease of adjustment in factor allocations within an high-technology sector? This question is left unexplored though a vast Business literature on manufacturing flexibility and production efficiency. This is because the concept of production flexibility has not been formalized or rigorously studied theoretically in the existing studies and the lack of disaggregated firm-level data of operational details in the interested IT manufacturing sectors. To remedy these two problems, this proposal formalizes the concept of "production flexibility" using a constant elasticity of substitution (CES) production function. This specification in turn allows us to calibrate industry and firm-level production function parameters, using an constructed data set of the foundry industry with giant duopolists producing over 70 percent of the world products. We found that the giant TSMC has dominated the market by its reputed quality and accumulated techniques while UMS remains surviving in the market by its flexibility. This enables us to gain better insight toward understanding the duopolists's technology flexibility choice and their consequences for factor allocation and production efficiency. Such an endeavor also permits future counterfactual policy experiments using a structural model consistent with the empirically observed industry framework.

Keywords: Production Flexibility, Productivity, Adjustment Cost, Counterfactual Analysis, Semi-conductor Foundry Industry.

1 Introduction

The discussion regrading production flexibility as well as the producing factor allocation always fascinates economists. The economists would like to ease the gap between the long believed neoclassical production technology assuming constant returns to scale technology and the production process that governs the real profitable model in the production side. In this vein the firm would have to deal with some limited access to the key production techniques or limited usage of producing factors in the short-term adjustment production batch. In this research project I; thus, describe the role of techniques substitution in an industry characterized by labor adjustment costs (such as labor hoarding): For example, the skill intensive IT industry where firms can adjust their Human Capital (labor in the follow-up setting in the model formulation) in the short-run only if they incur some adjustment costs. The research efforts are exerted to show that the ability to adjust production techniques (towards labor intensive production) mitigates labor adjustment costs and further to investigate whether the flexibility of production determines the ease of technique substitution.[1] Specifically, we try to revisit the big-push development issues in the semiconductor foundry industry and apply a well-devised theoretic model to calibrate the crucial factors in the name of production flexibility to back out the embeded rationales that shape the leading Semiconductor Foundry Industry in Taiwan.[2]

This paper begins by briefly reviewing the economics as well as the business economics literatures in the discussion of how the levels of production flexibilities affects the firm-level performance in the manufacturing sectors. On the one hand, the theroretic and empirical economic literatures elaborates on the importance of production flexibilities. First, the notion of flexibility in the operations of the firm seems to have been first introduced into the economics literature by George Stigler (JPE, 1939). He defined flexibility as those attributes of a production technology which accommodate greater output variation. Following Stigler's definition on flexibility, Marschak and Nelson (Metroeconomica, 1962) take more specific view in the following three viewpoints: (1) The size of the choice set: a more flexible initial action preserves more choices for actions in the following periods. (2) Marginal cost: a more flexible plant requires less additional cost to move toward the next position (essentially the Stigler view). (3) Marginal expected profit: a more flexible plant generates more profits or smaller losses in moving to a new position. Jones and Ostroy (RES, 1984), for example, following Marschak and Nelsons ideas of flexibility. They defined flexibility as "a property of initial positions. It refers to the cost, or possibility, of moving to various second period positions." Industrial economists also view the flexibility as means to counter the uncertainty existing in the market. Burton Klein (1984) states a dynamically efficient firm is one which generates new ideas and is quick to respond to new ideas, wherever they happen to originate, so that

[1] Although there is a vast Business literature on manufacturing flexibility and production efficiency. Nonetheless, the concept of production flexibility has not been formalized or rigorously studied theoretically.

[2] The foundry industry originates itself by the the separation of the production side from a whole vertically integrated semiconductor company. In other words, a semiconductor fabrication plant operation (foundry) is splitted from an integrated circuit design operation, into separate companies or business units. The separate foundry firms use cutting-edge production facilities or techniques to do the contracting manufacturing for the brand name semiconducotr designing companies.

it can take advantage of these new ideas before its competitors do. By organizing the firm and providing internal incentives in such a way as to be able to react quickly to new impulses, no matter what their particular content, it is possible to reduce the cost of a negative impact and to increase the probability of a positive result for the firm. In this vein, Vives (IJIO, 1986) has analyzed the choice of flexible production technology in a game-theoretic approach and found that if the technology is inflexible, capacity is a good precommitment variable; on the other hand, if the technology is flexible, precommitment to a particular capacity is not a good strategy. Vives has also shown that where firms have the same precision of information, an increase in uncertainty leads them to seek a more flexible position. Other than the theoretic viewpoints, Mills and Schumann (AER, 1985) formulated and tested the hypothesis that a competitive equilibrium with demand fluctuations can have diverse firms with varying cost structures coexisting: ”Small firms are able to compete successfully with large, more staticefficient producers by absorbing a disproportionate share of industrywide output fluctuations. This is possible because small firms use production technologies that are more flexible than those chosen by large firms. Large firms . . . (have) lower minimum average costs, due largely to scale economies, while small competitors have an offsetting advantage in their superior responsiveness to cyclical or random swings in demand. (Mills and Schumann, p. 766).” However, all the above mentioned literatures share one common research caveat by lacking in the full specification of production flexibility in the producer side. The best work horse idea is to take the ad hoc assumption by adding a reduced form model to apply a vague idea of production flexibility to the ambiguous production efficiency measurement mentioned in the current existing literatures.

On the other hand, there has been a vast literature “manufacturing flexibility and production efficiency”. The literature highlights “insurance” and “strategic competitiveness” roles of manufacturing flexibility. To the end of insurance role, including Fine and Freund (1990, Management Science), Fine (1993, Handbook in OR and MS) and Netessine et al. (2002, OR), many have argued that managers see flexibility as an adaptive response when hedging against uncertain environments (factor or technology related uncertainty as well as product uncertainty). With respect to the competitiveness role, as pointed out for example by Roller and Tombak (1990, Journal of Industrial Economics) and (1993, Management Science), high manufacturing flexibility of a particular firm can induce higher competitive pressure for its rivals, and increase profit margins for the relatively more flexible firm. Concerning both views: Firms might "bank flexibility", that is holding flexibility in reserve to meet future needs. In this sense flexibility is an investment which creates future options for a company. Gerwin (1993, Management Science) provides empirical evidence in line with these theoretical arguments: As the author shows, for example Minnesota Manufacturers Survey reports that as market unpredictability and competitiveness increases, flexibility of the production processes go up.

Concerning the effects of factor and technology flexibility on efficiency the following theoretical and empirical observations are important for our work: In an empirical study, Upton (1995, Harvard Business Review) documents for the U.S. paper-manufacturing industry, where products are quite comparable across manufacturers that there is substantial cross-sectional heterogeneity in production flexibility. Interestingly, the paper finds that newer and bigger processes are typically better able to perform quick changeovers than older and smaller machines. As another empirical evidence, Adler et al. (1999, Organization Science) studies the effect of organizational flexibility on efficiency. By providing detailed micro-level evidence from Toyotas NUMMI plant in California, authors document that companys policy changes that have led to increases in its labor input flexibility stimulated production efficiency at the beginning of 1990s, and gained the company a large competitive advantage over its big rivals Ford, Chrysler and GM. Theoretically, Slack (1988, Computer-Integrated Manufacturing Systems) proposes a hypothetical business model where a manufacturing firm determines the appropriateness of various level of manufacturing flexibility by analyzing how flexibility contributes to the competitive advantage of the firm, and how flexibility guides the selection of various productive resources, such as the production technology. Goyal and Netessine (2007, Management Science) study the causality of structure of competition on firms technology flexibility choice using a game-theoretic framework. Formally, the authors show that the cost premium which a duopolist is willing to accept, when investing in a flexible technology, is higher than the premium which a monopolist is willing to accept, if the rival duopolist is investing in a rigid production technology.

This paper is related with both Economic and Business Economics literature by the following two dimensions. Theoretically, this paper contributes by formalizing the concept of "production flexibility" using a constant elasticity of substitution (CES) production function in the theoretic set-up. Numerically, this theoretical specification in turn allows us to calibrate industry and firm-level production function parameters and run counterfactual policy experiments using a structural model consistent with the empirically observed industry framework. In the end, our theoretic model when using the intended hand-collected firm-level dataset in the Semiconductor Foundry industry would reflect the true interaction intertwined among production flexibility, factor allocations and production efficiency in the firm level.

The large Taiwan Semiconductor Manufacturing Company (TSMC) dominates the market by its premium quality and accumulated production techniques while UMC stay survived in the market by its production flexibility to keep its cost pegging the level of TSMC.

The rest of the paper is structured as follows. Section 2 introduces the data and describes the characteristics of educational networks between venture capitalists and start-up entrepreneurs. Section 3 discusses the hypotheses to be tested and show the descriptive statistics of all the used variables. Section 5 presents the empirical analysis and the main findings. Section 6 concludes.

2 The Methodology

This paper is devoted to investigate the causal relationship intertwined among production flexibility, productivity and factor allocation. In this end, the past literatures in both economics and business economics did not specify clearly the formalized definition of profuction flexibility. This paper; thus, have to suggest a clear and valid theoretic definition of production flexibility that would facilitate our parameter clibration by applying the firm-level foundry firms data. In the last step we can have a policy implication on the IT developmental miracles in the Taiwanese foundry industry.

Thus in the first stage of the research, I would suggest a theoretic framework methodologically to capture the effects of production flexibility on the productivities and factor allocation. The concept of "production flexibility" can be best descibed by using a constant elasticity of substitution (CES) production function in the theoretic set-up since this theoretical specification in turn would numerically allow us to calibrate industry and firm-level production function parameters. The counterfactual policy experiments using the structural model consistent with the empirically observed industry framework can also be possible to point out the policy implications accordingly. In the end, our theoretic model when using the intended hand-collected firm-level dataset in the Semiconductor Foundry industry would reflect the true interaction intertwined among production flexibility, factor allocations and production efficiency in the firm level.

2.1 Methods: The Theoretic Model

Here in this section, a benchmark theoretic framework without any factor adoption frictions (labor adjustment cost in terms of the labor hoarding) is proposed. A generalized version with the prospective factor adoption frictions will follow later.

To reflect the importance of production flexibility in the output production in semiconductor manufacturing industry, we assume that firms within a narrowly-defined industry produce by using the procured labor and capital in the form of CES aggregator introduced by Solow (1956). Specifically, suppose the production function of a firm takes the following functional form:

$$Y = [\lambda(a_K K)^\rho + (1-\lambda)(a_L L)^\rho]^{\frac{1}{\rho}}$$

Firm decides on K and L (namely, production factors), and a_K and a_L (production techniques).

At first, we study firm's optimization problem without labor and technique adjustment costs. Then, we will introduce technique adjustment and labor adjustment costs and study the implications of labor hoarding on optimum technique substitution.

2.2 Cost Minimization

The optimization program is devised to be a 2-stage process. In the first stage the firm decides on the optimal $K-L$ (as in the standard neoclassical cost minimization problem), and then in the second stage the $a_K - a_L$ decision is made.[3]

2.2.1 Factor Allocation: K-L Choice

This is the standard Neo-classical cost minimization problem:

$$\min_{K,L} \qquad wL + rK \tag{1}$$

$$s.t. \qquad Y = [\lambda(a_K K)^\rho + (1-\lambda)(a_L L)^\rho]^{\frac{1}{\rho}} \tag{2}$$

Denote the lagrange multiplier with respect to constraint (2) with μ_1. Note that solving for μ_1 will provide the marginal cost of producing one extra unit of output. FOCs with respect to K and L are as the following:

$$K: \qquad r = \mu_1 \lambda a_K^\rho K^{\rho-1}[(a_K K)^\rho + (a_L L)^\rho]^{\frac{1-\rho}{\rho}}$$

$$\Rightarrow \qquad K = \mu_1^{\frac{1}{1-\rho}} r^{\frac{-1}{1-\rho}} \lambda^{\frac{1}{1-\rho}} a_K^{\frac{\rho}{1-\rho}} Y \tag{3}$$

$$L: \qquad w = \mu_1 (1-\lambda) a_L^\rho L^{\rho-1}[(a_K K)^\rho + (a_L L)^\rho]^{\frac{1-\rho}{\rho}}$$

$$\Rightarrow \qquad L = \mu_1^{\frac{1}{1-\rho}} w^{\frac{-1}{1-\rho}} (1-\lambda)^{\frac{1}{1-\rho}} a_L^{\frac{\rho}{1-\rho}} Y \tag{4}$$

Putting (3) and (4) together we can solve for the optimum K/L ratio:

$$\frac{K}{L} = \left(\frac{w}{r}\right)^{\frac{1}{1-\rho}} \left(\frac{\lambda}{1-\lambda}\right)^{\frac{1}{1-\rho}} \left(\frac{a_K}{a_L}\right)^{\frac{\rho}{1-\rho}}. \tag{5}$$

Plugging K and L from (3) and (4) into (2) gives:

$$Y = \left[\left(\frac{r}{a_K}\right)^{\frac{\rho}{\rho-1}} \lambda^{\frac{1}{1-\rho}} \mu_1^{\frac{\rho}{1-\rho}} + \left(\frac{w}{a_L}\right)^{\frac{\rho}{\rho-1}} (1-\lambda)^{\frac{1}{1-\rho}} \mu_1^{\frac{\rho}{1-\rho}}\right]^{\frac{1}{\rho}} Y$$

[3] The novel feature of this research is that the dual approach is utilized to solve for the optimal production factor adoption and the production technique is model as the labor augumented (a_L) or the capital augumented production process (a_K).

Solving for μ_1 gives the unit cost of production:

$$\mu_1 = c(r, w; a_K, a_L, \rho) = \left[\left(\frac{r}{a_K}\right)^{\frac{\rho}{\rho-1}} \lambda^{\frac{1}{1-\rho}} + \left(\frac{w}{a_L}\right)^{\frac{\rho}{\rho-1}} (1-\lambda)^{\frac{1}{1-\rho}} \right]^{\frac{\rho-1}{\rho}} \tag{6}$$

The total cost of producing Y units:

$$\begin{aligned} C(Y) &= c(r, w; a_K, a_L, \rho)Y \\ C(Y) &= \left[\left(\frac{r}{a_K}\right)^{\frac{\rho}{\rho-1}} \lambda^{\frac{1}{1-\rho}} + \left(\frac{w}{a_L}\right)^{\frac{\rho}{\rho-1}} (1-\lambda)^{\frac{1}{1-\rho}} \right]^{\frac{\rho-1}{\rho}} Y. \end{aligned} \tag{7}$$

Having determined the unit cost of production we can move on to determine the optimum $a_K - a_L$ Choice.

2. Production Technique Choice: a_K**-**a_L

Our next objective is to find the optimum a_K and a_L that minimize the unit cost of production derived at (6):

$$\begin{aligned} \min_{a_K, a_L} \quad & c(r, w; a_K, a_L, \rho) \\ s.t. \quad & H(a_K, a_L) = z, \end{aligned}$$

where z is the scale of knowledge, and $H(a_K, a_L)$ summarize the combinations of $a_K - a_L$ pairs that attain a certain level of z. For now, we don't assume adjustment costs in techniques (an adjustment $\phi()$ function will be introduced later on). We will put adjustment costs later on to see how things change when we deviate from this benchmark model. We assume that $H(a_K, a_L) = a_K^{\alpha} a_L^{1-\alpha}$. So the second stage cost minimization problem can be stated as the following:

$$\min_{a_K, a_L} \quad \left[\left(\frac{r}{a_K}\right)^{\frac{\rho}{\rho-1}} \lambda^{\frac{1}{1-\rho}} + \left(\frac{w}{a_L}\right)^{\frac{\rho}{\rho-1}} (1-\lambda)^{\frac{1}{1-\rho}} \right]^{\frac{\rho-1}{\rho}} \tag{8}$$

$$s.t. \quad a_K^{\alpha} a_L^{1-\alpha} = z \tag{9}$$

Denote the Lagrange multiplier associated with (9) by μ_2. FOCs with respect to

a_K and a_L:

$$a_K: \quad r^{\frac{\rho}{\rho-1}}\lambda^{\frac{1}{1-\rho}}a_K^{-\frac{\rho}{\rho-1}-1}\left[\left(\frac{r}{a_K}\right)^{\frac{\rho}{\rho-1}}\lambda^{\frac{1}{1-\rho}}+\left(\frac{w}{a_L}\right)^{\frac{\rho}{\rho-1}}(1-\lambda)^{\frac{1}{1-\rho}}\right]^{\frac{\rho-1}{\rho}-1} = \mu_2\alpha a_K^{\alpha-1}a_L^{1-\alpha}$$

$$a_L: \quad w^{\frac{\rho}{\rho-1}}(1-\lambda)^{\frac{1}{1-\rho}}a_L^{-\frac{\rho}{\rho-1}-1}\left[\left(\frac{r}{a_K}\right)^{\frac{\rho}{\rho-1}}\lambda^{\frac{1}{1-\rho}}+\left(\frac{w}{a_L}\right)^{\frac{\rho}{\rho-1}}(1-\lambda)^{\frac{1}{1-\rho}}\right]^{\frac{\rho-1}{\rho}-1} = \mu_2(1-\alpha)a_K^{\alpha}$$

Putting (10) and (11) together we can solve for the optimum a_K/a_L ratio:

$$\frac{a_K}{a_L} = \frac{r}{w}\left(\frac{1-\lambda}{\lambda}\right)^{\frac{1}{\rho}}\left(\frac{1-\alpha}{\alpha}\right)^{\frac{\rho-1}{\rho}}. \tag{12}$$

Plugging (12) in (5) solves for the optimum K/L ratio:

$$\frac{K}{L} = \frac{w}{r}\frac{\alpha}{1-\alpha}\frac{\lambda}{1-\lambda}. \tag{13}$$

To solve for the scale of a_K and a_L as a function of z, w/r, α and ρ, we plug (12) in (9), and solve:

$$a_K = z\left(\frac{r}{w}\right)^{1-\alpha}\left(\frac{\alpha}{1-\alpha}\right)^{(1-\alpha)\left(\frac{1-\rho}{\rho}\right)}\left(\frac{1-\lambda}{\lambda}\right)^{(1-\alpha)\left(\frac{1}{\rho}\right)}, \tag{14}$$

$$a_L = z\left(\frac{r}{w}\right)^{-\alpha}\left(\frac{\alpha}{1-\alpha}\right)^{-\alpha\left(\frac{1-\rho}{\rho}\right)}\left(\frac{1-\lambda}{\lambda}\right)^{-\alpha\left(\frac{1}{\rho}\right)}. \tag{15}$$

a_K and a_L in (6) provides the unit cost of production in terms of z, w, r, α and ρ:

$$c(w,r;z,\alpha,\rho) = \frac{1}{z}r^{\alpha}w^{1-\alpha}\left[\lambda^{\alpha}(1-\lambda)^{1-\alpha}\right]^{-\frac{1}{\rho}}\left[\left(\frac{\alpha}{1-\alpha}\right)^{1-\alpha}+\left(\frac{1-\alpha}{\alpha}\right)^{\alpha}\right]^{\frac{\rho-1}{\rho}} \tag{16}$$

Putting related terms together:

$$c(w,r;z,\alpha,\rho) = \frac{1}{z}\left(\left(\frac{r}{\alpha}\right)\left(\frac{\lambda}{\alpha}\right)^{-\frac{1}{\rho}}\right)^{\alpha}\left(\left(\frac{w}{1-\alpha}\right)\left(\frac{1-\lambda}{1-\alpha}\right)^{-\frac{1}{\rho}}\right)^{1-\alpha} \tag{17}$$

When K and L are perfect complements ($\rho \to -\infty$) unit cost of production converges to:

$$c(w,r;z,\alpha,\rho) = \frac{1}{z}\left(\frac{r}{\alpha}\right)^{\alpha}\left(\frac{w}{1-\alpha}\right)^{1-\alpha}, \tag{18}$$

when K and L are perfect substitutes ($\rho \to 1$) unit cost of production converges to:

$$c(w, r; z, \alpha, \rho) = \frac{1}{z} \left(\frac{r}{\lambda}\right)^{\alpha} \left(\frac{w}{1-\lambda}\right)^{1-\alpha}. \tag{19}$$

2.3 Optimum Level of Production Flexibility

Studying comparative statistics at marginal cost function (17) provides important insights:

1. As a standard result, the level of technology z monotonically decreases the marginal cost of production. So if firms had a choice of technology level z, they would choose the highest possible one because this would minimize the unit cost of production and hence maximize profits.
2. Another standard result is related to r and w: As the input prices rise the marginal cost of production rises monotonically.

Just to compare the effects of ρ on cost of production c in this current specification (with λ shares in CES) against that of from the previous section (without λ shares in CES), we produce the following math step which is comparable to (17):

$$c(w, r; z, \alpha, \rho) = \frac{1}{z} r^{\alpha} w^{1-\alpha} \left[\underbrace{\left(\lambda^{\alpha}(1-\lambda)^{1-\alpha}\right)^{-1}}_{\Omega_1} \right]^{\frac{1}{\rho}} \left[\underbrace{\alpha^{\alpha}(1-\alpha)^{1-\alpha}}_{\Omega_2} \right]^{\frac{1-\rho}{\rho}} \tag{20}$$

The first term inside the square brackets (Ω_1) is greater than 1 whereas the second term (Ω_2) is smaller than 1. Therefore, with λ shares in CES specification we no longer have the weird limiting case that implies as $\rho \to 0$, $c() \to 0$.

However, one can easily see that the impact of more flexibility on marginal cost of production depends on λ and α. Specifically, if

$$\lambda^{\alpha}(1-\lambda)^{1-\alpha} > \alpha^{\alpha}(1-\alpha)^{1-\alpha} \tag{21}$$

more flexibility is desirable.

2.4 Optimum scale of production

Optimum scale of production can be computed for various demand specifications. For the simplest case of linear demand:

$$Y^d = b_1 P + b_2,$$

where Y^d is quantity demanded and P as the price of output, firm's optimization problem is:

$$\max_{Y} \; Y \left(\frac{Y - b_2}{b_1} \right) - c(w, r; z, \alpha, \rho) Y.$$

The optimum scale of production can be derived as:

$$Y^* = \frac{b_1 c(w, r; z, \alpha, \rho) + b_2}{2}$$

Note that as for case 1 described above: Firm 1, who has $0 < \rho_1 < \rho_2$ compared to another Firm 2, operates at a larger scale of production due to its cost advantage associated in being closer to the unit elasticity of input substitution. For case 2 the opposite result is true.

We can derive clear results for the case of monopolistic competition, Cournot and Bertrand as well.

The results so far show that:

1. Production flexibility is important for the cost of production and hence explaining price, scale differences across firms.
2. The effects of flexibility on firm performance is not trivial. It all depends how firms' production flexibility compares to unit-elastic production function.

2.5 Generalized Model with Technique and Labor Adjustment Costs

Suppose firms face (linear) labor adjustment costs when they deviate from a pre-set $\bar{L}$ level. We treat $\bar{L}$ as exogenously given for the moment. Later when we will do the dynamic analysis, $\bar{L}$ will be the level of capital utilized in the previous period. So, firm's cost minimization problem now looks as the following:

$$\min_{K,L} \quad wL + rK + \eta|L - \bar{L}| \tag{22}$$

$$s.t. \quad Y = [\lambda(a_K K)^\rho + (1-\lambda)(a_L L)^\rho]^{\frac{1}{\rho}} \tag{23}$$

Denote the lagrange multiplier with respect to constraint (23) with μ_1. Note that solving for μ_1 will again provides us the unit cost of producing one extra unit of output. FOCs with respect to K and L are as the following:

$$K: \quad r = \mu_1 \lambda a_K^\rho K^{\rho-1}[(a_K K)^\rho + (a_L L)^\rho]^{\frac{1-\rho}{\rho}}$$

$$\Rightarrow \quad K = \mu_1^{\frac{1}{1-\rho}} r^{\frac{-1}{1-\rho}} \lambda^{\frac{1}{1-\rho}} a_K^{\frac{\rho}{1-\rho}} Y \tag{24}$$

$$L: \quad w + \eta = \mu_1(1-\lambda) a_L^\rho L^{\rho-1}[(a_K K)^\rho + (a_L L)^\rho]^{\frac{1-\rho}{\rho}}$$

$$\Rightarrow \quad L = \mu_1^{\frac{1}{1-\rho}} w^{\frac{-1}{1-\rho}} (1-\lambda)^{\frac{1}{1-\rho}} a_L^{\frac{\rho}{1-\rho}} Y \tag{25}$$

Putting (24) and (25) together we can solve for the optimum K/L ratio:

$$\frac{K}{L} = \left(\frac{w+\eta}{r}\right)^{\frac{1}{1-\rho}} \left(\frac{\lambda}{1-\lambda}\right)^{\frac{1}{1-\rho}} \left(\frac{a_K}{a_L}\right)^{\frac{\rho}{1-\rho}}. \tag{26}$$

Plugging K and L from (24) and (25) into (23) gives:

$$Y = \left[\left(\frac{r}{a_K}\right)^{\frac{\rho}{\rho-1}} \lambda^{\frac{1}{1-\rho}} \mu_1^{\frac{\rho}{1-\rho}} + \left(\frac{w+\eta}{a_L}\right)^{\frac{\rho}{\rho-1}} (1-\lambda)^{\frac{1}{1-\rho}} \mu_1^{\frac{\rho}{1-\rho}}\right]^{\frac{1}{\rho}} Y$$

Solving for μ_1 gives the unit cost of production:

$$\mu_1 = c(r, w; a_K, a_L, \rho) = \left[\left(\frac{r}{a_K}\right)^{\frac{\rho}{\rho-1}} \lambda^{\frac{1}{1-\rho}} + \left(\frac{w+\eta}{a_L}\right)^{\frac{\rho}{\rho-1}} (1-\lambda)^{\frac{1}{1-\rho}}\right]^{\frac{\rho-1}{\rho}} \tag{27}$$

The total cost of producing Y units:

$$C(Y) = c(r, w; a_K, a_L, \rho)Y$$

$$C(Y) = \left[\left(\frac{r}{a_K}\right)^{\frac{\rho}{\rho-1}} \lambda^{\frac{1}{1-\rho}} + \left(\frac{w+\eta}{a_L}\right)^{\frac{\rho}{\rho-1}} (1-\lambda)^{\frac{1}{1-\rho}}\right]^{\frac{\rho-1}{\rho}} Y. \tag{28}$$

Having determined the unit cost of production we can move on to determine the optimum $a_K - a_L$ Choice.

$a_K - a_L$ Choice with Technique and Labor Adjustment Costs

As we did at section 2-4, we will proceed with factor adoption frictions in terms of technique adjustment and the labor adjustment costs. Our objective is to find the optimum a_K and a_L that minimize the marginal cost of production with technique and labor adjustment costs:

$$\min_{a_K, a_L} \quad c(\eta, r, w; a_K, a_L, \rho) + \phi(a_K, a_L) c(\eta, r, w; a_K, a_L, \rho) \tag{29}$$

$$s.t. \quad H(a_K, a_L) = z, \tag{30}$$

Denote the Lagrange multiplier associated with the hyperbola by μ_2. FOCs with respect to a_K and a_L are:

$$a_K: \quad (1+\phi_K)(r)^{\frac{\rho}{\rho-1}} \lambda^{\frac{1}{1-\rho}} a_K^{-\frac{\rho}{\rho-1}-1} \left[\left(\frac{r}{a_K}\right)^{\frac{\rho}{\rho-1}} \lambda^{\frac{1}{1-\rho}} + \left(\frac{w+\eta}{a_L}\right)^{\frac{\rho}{\rho-1}} (1-\lambda)^{\frac{1}{1-\rho}} \right]^{\frac{\rho-1}{\rho}-1} = \mu_2 \alpha a_K^{\alpha-1} a_L^{1-\alpha} \tag{31}$$

$$a_L: \quad (1+\phi_L)(w+\eta)^{\frac{\rho}{\rho-1}} (1-\lambda)^{\frac{1}{1-\rho}} a_L^{-\frac{\rho}{\rho-1}-1} \left[\left(\frac{r}{a_K}\right)^{\frac{\rho}{\rho-1}} \lambda^{\frac{1}{1-\rho}} + \left(\frac{w+\eta}{a_L}\right)^{\frac{\rho}{\rho-1}} (1-\lambda)^{\frac{1}{1-\rho}} \right]^{\frac{\rho-1}{\rho}-1} = \mu_2 (1-\alpha) a_K^{\alpha} a_L^{-\alpha} \tag{32}$$

Putting (31) and (32) together we can solve for the optimum a_K/a_L ratio:

$$\frac{a_K}{a_L} = \frac{r}{w+\eta} \left(\frac{1-\lambda}{\lambda}\right)^{\frac{1}{\rho}} \left(\frac{1-\alpha}{\alpha}\right)^{\frac{\rho-1}{\rho}} \left(\frac{1+\phi_K}{1+\phi_L}\right)^{\frac{\rho-1}{\rho}}. \tag{33}$$

Plugging (33) in (26) solves for the optimum K/L ratio:

$$\frac{K}{L} = \frac{w+\eta}{r} \frac{\alpha}{1-\alpha} \frac{\lambda}{1-\lambda} \frac{1+\phi_L}{1+\phi_K}. \tag{34}$$

I define again:

$$\Phi \equiv \frac{1+\phi_L}{1+\phi_K} \tag{35}$$

To solve for the scale of a_K and a_L as a function of z, w/r, α and ρ, we plug (33) in (30) and use (35):

$$a_K = z \left(\frac{r}{w+\eta}\right)^{1-\alpha} \left(\frac{\alpha}{1-\alpha}\right)^{(1-\alpha)\left(\frac{1-\rho}{\rho}\right)} \left(\frac{1-\lambda}{\lambda}\right)^{(1-\alpha)\left(\frac{1}{\rho}\right)} \Phi^{(1-\alpha)\left(\frac{1-\rho}{\rho}\right)}, \tag{36}$$

$$a_L = z \left(\frac{r}{w+\eta}\right)^{-\alpha} \left(\frac{\alpha}{1-\alpha}\right)^{-\alpha\left(\frac{1-\rho}{\rho}\right)} \left(\frac{1-\lambda}{\lambda}\right)^{-\alpha\left(\frac{1}{\rho}\right)} \Phi^{-\alpha\left(\frac{1-\rho}{\rho}\right)}. \tag{37}$$

Unit cost of production is then provided by:

$$c(\Phi,\eta) = \frac{1}{z} r^{\alpha}(w+\eta)^{1-\alpha}\left[\lambda^{\alpha}(1-\lambda)^{1-\alpha}\right]^{-\frac{1}{\rho}}\left[\left(\frac{\alpha\Phi}{1-\alpha}\right)^{1-\alpha}+\left(\frac{1-\alpha}{\alpha\Phi}\right)^{\alpha}\right]^{\frac{\rho-1}{\rho}} \quad (38)$$

Putting related terms together:

$$\begin{aligned} c(\Phi,\eta) &= \frac{1}{z}\left(\left(\frac{r}{\alpha}\right)\left(\frac{\lambda}{\alpha}\right)^{-\frac{1}{\rho}}\right)^{\alpha}\left(\left(\frac{w+\eta}{1-\alpha}\right)\left(\frac{1-\lambda}{1-\alpha}\right)^{-\frac{1}{\rho}}\right)^{1-\alpha}\Phi^{\alpha\left(\frac{1-\rho}{\rho}\right)}\left[1+\alpha\left(\Phi-1\right)\right]^{\frac{\rho-1}{\rho}} \\ &= \frac{1}{z}\left(\left(\frac{r}{\alpha}\right)\left(\frac{\lambda}{\alpha}\right)^{-\frac{1}{\rho}}\right)^{\alpha}\left(\left(\frac{w+\eta}{1-\alpha}\right)\left(\frac{1-\lambda}{1-\alpha}\right)^{-\frac{1}{\rho}}\right)^{1-\alpha}\left(\frac{\Phi^{\alpha}}{1+\alpha\left(\Phi-1\right)}\right)^{\frac{1-\rho}{\rho}} \quad (39) \end{aligned}$$

Remarks.

Labor Adjustment Costs, Technique Adjustment Costs and Flexibility.

1. The unit cost of production with labor and technique adjustment costs is $c(\Phi,\eta)$.
2. The only term that contains the labor-adjustment cost parameter at $c(\Phi,\eta)$ function from (39) is the first term in brackets. η creates a wedge above the neoclassical unit cost of production (c from equation 17) . η has a monotone distortionary effect. The higher η the larger is the distortion.
3. As we can see from $c(\Phi,\eta)$ the only term that contains η does not directly interact with the flexibility parameter ρ.

   ⇒ This means unlike what we have seen in the previous section with technique adjustment costs ($c(\Phi)$), a change in flexibility ρ does not dampen the distortionary effects of labor-adjustment costs on unit cost of production (relative to c).

* **Result. Flexibility dampens the distortionary effects of adjustment costs only when adjustment friction is related to techniques. When adjustment friction is only related to labor (or capital), which means a_K and a_L can be**

freely adjusted, then flexibility does not have an influence on relative wedges created above the unit cost of production.

The figure 1 below draws the unit cost function $c(\Phi, \eta)$ as a function of Φ and shows an increase in η shifts the unit cost function. The figure 2 draws η and Φ combinations that keep the unit cost constant (iso-cost): Ability to substitute techniques vs. ability to adjust labor.

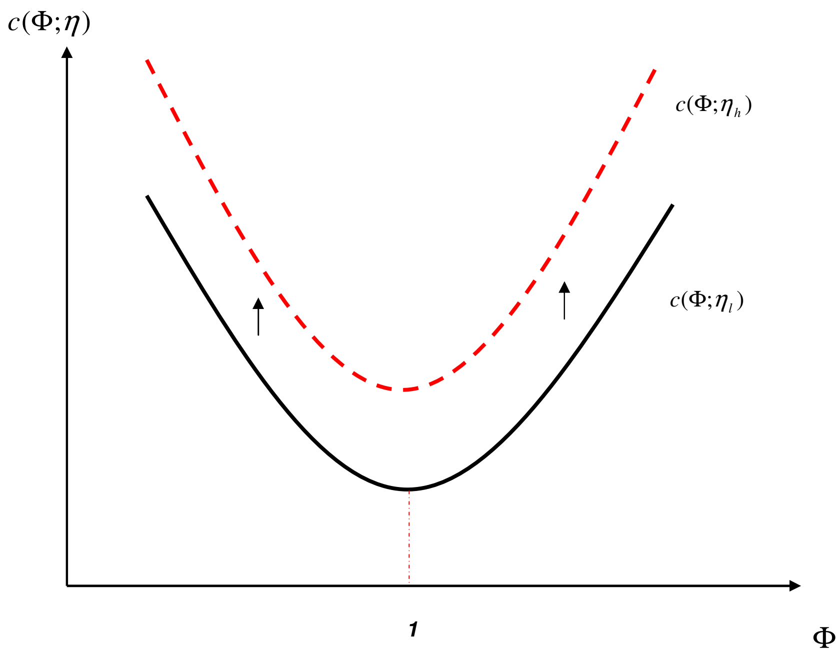


Figure 1. The Effect of a rise in η on unit cost of production

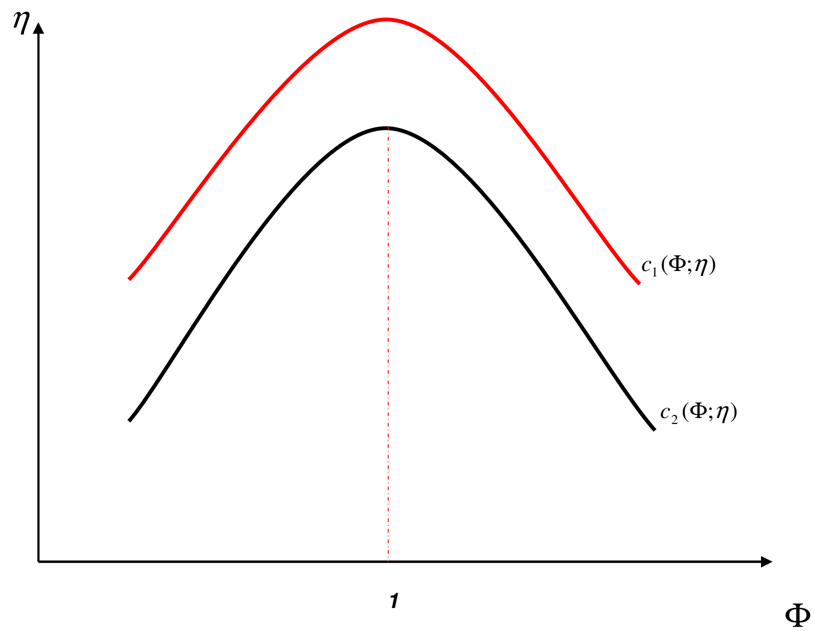


Figure 2. Isocost Functions with $c_1(\Phi;\eta) > c_2(\Phi;\eta)$

3 Data and Results

3.1 Data

We compute the average α and average ρ for two Taiwanese foundry firms (UMC and TSMC), by assuming $\lambda = \frac{1}{2}$ (Later we will test the robustness of the numerical results when variating$\lambda \in [0.45, 0.55]$). We use the Taiwanese borrowing rate announced by the Bank of Taiwan as our interst rate in the computation. There we can compute the average $r = 4.29\%$ (assuming including the depreciation) as well as have all the quarterly data (for 2000Q1-2013Q2) of Y, K, L, c, and w.[45]

3.2 Calibration in the Benchmarked Model

At calibrating the model parameters we will exploit the following equations:

$$\frac{K}{L} = \frac{w}{r}\frac{\alpha}{1-\alpha}\frac{\lambda}{1-\lambda} \tag{40}$$

$$\frac{a_K}{a_L} = \frac{r}{w}\left(\frac{1-\lambda}{\lambda}\right)^{\frac{1}{\rho}}\left(\frac{1-\alpha}{\alpha}\right)^{\frac{\rho-1}{\rho}} \tag{41}$$

$$Y = [\lambda(a_K K)^\rho + (1-\lambda)(a_L L)^\rho]^{\frac{1}{\rho}} \tag{42}$$

$$z = a_K^\alpha a_L^{1-\alpha} \tag{43}$$

$$c(w, r; z, \alpha, \rho) = \frac{1}{z}\left(\left(\frac{r}{\alpha}\right)\left(\frac{\lambda}{\alpha}\right)^{-\frac{1}{\rho}}\right)^\alpha \left(\left(\frac{w}{1-\alpha}\right)\left(\frac{1-\lambda}{1-\alpha}\right)^{-\frac{1}{\rho}}\right)^{1-\alpha} \tag{44}$$

Since we know K, L, w, r, c, and Y we can follow the following algorithm:

Step 1: Using sector-level data from the Taiwanese foundry industry we will have a "guess" for λ by probably adopting the industrial average output share of labor: This will provide us 5 equations with 5 unknowns.

[4] Y is derived from the quarterly net sales data of each of foundry firm. K is the quarterly stock of fixed capital net of depreciation. L is derived by using the annual data of hired employees. We also have the ship-out quantities of the wafers which are recomputed into the 8 inch equivalent wafers and then we divide the netsales by the 8 inch ship-out quantities to get the unit price. The unit cost is derived by the multilication of the unit price and the operating cost percentage which can be computed by subtracting the operating margins from one. Finally the wage can be computed by dividing the total labor compensation by the hired employee numbers.

[5] The K, Y, c, w data are backed out from the quarterly media annoucement of the operational financial information of the foundry firms. The employee numbers L is retrieved from the annual finacial reports in the covered data time.

Step 2: Using equation 40 back-out α.

Step 3: Using equation 41 write $\frac{a_K}{a_L}(\rho)$.

Step 4: Draw out the labor input L and a_L from the CRS production function (42). Then, put $\frac{a_K}{a_L}(\rho)$ into (42). Now, we know $a_L(\rho)$.

Step 5: Put $a_L(\rho)$ and $\frac{a_K}{a_L}(\rho)$ into 43 and derive $z(\rho)$.

Step 6: Put $z(\rho)$ in 44, and solve for ρ.

Step 7: Solve for all model parameters, and derive the firm-level TFP from 42. (Note: Sectoral parameters ρ and α will be common to all firms, therefore knowledge z will derive idiosyncratic TFP differences across the Taiwanese foundry producers in step 7.)

Step 8: Provide a test for the model by comparing the z we derived from the model against the z from the patent count data.

Since ρ is in the exponent the system will be highly non-linear.

Since ρ is in the exponent the system will be highly non-linear.

Using equation (60) we back out $\alpha_i, i \in \{UMC, TSMC\}$ as explained above: The average firm-level $\alpha_i, i \in \{UMC, TSMC\}$ specifically can be computed by

$$\frac{K_i}{L_i} = \frac{w_i}{r_i}\frac{\alpha_i}{1-\alpha_i}\frac{\lambda}{1-\lambda}, i \in \{UMC, TSMC\}$$

The benchmark case is $\lambda = \frac{1}{2}$

$$\alpha_{UMC} = 0.6081$$
$$\alpha_{TSMC} = 0.6184$$

For $\lambda = \frac{1}{2}$, the equation (69) reduces to:

$$\frac{w_i L_i}{c_i Y_i} = \left(\frac{1-\alpha_i}{\alpha_i}\right)^{\alpha_i} [\alpha_i(1-\alpha_i)]^{\frac{1}{\rho_i}}, i \in \{UMC, TSMC\} \tag{45}$$

Now using the following average data observations we back-out the flexibility parameter for each firm:

$$\begin{aligned} \left(\frac{cY}{wL}\right)_{UMC} &= 6.28 \\ \left(\frac{cY}{wL}\right)_{TSMC} &= 6.70 \\ c_{UMC} &= 31157 \\ c_{TSMC} &= 28121 \end{aligned}$$

The equation (70) can be further simplified to

$$\rho_i = \frac{\log[\alpha_i(1-\alpha_i)]}{\log \frac{c_i Y_i}{w_i L_i} + \alpha_i \log(\frac{1-\alpha_i}{\alpha_i})}, i \in \{UMC, TSMC\} \tag{46}$$

Plugging the associated data into equation (71) yields the firm-level elasticity of substitution ρ as follows:

$$\rho_{UNC} = 0.9131$$
$$\rho_{TSNC} = 0.9000$$

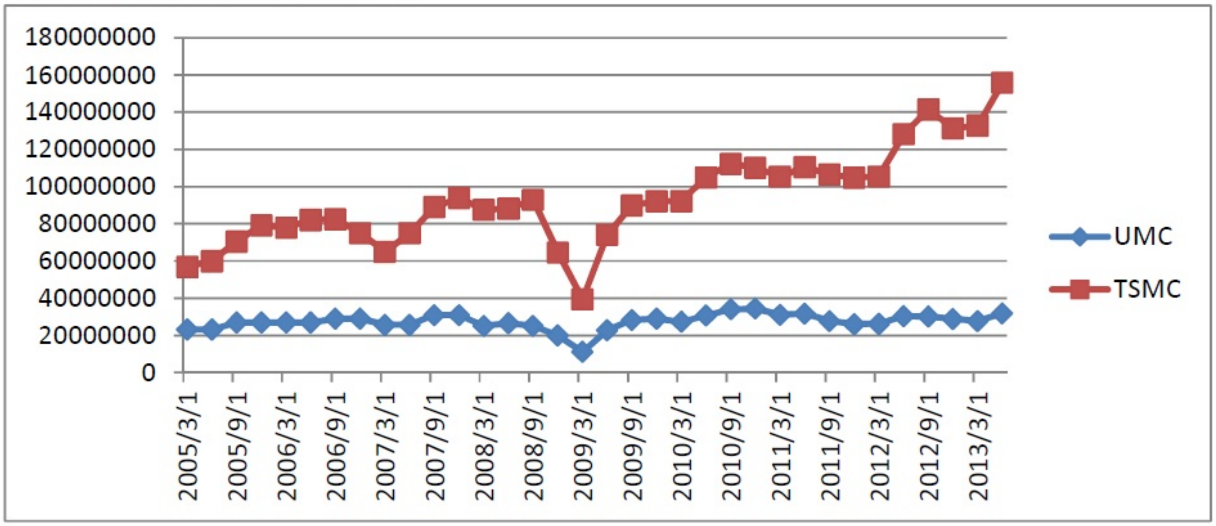
We thus proceed the computation of the firm-level knowledge z_i based on the equation (67) and the firm-level TFP_i based on the definitions of the neoclassical total factor productivities (TFP) as follows:

$$TFP_i = \frac{Y_i}{[\lambda(K_i)^{\rho_i} + (1-\lambda)(L_i)^{\rho_i}]^{\frac{1}{\rho_i}}}, i \in \{UMC, TSMC\} \tag{47}$$

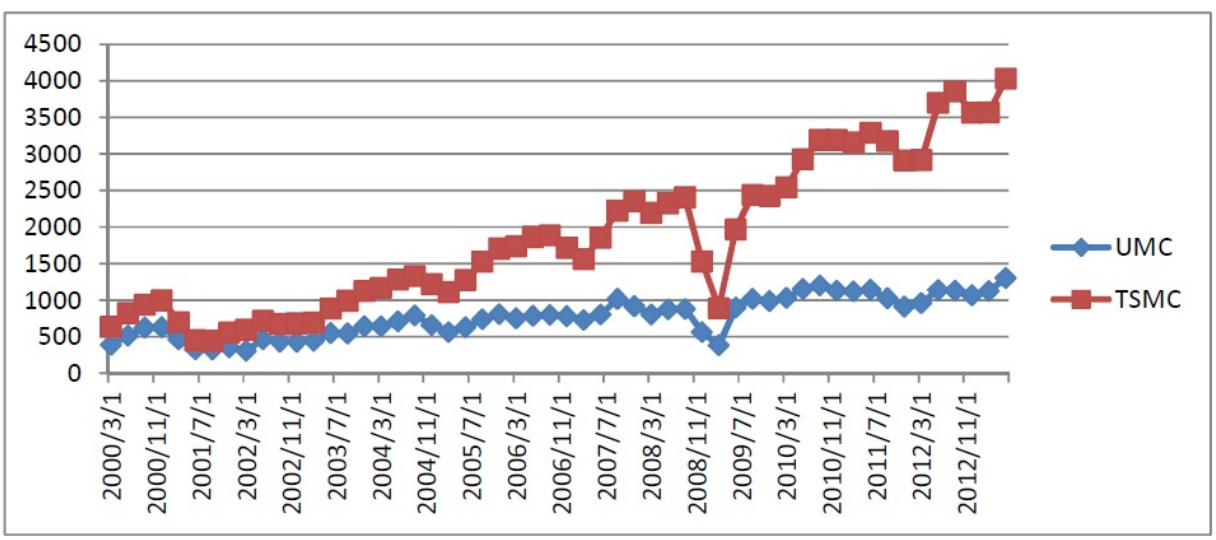
The firm-level z_i and TFP_i is computed and reported in the following section.

3.3 Summary Statistics

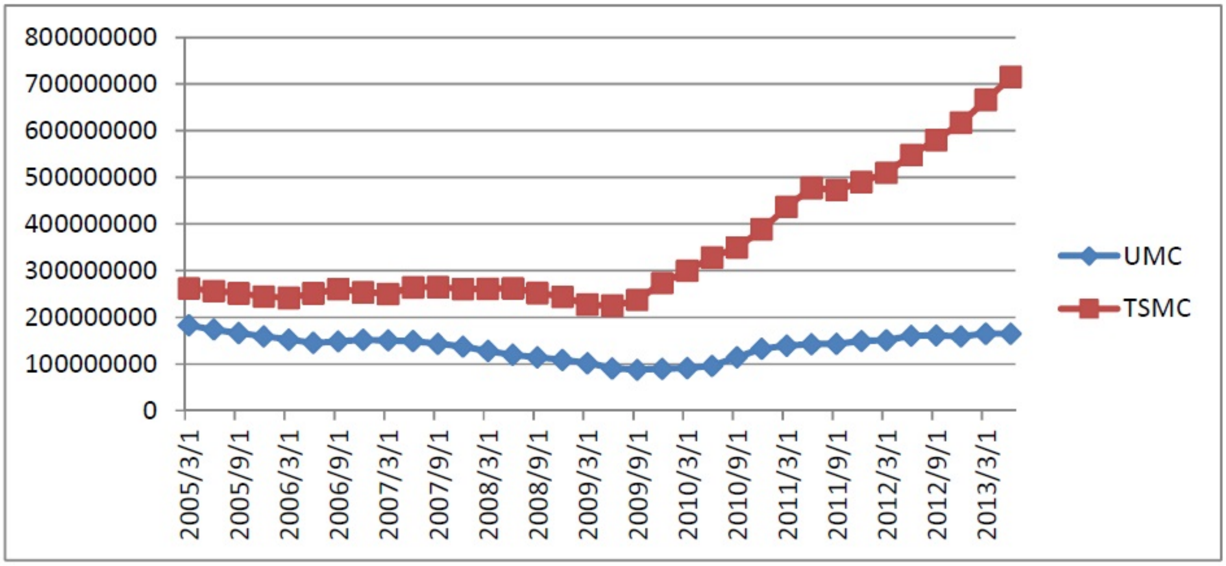
1. Revenue (P*Y, in ,000 $NT)



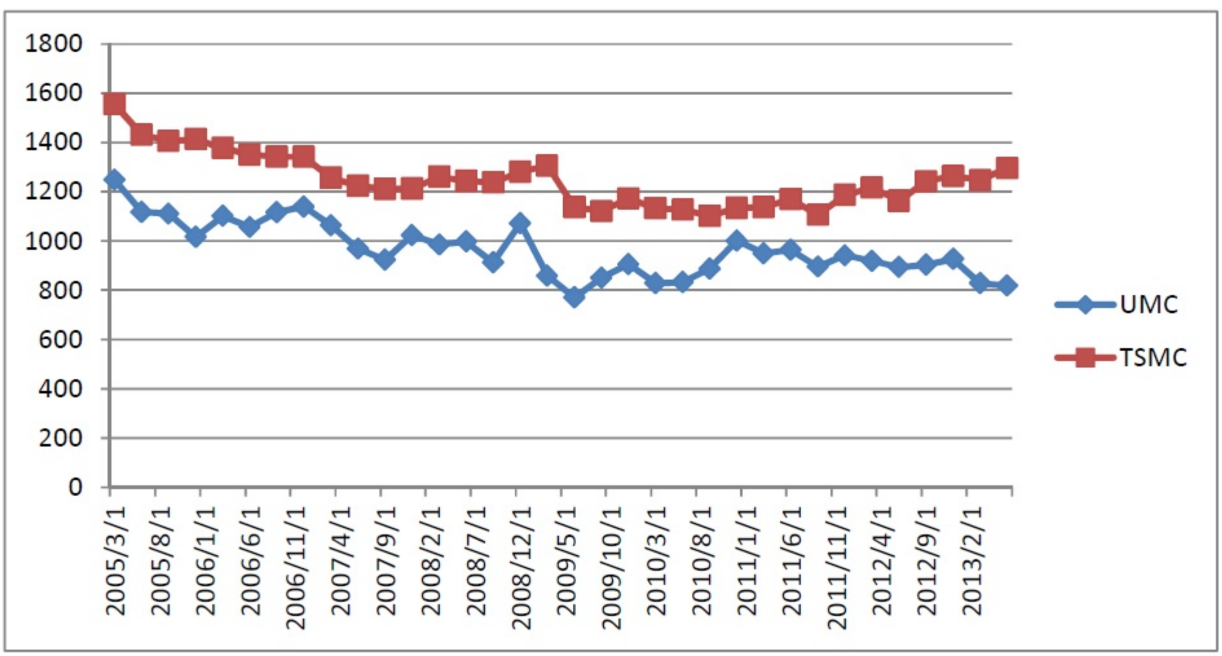
2. Production (Y, in ,000 unit of wafers)



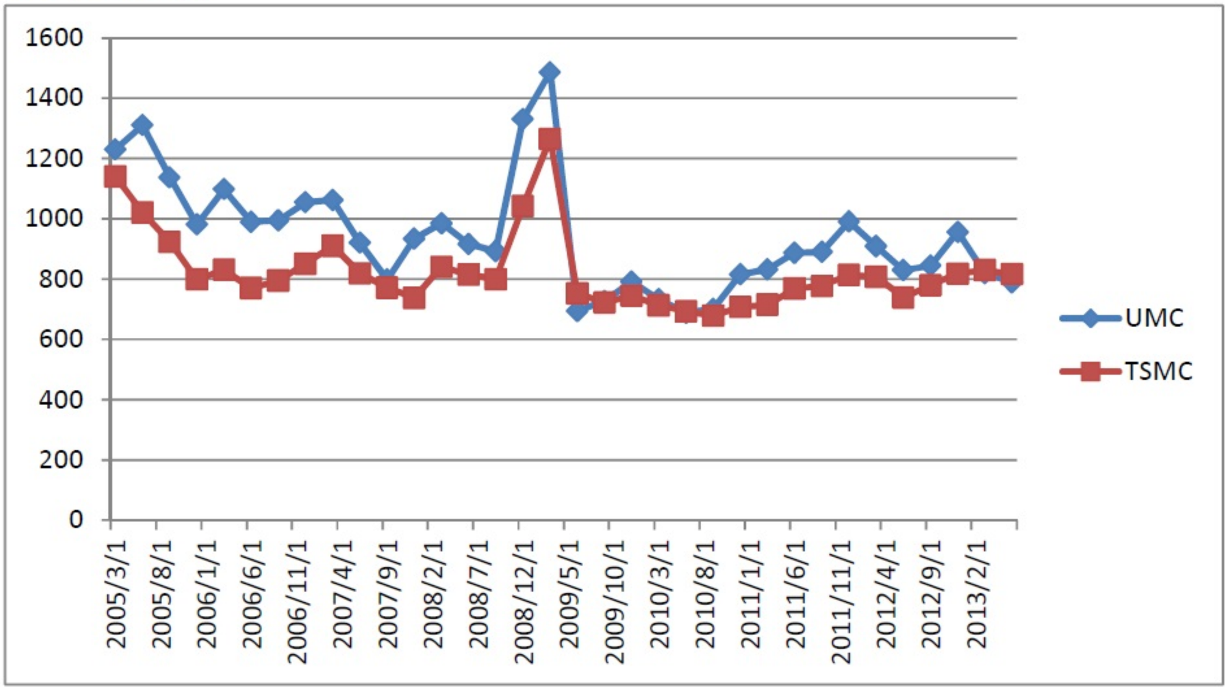
3. Fixed Capital (K):



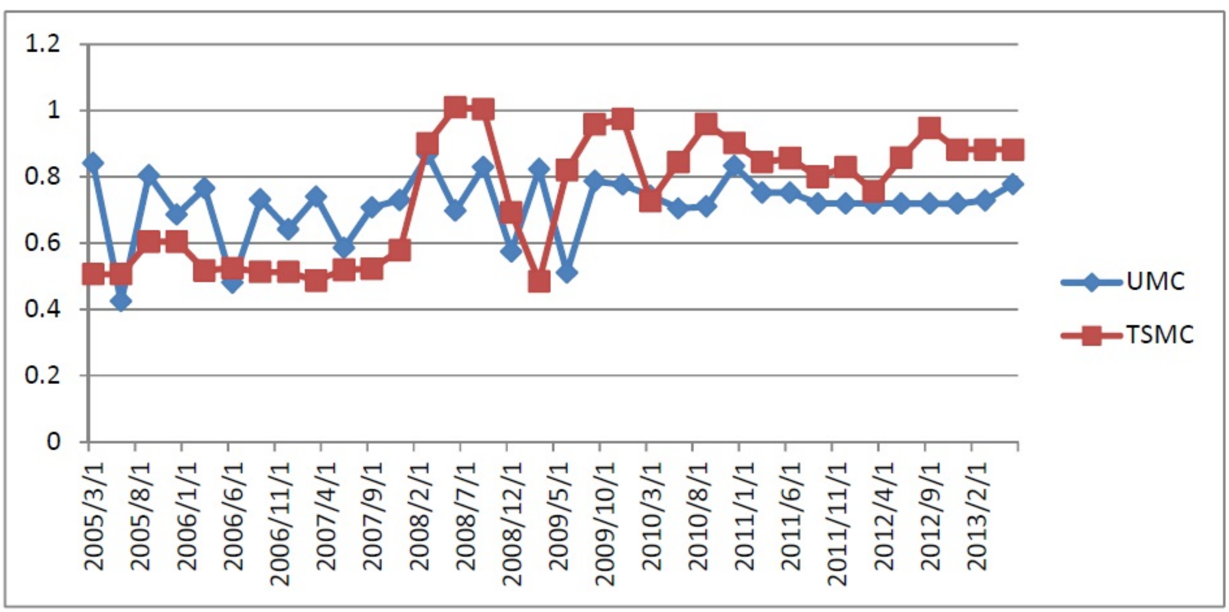
4. Price (P): (in $USD)



5. Unit cost (c):



6. wage (w, hourly wage rate in ,000 $NTD)

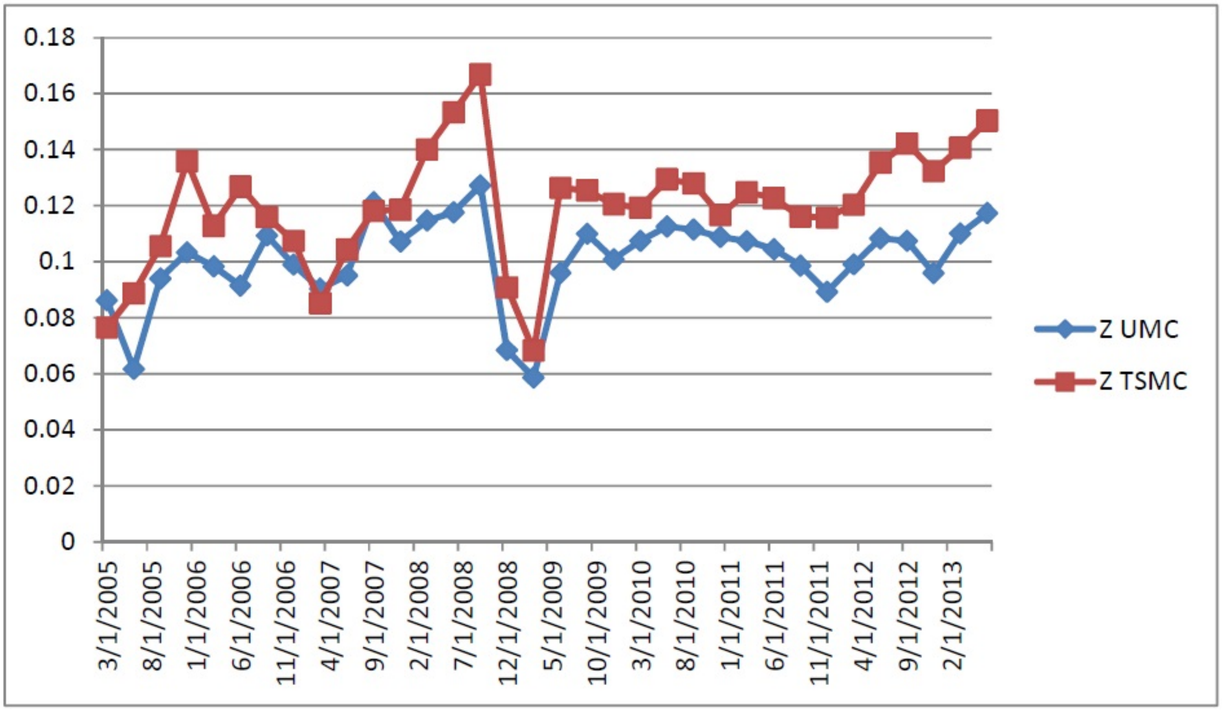


3.4 Calibration Results

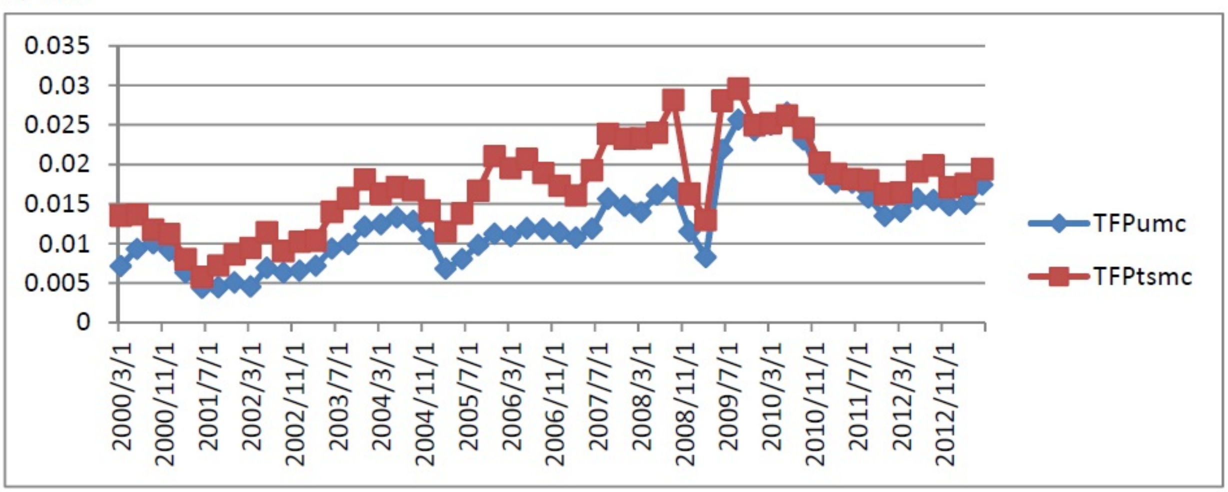
We utilize firm-level data on unit costs, prices and capital and labor allocation, assume $\lambda = \frac{1}{2}$, and calibrate production parameters for two Taiwanese foundry producers (UMC and TSMC) as follows:

Firm	α	ρ	Average-Z	Average-TFP
UMC	0.6081	0.9131	0.0917	0.012
TSMC	0.6184	0.9000	0.1199	0.017

1. Z


0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
3/1/2005
8/1/2005
1/1/2006
6/1/2006
11/1/2006
4/1/2007
9/1/2007
2/1/2008
7/1/2008
12/1/2008
5/1/2009
10/1/2009
3/1/2010
8/1/2010
1/1/2011
6/1/2011
11/1/2011
4/1/2012
9/1/2012
2/1/2013
Z UMC
Z TSMC

2. TFP


0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
2000/3/1
2000/11/1
2001/7/1
2002/3/1
2002/11/1
2003/7/1
2004/3/1
2004/11/1
2005/7/1
2006/3/1
2006/11/1
2007/7/1
2008/3/1
2008/11/1
2009/7/1
2010/3/1
2010/11/1
2011/7/1
2012/3/1
2012/11/1
TFPumc
TFPtsmc

4 Conclusion

Collecting and supplementing data on Taiwanese Foundry Industry and modelling the foundry business competition with a CES framework, We found that the giant TSMC has dominated the market by its reputed quality and accumulated techniques while UMS remains surviving in the market by its flexibility. We also discuss the relation between Labor Adjustment Costs, Technique Adjustment Costs and Flexibility. Flexibility dampens the distortionary effects of adjustment costs only when adjustment friction is related to techniques. When adjustment friction is only related to labor (or capital), which means a_K and a_L can be freely adjusted, then flexibility does not have an influence on relative wedges created above the unit cost of production.

References

[1] Adler, B. Goldoftas, D. I. Levine, "Flexibility versus efficiency? A case study of model changeovers in the Toyota production system", *Organization Science*, 10:1 (1999), 43-68.

[2] Fine, C. H. and Freund, R. M., "Optimal Investment in Product Flexible Manufacturing Capacity", *Management Science*, 36:4 (1990), 449-466.

[3] Fine, C.H.,"Developments in manufacturing technology and economic evaluation models", in: S.C. Graves et al. (Eds.), *Handbooks in OR and MS*, vol. 4, Elsevier, Amsterdam, (1993), 711-750.

[4] Grewin, D., "Manufacturing exibility: a strategic perspective, *Management Science*, 39:4 (1993), 395-410.

[5] Goyal, M., Netessine, S., "Strategic technology choice and capacity investment under demand uncertainty", *Management Science*, 53 (2007), 192-207.

[6] Jones, Robert A. and Ostroy, Joseph M., "Flexibility and Uncertainty," *Review of Economic Studies*, 51 (1984), 13-32.

[7] Klein, B. H., “Prices, Wages and Business Cycles: A Dynamic Theory”. *Pergamon*, (1984) New York.

[8] Marschak, T. and Nelson, R., “Flexibility, Uncertainty, and Economic Theory”, *Metroeconomica*, 14 (1962), 42-60.

[9] Milla, D. E. and Schumann, L., “Industry Structure with Fluctuating Demand”, *American Economic Review*, 75 (1985), 758-767.

[10] Netessine, S., G. Dobson and R.A. Shumsky, “Flexible service capacity: optimal investment and the impact of demand correlation”, *Operations Research*, 50 (2002), 375-388.

[11] Nigel Slack, “Manufacturing systems flexibility an assessment procedure”, *computer-integrated manufacturing systems*, 1:1 (1988), 25-31

[12] Solow, R., “A contribution to the theory of economic growth”, *Quarterly Journal of Economics*, 70 (1956), 65-94.

[13] Roller, L. and Tombak, M., “Strategic choice of flexible production technologies and welfare implications”, *Journal of Industrial Economics*, 38 (1990), 417-32.

[14] Roller, L. and Tombak, M., “Competition and investment in flexible technologies”, *Management Science*, 39:1 (1993), 107-114.

[15] Stigler, George J., “Production and Distribution in the Short Run,” *Journal of Political Economy*, 47 (1939), 305-27.

[16] Upton, D. M., “What really makes factories flexible?”, *HarvardBusinessReview*, 73:4 (1995), 74-84.

[17] Vives, X., “Commitment, Flexibility, and Market Outcomes,” *International Journal of Industrial Organization*,4 (1986), 217-29.

(出國類別：研究)

「赴美國聖路易華盛頓大學
執行 103 年國科會補助專題計畫：」
心得報告書

服務機關：國立政治大學經濟系

職稱：助理教授

姓名：李文傑

出國地區：美國密蘇里州聖路易市

出國期間：104 年 4 月 12 日

至 104 年 4 月 27 日

報告日期：104 年 4 月 30 日

出國成果報告書（格式）

計畫編號		執行單位	政大經濟系
出國人員	助理教授李文傑	出國日期	104 年 4 月 12 日至 104 年 4 月 27 日，共 16 日
出國地點	美國密蘇里州聖路易市	出國經費	新台幣 10 萬元

報告內容摘要(請以 200 字～300 字說明)

在國科會計畫以及王平院士的支持下,本研究團隊得以委派經濟系李文傑助理教授得以至聖路易華盛頓大學的動態經濟研究中心與王平院士共同針對國科會計畫「高科技廠商的最適生產結構調整: 以台灣的晶圓代工產業之生產靈活性對公司表現指標影響為例」,發展計劃中所需的理論模型，並且進一步推導相關的參數動差估計式，此次研究成果豐碩，已完成理論模型設定並分析。根據理論模型縮減式之分析討論以及實際資料的運算結果,我們歸納出以下結論,晶圓代工的兩家主要廠商其關鍵勝出條件為產品品質,及由技術累積形成的關鍵技術力,以及生產彈性。台積電席捲市場的原因為其技術領先而聯電能繼續生存的主要理由為其具有相當高的生產彈性。

。

目　　錄

壹、前言:

本年度國科會計畫「高科技廠商的最適生產結構調整: 以台灣的晶圓代工產業之生產靈活性對公司表現指標影響為例」,須以一精密理論模型支持主要推論，由於研究時程設定相當緊迫，因此研究團隊指派經濟系助理教授李文傑前往美國聖路易華盛頓大學動態經濟研究中心，與王平院士針對研究議題: 對於不同廠商的生產彈性對於組織層級競爭力的影響，密集討論並設定一精密的理論模型以供後續政策分析建議及評估做一確實推估，在與王平院士的 16 天密切互動中，完成核心理論模型的推導，得出了晶圓代工的兩家主要廠商其關鍵勝出條件為產品品質，及由技術累積形成的關鍵技術力，以及生產彈性。台積電席捲市場的原因為其技術領先而聯電能繼續生存的主要理由為其具有相當高的生產彈性，出國學者帶回的寶貴研究成果將供研究團隊後續之參數估計及供政策推論之用。除此之外，出國學者也得以將此一寶貴研究成果，廣泛徵詢聖路易華盛頓大學的著名學者，以確實改進本理論模型的可能缺失，在這 4 周的緊密研究形成中，相信對此一計畫的品質及未來發表方向都有了更進一步的掌握,以下則針對與王平院士完成的研究成果做詳細說明。

貳、研究過程:

美國聖路易華盛頓大學的動態經濟研究中心為聖路易地區內動態經濟學領域的最高層級學術交流及研討中心，其成立主旨在於鼓勵方法及發展對於人力資本，區域經濟，國際經濟，經濟體內重要人力資本累積等各類美國及世界重要經濟體面對的當前重要經濟議題之關注及進一步提出解決方法之高階研究場所，因此本次國科會計畫研究團隊因計畫「高科技廠商的最適生產結構調

整: 以台灣的晶圓代工產業之生產靈活性對公司表現指標影響為例」，與動態經濟研究中心之研究主旨切合，故透過計畫主持人李文傑與計畫協同研究人員王平院士的申請，經半個多月的行政申請作業程序後，由動態經濟研究中心的秘書 Carissa 發給研究成員經濟系助理教授李文傑邀請函，即期動身前往美國密蘇里州聖路易市。

總計本次在美國動態經濟研究中心主要在與王平院士處理關於廠商生產彈性的 1. 各項文獻整理以及分析 2. 設定及發展生產彈性測度的理論模型 3.推導理論模型的縮減式 4. 發展模型參數校正方法 (Calibration) 5.提出目前現階段的結論及建議等。總歸來說，除了出國學者義務必須完全參與的與王平院士的討論及工作之外，仍盡力貢獻所學及研究知識與國際學者積極交流，了解最新發展經濟學中關於資源錯置領域的明日之星研究，並在出國人研究生產彈性問題以及資源錯置衡量上讓與會的各國同領域研究者了解國科會計畫目前研究進展，使其他學者了解此際計畫的研究資料，獨有的模型設定，以及模型運算的結果，相信在同行加持下，研究成果會更加豐富。

參、本次出國研究目的:

在研究計畫發想之初，計畫主持人李文傑即針對目前各研究文獻作衣全面性回顧及整理，了解到晚近發展之探討廠商生產彈性差異的經濟模型，為了反映不同生產彈性對企業全要素生產力(TFP)差異的影響，既存文獻有兩種不同的處理形式，如前所述(1)商學領域中的生產彈性個案研究(2)經濟學中的生產彈性的定義的研究，此為近期異質性生產者(Heterogeneous Producers)的一

般均衡模型研究著力及側重方向，然而不同模型側重點並不能精確符合台灣晶圓代工的產業特性，因此由模型所得的政策並不能給予台灣此類的新興工業國訂定研發及產業發展的政策依據，例如探討生產彈性的早期文獻 Stigler (1939) 所提及的產業內廠商間的生產彈性差異致使廠商觀摩差異是一例，其發現了以下生產彈性與廠商競爭力的重要關係: (i)生產彈性與生產成本為一負向的指數關係，其稱之為廠商的可行的最適生產規模調整，每一次成功的生產規模調整將導致廠商可用高一個層級的規模生產較低成本的產品(ii) 生產彈性與產品品質之間的抵換關係，生產彈性之高低並不意味著廠商產品品質的走向，過去的商學文獻通過運用個別廠商的表現個案來推測此兩者關係並不必然存在。

基於既存文獻分別有兩種不同的型式處理生產彈性對於廠商競爭力的影響，最終，本一年期計畫的執行兼顧由於生產彈性的討論以及各項企業表現指標的衡量，對台灣晶圓代工產業的個別生產者選取的規模與社會最適規模差異的影響，而我們完成了台灣晶圓代工產業的產業結構及生產彈性差異對產業的生產效率差別的分析，而所建構的台灣晶圓代工的廠商層級資料庫可以供做後續關於東亞新興工業國家產業轉型或是產業生產力比較之使用，本研究結果實際證明晶圓代工的兩家主要廠商其關鍵勝出條件為產品品質，及由技術累積形成的關鍵技術力，以及生產彈性。台積電席捲市場的原因為其技術領先而聯電能繼續生存的主要理由為其具有相當高的生產彈性，並充分探究不同的生產彈性在不同的產業結構上，對廠商 TFP 的影響。

肆、此次出國研究之重要結論

一. 實證結果

晶圓代工的兩家主要廠商其關鍵勝出條件為產品品質，及由技術累積形成的關鍵技術力，以及生產彈性。台積電席捲市場的原因為其技術領先而聯電能繼續生存的主要理由為其具有相當高的生產彈性。後續，並可藉由擬真分析 (Counterfactual Analysis) 計算廠商的生產靈活性改善是如何影響 (1) 生產要素配置 (2)生產技術調整的程度，並以之做各項產業政策分析。

伍、心得與建議

本次出國研究，發展以及推倒出的模型的強項在於我們將可以實際計算產業內廠商之生產彈性以及各項生產力衡量指標的差異性間的關係，並討論政策當局可否藉著調整產業結構以矯正廠商的資源錯置程度並藉此提升產業的生產效率，結果發現晶圓代工的兩家主要廠商其關鍵勝出條件為產品品質，及由技術累積形成的關鍵技術力，以及生產彈性。台積電席捲市場的原因為其技術領先而聯電能繼續生存的主要理由為其具有相當高的生產彈性。

科技部補助計畫衍生研發成果推廣資料表

日期:2016/02/01

科技部補助計畫	計畫名稱: 高科技廠商的最適生產結構調整: 以台灣的晶圓代工產業之生產靈活性對公司表現指標之影響為例
	計畫主持人: 李文傑
	計畫編號: 103-2410-H-004-022- 學門領域: 經濟發展、技術變動與成長

無研發成果推廣資料

103年度專題研究計畫研究成果彙整表

計畫主持人：李文傑	**計畫編號：**103-2410-H-004-022-
計畫名稱：高科技廠商的最適生產結構調整：以台灣的晶圓代工產業之生產靈活性對公司表現指標之影響為例	

成果項目			量化：實際已達成數（被接受或已發表）	量化：預期總達成數（含實際已達成數）	量化：本計畫實際貢獻百分比	單位	備註（質化說明：如數個計畫共同成果、成果列為該期刊之封面故事...等）
國內	論文著作	期刊論文	0	0	100%	篇	
		研究報告/技術報告	0	0	100%		
		研討會論文	1	1	100%		於2014年台灣經濟學年會發表
		專書	0	0	100%	章/本	
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（本國籍）	碩士生	0	0	100%	人次	
		博士生	0	0	100%		
		博士後研究員	0	0	100%		
		專任助理	0	0	100%		
國外	論文著作	期刊論文	1	1	100%	篇	獲得國際期刊遴選收錄
		研究報告/技術報告	0	0	100%		
		研討會論文	1	1	100%		獲得2015年之公共經濟年會發表機會
		專書	0	0	100%	章/本	
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（外國籍）	碩士生	3	3	100%	人次	
		博士生	1	1	100%		
		博士後研究員	0	0	100%		
		專任助理	0	0	100%		

其他成果 （無法以量化表達之成果如辦理學術活動、獲得獎項、重要國	訓練重要產業分析人力，發展之模型以及生產彈性衡量方法可供後續的政策分析及擬真分析之用

際合作、研究成果國際影響力及其他協助產業技術發展之具體效益事項等，請以文字敘述填列。）	

	成果項目	量化	名稱或內容性質簡述
科教處計畫加填項目	測驗工具(含質性與量性)	0	
	課程/模組	0	
	電腦及網路系統或工具	0	
	教材	0	
	舉辦之活動/競賽	0	
	研討會/工作坊	0	
	電子報、網站	0	
	計畫成果推廣之參與（閱聽）人數	0	

科技部補助專題研究計畫成果報告自評表

請就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）、是否適合在學術期刊發表或申請專利、主要發現或其他有關價值等，作一綜合評估。

1. 請就研究內容與原計畫相符程度、達成預期目標情況作一綜合評估
   ■達成目標
   □未達成目標（請說明，以100字為限）
   　　□實驗失敗
   　　□因故實驗中斷
   　　□其他原因
   說明：

2. 研究成果在學術期刊發表或申請專利等情形：
   論文：■已發表 □未發表之文稿 □撰寫中 □無
   專利：□已獲得 □申請中 ■無
   技轉：□已技轉 □洽談中 ■無
   其他：（以100字為限）

3. 請依學術成就、技術創新、社會影響等方面，評估研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）（以500字為限）
   計畫發展的模型可供測度高科技產業廠商的生產彈性、技術力、及探究生產彈性與各項生產力指標間的關係