Productivity, Returns to Scale and Product Differentiation in the Retail Trade Industry*

--- An Empirical Analysis using Japanese Firm-Level Data ---

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Abstract

This paper examines productivity and returns to scale under the assumption of monopolistic competition using Japanese firm-level data. Although differentiating products (services) is considered important in firms' strategies and productivity growth, it has not been sufficiently investigated in previous studies. In this paper, we study this issue in two retail trade industries, department stores and supermarkets, applying the model of Melitz (2000). Our results indicate that the retail trade industries possibly follow increasing returns to scale if we consider the effects of product differentiation. In addition, product differentiation has a positive effect on firms' revenue. Thus, policy measures that promote economies of scale and product differentiation should contribute to further growth in these industries. In addition, the results indicate that the regulatory reform of the retail trade industry in 2000made a positive contribution.

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"Productivity isn't everything, but in the long run it is almost everything"

--- *Paul Krugman*[1] ---

1. Introduction

Productivity has been studied by economists and policy makers for a long time. This is because only productivity growth is considered as an engine to yield economic growth in the long run. The surge of productivity growth in the U.S. in the later half of the 1990s reinforces their interests. It shows that the service sectors which were thought as stagnant sectors before can also raise their productivity growth and become a driving force of macro economic growth. To better understand these facts and obtain useful implications, many theoretical and empirical studies have been conducted. In particular, the increased availability of micro (firm or establishment level) data has produced many empirical papers to estimate productivity and examine the relationships between productivity and industrial policy (including the regulatory reform).

In those studies using firm level data, differentiation of products (services) has not been well examined although it is thought to play some important roles in firm strategies and productivity growth. This is partly because the data availability for product differentiation is still poor, particularly for service producing firms. Neglecting this problem in estimation, however, may bias the estimated returns to scale and productivity. For this issue, Melitz (2000) proposes an interesting model which incorporates monopolistic competition into the estimation of production function. His model also explicitly tackles the problem that total sales are different from actual output of firms' production if product (service)-specific prices are heterogeneous although they

[1] Krugman (1990)

are interpreted to be identical in estimating productivity. In this model, productivity estimation does not rely on the product-specific price data although it imposes some limitation on productivity estimation. Loecker (2007) modifies Melitz's model adding product-specific price data. This model improves estimation of productivity by decomposing demand shocks and productivity growth. But, it is not much applicable for service industries because service-specific price data are not usually available.

In this paper, we examine productivity, returns to scale, and product (service) differentiation, applying a slight modification of Melitz's approach to Japanese firm-level data. To the best of our knowledge, this is the first paper which incorporates product differentiation into productivity estimation following Melitz. In addition, in order to compare the results and discuss the effects of product differentiation on productivity, we estimate three different models using data for the retail trade industry, in particular departmental stores and supermarkets. Furthermore, we examine the relationships between productivity and the regulatory reform.

The layout of this paper is as follows. In section 2, we detail the model which we examine. Section 3 describes the data which we use. In section 4, we discuss the empirical results and their implications. And the last section draws concluding remarks from the above discussion.

2. The Model

This section briefly describes the model which we examine. Following Melitz, we start with the case where any firm produces a single product or service[2]. Suppose that firms in an industry produce symmetrically differentiated products with a common elasticity

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[2] To avoid redundancy, the term, product, includes both meanings of product and service, henceforth.

of substitution (CES) σ between any two of them. According to Blanchard and Kiyotaki (1987), we assume the utility function of a representative consumer for products in industry *c* is described as follows[3]:

$$U_c = N^{\frac{1}{1-\sigma}} \left(\sum_{i=1}^{N} \left(\Lambda_i Q_i \right)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} , \quad (1)$$

where N is the number of firms in this industry[4]. Λ_i and Q_i denote the consumer's valuation of the product quality of firm i, and the quantity of it, respectively. The parameter σ is restricted to be greater than unity otherwise there might be no equilibrium. The utility function is assumed to be differentiable and quasi-concave. In addition, an increase in the number of products does not change marginal utility after optimisation because the utility function is normalised by $N^{\frac{1}{\sigma-1}}$. In this simple model of monopolistic competition, changes in Λ_i over time stem from changes in the actual quality of the product or changes in the consumer's preference. To simplify the model, the shifts of preference which affect all products are excluded. For this utility function, the budget constraint of the consumer to purchase products of industry *c* is

$$B = \sum_{i=1}^{N} P_i Q_i , \quad (2)$$

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[3] Melitz assumes the utility function as $\left(\sum_{i=1}^{N} \left(\Lambda_i Q_i \right)^{\frac{\sigma-1}{\sigma}} , Z \right)^{\frac{\sigma}{\sigma-1}}$, where Z is an overall demand shifter. But we don't follow it because equation (1) is mathematically compatible with the following equations.

[4] Holtz-Eakin and Lovely (1996) uses a similar framework of differentiation for production function with a large input variety (in particular, intermediate inputs).

where P_i is the price of firm i's product. From the first order condition of utility maximisation, we obtain the following:

$$\lambda^{-1} \equiv \tilde{P} = \left(\frac{1}{N} \sum_{i=1}^{N} \left(\frac{P_i}{\Lambda_i} \right)^{1-\sigma} \right)^{\frac{1}{1-\sigma}}, \qquad (3)$$

where $\tilde{P}$ is the average price of products adjusted on the quality in this industry[5]. From the above equations, the demand for firm i's product is written as follows:

$$Q_i = \Lambda_i^{-(1-\sigma)} \cdot U_c \cdot \left(\frac{1}{N} \right)^{\sigma} \left(\frac{P_i}{\tilde{P}} \right)^{-\sigma}, \qquad (4)$$

Now, we denote the sales of firm i's product as $P_i Q_i = R_i$, and total sales in the industry which is equivalent to total revenue as $\sum_{i=1}^{N} R_i = R$. Using them, equation (4) is rewritten as follows.

$$Q_i = \Lambda_i^{\sigma - 1} \left(\frac{P_i}{\tilde{P}} \right)^{-\sigma} \frac{1}{N} \left(\frac{R}{\tilde{P}} \right) \qquad (5)$$

This equation indicates that the number of firms which equals the number of products determines output of firm i, together with other factors.

On the other hand, the production function in this paper is defined as follows. First,

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[5] λ is a Lagrange multiplier.

we assume that firms use the production technology which is homogeneous of degree $\gamma > 0$. We do not assume that $\gamma = 1$ but rather examine this issue empirically. X_i is the vector of inputs which are consumed in production of Q_i. X_i is an aggregate input index which is constructed as a linearly homogeneous function of inputs, $f(\mathrm{X}_i)$. Similarly, the vector of the factor prices is Ω_i, and an aggregate factor price index is $W_i = h(\Omega_i)$. Following them, our production function for firm i is described as follows:

$$Q_i = \Phi_i X_i^{\gamma}, \qquad (6)$$

where Φ_i represents productivity of firm i.

Now, we take logs of equation (5) and (6), and solve the demand function for firm-specific price p_i. Plugging in the production and the inverse demand functions into the revenue function, $r_i - \tilde{p} = q_i + p_i - \tilde{p}$, we obtain the following revenue production function:

$$r_{it} - \tilde{p}_t = \frac{\sigma - 1}{\sigma}\gamma x_{it} + \frac{1}{\sigma}\left[(r_t - \tilde{p}_t) - n_t\right] + \frac{\sigma - 1}{\sigma}(\phi_{it} + \lambda_{it}), \qquad (7)$$

where lower case variables are logs of upper case variables in equation (5) and (6). The subscript t represents time. From the definition of Φ_i and Λ_i, $\phi_{it} + \lambda_{it}$ is a quality adjusted productivity index, and is denoted as $\varphi_{it} = (\phi_{it} + \lambda_{it})$. Without additional information, neither ϕ_{it} nor λ_{it} is separately identified.

As Melitz details, equation (7) does not include the product-specific price which is not usually available in empirical study. Equation (7) also reveals that estimation of revenue production function without product differentiation may understate the degree of returns to scale by $\frac{\sigma-1}{\sigma}$. This is consistent with a finding of Klette and Griliches (1996). Productivity differences $\Delta\varphi_{it}$ are also understated by $\frac{\sigma-1}{\sigma}$ as well. In addition, an industry aggregate sales regressor $(r_t - \tilde{p}_t)$ does not always obtain a significant and positive coefficient, and only the estimated coefficient greater than $1/\sigma$ possibly means that there are external economies unlike Cooper and Johri (1997)[6].

Next, we expand the above model to the case where firms produce different numbers of products. Now, firm i produces M_i products. Since we do not add any change on the structure of the model, the production and demand are respectively presented as follows;

$$Q_{ij} = \Phi_{ij} X_{ij}^{\gamma}, \qquad (8)$$

$$Q_{ij} = \Lambda_{ij}^{\sigma-1} \left(\frac{P_{ij}}{\tilde{P}} \right)^{-\sigma} \frac{1}{M} \left(\frac{R}{P} \right), \qquad (9)$$

where $M = \sum_{i=1}^{N} M_i$. We also assume $\sum_{i=1}^{N} \sum_{j=1}^{M_i} R_{ij} = \sum_{i=1}^{N} R_i = R$, $P_{ij} Q_{ij} = R_{ij}$ and $X_i = \sum_{j=1}^{M_i} X_{ij}$. We add the assumption that introducing an additional product has a sunk cost for firms as well. An average quality adjusted productivity for each firm is denoted as $\tilde{\varphi}_i$, and formulated as follows:

[6] Melitz also discuss issues related to firm markups, and concludes that productivity differences can be separately estimated without firm specific price information because the firm markups is inseparably related to the inputs.

$$e^{-\frac{1}{\gamma}\tilde{\varphi}_i} = \frac{1}{M_i}\sum_{j=1}^{M_i}\left[\left(\frac{M_i R_{ij}}{R_i}\right)^{\frac{\sigma}{\sigma-1}} e^{-\varphi_{ij}}\right]^{\frac{1}{\gamma}}, \qquad (10)$$

where φ_{it} is a quality adjusted productivity of each product. Under these assumptions, a revenue production function of firm i divided by the number of products at period t is described as follows.

$$r_{it} - m_{it} - \tilde{p}_t = \frac{\sigma-1}{\sigma}\gamma(x_{it} - m_{it})x_{it} + \frac{1}{\sigma}[(r_t - \tilde{p}_t) - m_t] + \frac{\sigma-1}{\sigma}\tilde{\varphi}_{it}$$

The term m_{it} in the left hand side is transposed to the right hand side. Then, the following revenue function of firm i is obtained.

$$r_{it} - \tilde{p}_t = \frac{\sigma-1}{\sigma}\gamma x_{it} + \frac{1}{\sigma}[(r_t - \tilde{p}_t) - m_t] + \frac{\sigma-1}{\sigma}\left[\tilde{\varphi}_{it} + \left(\frac{1}{\sigma-1} - (\gamma-1)\right)m_{it}\right] \qquad (11)$$

In this equation, as Melitz discusses, the term $\frac{1}{\sigma-1} - (\gamma-1)$ should be larger than zero if firms produce more than one product while the positive effects of increasing product varieties for each firm have a trade-off against increasing the sunk cost.

Following Levinsohn and Petrin (2003) (henceforth, LP), we estimate equation (11). LP discusses the issue of potential correlation between inputs and productivity and proposes to use the intermediate input's demand function which is assumed as a monotonic function of productivity[7]. Inverting the monotonic function can uncover the

[7] Olley and Pakes (1995) also propose an approach where the estimation of production

unobserved productivity term as a monotonic function of the intermediate input and capital[8]. To discuss a bias in returns to scale and effects of product differentiation, we examine the models with three different assumptions, (1) products are homogeneous across firms, (2) the average number of products per firm is constant over time, and (3) the numbers of products vary across firms. For assumption 1, the estimated model is equivalent to the LP model. An equation based on assumption 2 is equivalent to the model proposed by Melitz and is described as follows.

$$r_{it} - \tilde{p}_t = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + \beta_e e_{it} + \beta_\sigma \left[\left(r_t - \tilde{p}_t \right) - n_t \right] + \hat{\varphi}\left(k_{it}, e_{it} \right) + u_{it} \qquad (12)$$

where $\hat{\varphi}\left(k_{it}, e_{it}\right) = \dfrac{\sigma - 1}{\sigma} \left\{ \varphi_{it} + \left[\dfrac{1}{\sigma - 1} - \left(\gamma - 1\right) \right] m_{it} \right\}$. On the other hand, the model with assumption 3 is a modified one of equation (12) and is written as follows.

$$r_{it} - \tilde{p}_t = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + \beta_e e_{it} + \beta_\sigma \left[\left(r_t - \tilde{p}_t \right) - m_t \right] + \beta_m m_i + \breve{\varphi}\left(k_{it}, e_{it} \right) + u_{it} \qquad (13)$$

where $\breve{\varphi}\left(k_{it}, e_{it}\right) = \dfrac{\sigma - 1}{\sigma} \varphi_{it}$. An issue which we should discuss is what variable is examined as a proxy of the number of products sold by a firm. In this paper, we use the floor space per shop for each firm under an assumption that firms with similar business models in the retail trade industry follow similar use of space for their commercial establishment[9]. Estimating these three equations, the LP equation, equation (12) and

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function suffers problems due to endogeneity. Unlike LP, they propose to use investment as a proxy of unobserved productivity. It, however, has a significant shortcoming that investment data contain many zeros in conventional firm level data. Dropping many zeros remains the simultaneity problem unsolved.

[8] Souza (2006) details the LP methodology under monopolistic competition.

[9] This assumption seems to be reasonable between firms in the same country.

(13), we examine productivity, returns to scale and product differentiation.

3. Data

In this study, we use firm-level data of the retail trade industry in Japan over the 1995-2004 period. In particular, we focus on firms categorised as the department stores and supermarkets. The data are extracted from the annually compiled official statistics of firms' activities by the Ministry of Economy, Trade and Industry of Japan[10]. This statistics cover many activities of firms and are considered reliable[11]. In addition, we obtain figures on floor space of shops for each firm from the statistical yearbook named as Nikkei Almanac of the Distribution Industry. To construct a proxy of firms' product variety, they are divided by the number of commercial establishments for each firm. From these data source, we construct our own dataset composing of total revenue, labour, capital and intermediate inputs, and floor space per shop for each firm.

In our dataset, total revenue of each firm is represented as total sales. The proxy of accumulated capital is the tangible fixed assets. Labour input is calculated as man-hours[12]. Following Tokui, Inui and Kim (2007) and Kim, Kwon and Fukao (2007), henceforth KKF, the intermediate input is obtained as follows[13]:

$$Intermediate\ Input = COGS + SGA - \left(TW + Dep + T\,\&\,D + Purchase\right), \quad (14)$$

where *COGS*, *SGA*, *TW*, *Dep* and *T&D* are the cost of goods sold, the selling and

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10 This statistics is named as 'the Basic Survey of Business Structure and Activity'.
11 Kiyota and Matsuura (2004)
12 The data of working hours are available from Monthly Labour Survey.
13 In calculation of intermediate input, we slightly modify both Tokui et al. and KKF. The former does neither include tax and dues nor purchase in calculation of the intermediate inputs while the later does not include tax and dues.

general administrative expenses, the total wages, the depreciation and the tax and dues, respectively. In constructing our dataset, we rule out the firms which report zero or negative values as total sales, the number of regular workers, the tangible fixed assets, total wage, or intermediate inputs. Since figures on total revenue, capital and intermediate inputs in the original data source are reported as nominal values, we need to construct real series of those variables using reliable deflators. For total sales and intermediate inputs, JIP industry-specific deflators of output and intermediate input are used[14]. Capital is reported as book values including the land possessed by firms in the data source. We construct real series of capital following KKF. However, we don't subtract the estimated values of the land from the values of the tangible fixed assets because we consider the land is an important factor for production, particularly in retail trade industries.

4. Empirical Results

This section discusses the results of estimation and their implications. But, before that, we should discuss an issue related to the deflators. In our model framework, the industry-specific price index is defined as an average price of products adjusted on their quality. The actually available price index is, however, not exactly identical to that one. It means that our estimation might obtain biased coefficients. In fact, this is a shortcoming not only in our estimation, but also in all empirics using time series data[15]. But we do not think that it significantly harms our empirical analysis. Since equation (3) is essentially the methodology used to construct the industry-specific price indices, our

[14] JIP database is constructed as a joint project of REITI and the Hitotsubashi University global COE program (Hi-Stat), and is available from the following website. http://www.reiti.go.jp/jp/database/JIP2008/index.html

[15] The issues of deflators are also discussed in Kato (2007).

model framework is considered reasonable.

Tables 1 and 2 present the results from estimating the LP, equation (12) (Melitz 1) and (13) (Melitz 2) for both department stores and supermarkets, respectively. The results of the tests if $\gamma = 1$ unless considering a bias, $\frac{\sigma - 1}{\sigma}$, are in the bottom rows. The term "Variety" denotes the number of products. In our estimation, the floor space per shop for each firm is used as a proxy of it. In both tables, the estimated coefficients on the intermediate input are unreliable except for two estimations, Melitz1 and 2 in Table 1 because they are statistically insignificant[16]. Therefore, we do not discuss them. On the other hand, the coefficients on capital are significantly positive, save for the LP in Table 1. It reveals that land should be included in the capital stocks in this estimation[17].

These tables show that the Wald tests do not reject the assumption of constant returns to scale (CRS) in both department stores and supermarkets. Those results are, however, possibly biased because they do not include effects of the elasticity of substitution between products. Therefore, we obtain the degree of bias from the estimated coefficients, and carry out a test of the following null hypothesis.

$$H_0 : \frac{\sigma}{\sigma - 1}\left(\beta_k + \beta_l + \beta_e\right) = 1$$

Since the coefficients on the term, $\left[\left(r_t - \tilde{p}_t\right) - n_t\right]$ are significantly positive while those on $\left[\left(r_t - \tilde{p}_t\right) - m_t\right]$ are negative, we calculate the degree of bias using the former ones.

[16] We examined some slightly different forms of intermediate inputs as well. But none of them is significantly estimated.
[17] We also estimated the production function where capital stock does not include the land, but the estimates were insignificant.

According to the results of it, the *p*-value of the Wald tests on the CRS assumption are 0.005 (department stores) and 0.084 (supermarkets), respectively. That is, the null hypothesis that returns to scale are constant is rejected at the one and ten percent levels. It indicates that the validity of the CRS assumption is significantly controversial in the study of productivity at least in the retail trade industry if products are differentiated.

The estimated coefficient on the variable, Variety, is significantly positive for supermarkets. It reveals that product differentiation has a positive effect on firms' revenue. With quality adjusted productivity, it is positively associated with the estimated total factor productivity (TFP) in conventional approaches. On the other hand, the term, Variety, is insignificantly estimated for department stores. It indicates that department stores and supermarkets follow different business models as is well known[18]. These results indicate that the industrial policy which is helpful for pursuing economies of scale and product differentiation contributes to productivity growth of supermarkets.

Relating to the above issue, we discuss the effects of regulatory reforms on productivity. Among various industrial policies, regulatory reform, in particular deregulation, is usually considered as important instruments to promote a favourable economic environment. In 2000, the Japanese government enacted the Large-Scale Retail Store Location Law in order to liberalise location for large scale retail stores. From the above empirical results, this regulatory reform is expected to have a positive effect on productivity as a whole[19]. To test for the effect, we add a dummy variable which equals zero until 1999 and one after 2000 and re-examine the revenue functions[20].

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[18] Department Stores are thought to provide their differentiated services through various tenants such as high-class boutiques as well as their own service. In this meaning, the number of tenants per commercial establishment is possibly a better proxy although it is not examined because of data absence.

[19] Our data do not include small businesses.

[20] Since our data are relatively small, it is difficult to reasonably detect any pattern in a

The results are presented in Tables 3. In the tables the estimated coefficients on the deregulation dummies are significantly positive at the one percent level. Although this dummy variable contains not only effects of the deregulation but also all the economic environments varying before and after the millennium, the positive estimates still imply that the regulatory reform possibly contributed to improvement of productivity.

The above results indicate that the production function with the monopolistic competitive structure can be a useful instrument for estimating productivity and discussing desirable industrial policies.

5. Concluding Remarks

This paper examines returns to scale, productivity, and product differentiation using the firm-level data of department stores and supermarkets in Japan between 1995 and 2004. Following Melitz, we incorporate a monopolistic competitive structure into the production function, and compare the results from those of a conventional approach. In this study, our findings are as follows. First, the CRS assumption is controversial in empirics of production function of the retail trade industries. In both industries, the alternative assumption that the degree of returns to scale is not equal to unity is not statistically rejected in the bias corrected estimates. It implies that the CRS assumption should be carefully examined in the estimation of productivity since otherwise the estimated productivity might be biased. Secondly, product differentiation seems to give a positive contribution to productivity of supermarkets although it is not detected for department stores. This result suggests that future research should apply this approach to other industries using reliable proxies of product variety because product

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dynamics of their average productivity levels.

differentiation is an important in many other industries as well. Thirdly, the regulatory reform in 2000 seems to promote productivity growth in both forms of large-scale retail traders. These results give a policy implication that the industrial policies which promote economies of scale and product differentiation are favourable for the retail trade industry.

Appendix: Descriptive Statistics of Product Differentiation

	Department		Supermarket
Max	253490.00		141323.00
Min	1245.25		43.15
Ave	21266.55		2406.10
Med	16869.00		1235.39
Std	20768.57		5703.38
Skw	3.95		14.20
Sample	900		1606

The gaps of the floor space per shop between firms are significantly huge for both department stores and supermarkets. For both business models, data are considerably skewed toward the lowest range.

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Table 1: Department Stores

Coefficients	LP	Melitz1	Melitz2
Capital	0.065	0.422***	0.298***
	(0.088)	(0.137)	(0.109)
Labour	0.260***	0.268***	0.258***
	(0.035)	(0.033)	(0.033)
Intermediate	4.38e-24	0.543**	0.374**
	(0.105)	(0.228)	(0.189)
$[(r_t - \tilde{p}_t) - n_t]$		0.601***	
		(0.070)	
$[(r_t - \tilde{p}_t) - m_t]$			-0.246***
			(0.024)
Variety			0.014
			(0.012)
$Wald(P - value)$	0.000	0.434	0.771

Note: ***, **, ** are 1%, 5%, and 10% significance

Standard Errors are in Parentheses

Table 2: Supermarkets

Coefficients	LP	Melitz1	Melitz2
Capital	0.501***	0.733***	0.809***
	(0.181)	(0.201)	(0.234)
Labour	0.289***	0.269***	0.283***
	(0.022)	(0.024)	(0.027)
Intermediate	0.020	0.110	0.161
	(0.122)	(0.152)	(0.232)
$[(r_t - \tilde{p}_t) - n_t]$		0.282***	
		(0.057)	
$[(r_t - \tilde{p}_t) - m_t]$			-0.218***
			(0.080)
Variety			0.017**
			(0.008)
$Wald(P - value)$	0.306	0.624	0.244

Note: ***, **, ** are 1%, 5%, and 10% significance

Standard Errors are in Parentheses

Table 3: Revenue Function with the Deregulation Dummy

Coefficients	Depart	Super
Capital	0.429***	0.691***
	(0.104)	(0.174)
Labour	0.265***	0.274***
	(0.032)	(0.025)
Intermediate	0.557***	7.65e-09
	(0.196)	(0.101)
$\left[\left(r_t - \tilde{p}_t\right) - m_t\right]$	-0.178***	0.097*
	(0.027)	(0.054)
Variety	0.015	0.017**
	(0.010)	(0.007)
Dummy	0.090***	0.060***
	(0.012)	(0.013)
$Wald\left(P - value\right)$	0.298	0.412

Note: ***, **, ** are 1%, 5%, and 10% significance

Standard Errors are in Parentheses