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Articles

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Optimal Income Tax Rates for the Korean Economy†

By YONGSUNG CHANG, SUN-BIN KIM, BO HYUN CHANG*

Based on a quantitative, heterogeneous agent general equilibrium model, we compute the optimal tax rates for labor and capital incomes for the Korean economy. According to our model, a more progressive income tax schedule along with a higher capital tax rate can increase average welfare by as much as 0.86% of permanent consumption. Approximately 64% of house-holds, those with low assets and low productivity, are better off when a more progressive optimal tax schedule is adopted. Despite the potentially significant welfare gains, our calculation should be interpreted with caution because our benchmark model does not take into account possible capital outflows or the increased administrative costs associated with high taxes.

Key Word: Inequality, Korean Economy, Optimal Income Taxes, Progressivity Capital Tax
JEL Code: E25, E62, H21

I. Introduction

Among OECD members, Korea is considered a "low-inequality and low-redistribution" country. Figure 1 plots the before- and after-tax/transfer income Gini coefficients for 31 OECD countries. All 31 countries are located below the 45-degree line, indicating that in all countries incomes are redistributed from the rich to the poor. In terms of before-tax/transfer incomes, the Gini coefficient of Korea is the lowest (0.34) among the OECD members, whose average is 0.47. In terms of after-tax/transfer incomes, the Gini coefficient of Korea is about the average of the OECD countries (0.31). In terms of percentage changes in the income Gini—the so-called improvement rate of income inequality after taxes and transfer Korea exhibits only a 9% decrease, whereas the average decrease in Gini coefficients among the OECD countries is 35%.

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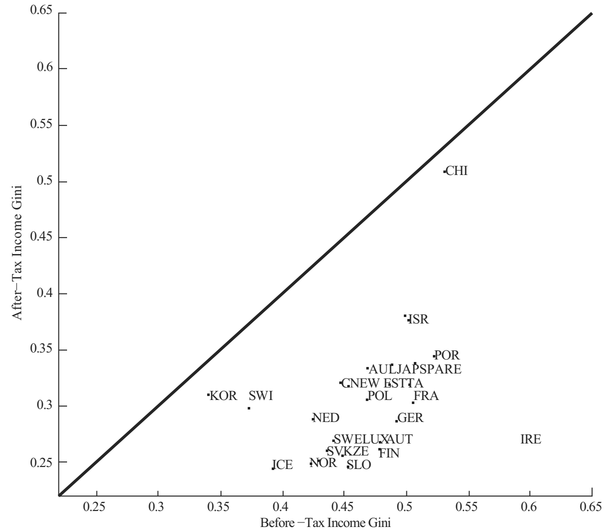

FIGURE 1. BEFORE-TAX AND AFTER-TAX INCOME INEQUALITY

While finding the right degree of income redistribution has always been a primary concern for economists and policy makers, it is not an easy task, since it requires modeling a complicated political process and aggregating individual preferences. A recent development of quantitative general equilibrium models with heterogeneous agents allows us to address this issue at least partially. In this paper, we compute the optimal income tax rates for labor and capital for the Korean economy. We ask the following two questions: (i) What is the labor and capital income tax rates that maximize the average utilitarian welfare of the society? (ii) Who will be better off or worse off from the fiscal reform that adopts the tax rate that maximizes average welfare?

We examine these questions through the lens of the Aiyagari model (1994) augmented with endogenous labor supply (e.g., Pijoan-Mas (2006) and Chang and Kim (2007)). In this model, workers are identical in preferences, but face uninsurable productivity shocks and borrowing constraints. Earnings and wealth distributions emerge as an equilibrium. In the model economy, we introduce three major taxes: total income tax, capital tax, and consumption tax.

Households are liable to a progressive income tax schedule. More specifically, we adopt a parametric net tax function developed by Heathcote, Storesletten, and Violante (2013) (referred to as HSV hereafter) to capture the progressive tax schedule in a simple way. In addition, we allow a separate capital income tax to distinguish the labor and capital income taxes. The consumption tax rate in our model is fixed at the current value-added tax (VAT) rate of 10%.

We calibrate the model economy to match several salient features of the Korean economy. For example, the stochastic process of individual productivity is estimated from the panel data of wages in the Korea Labor Income Panel Study (KLIPS). The cross-sectional income and wealth distributions of the model are somewhat less dispersed than but largely comparable to those in the data.

We then look for the optimal degree of progressivity in the income tax schedule and capital tax rate that maximizes the (equal-weight) utilitarian social welfare function. According to our model, the optimal tax policy requires a more progressive income tax schedule and a higher capital income tax rate than the current one. For example, the marginal tax rate for the household in the 9th decile (top 10%) in the income distribution has to increase from the current 22% to 31%. The average net income tax rate has to fall from the current 3.75% to -0.9%.

When the optimal tax reform is in place, the average welfare of households increases by as much as 0.86% of steady-state consumption, which is approximately 300 thousand won (in 2010 value) each year. About 64% of households will be better off from this optimal tax reform. Households with low assets and low productivity win, but households with high assets or high productivity will lose from the optimal tax reform. Across consumption deciles, households in the 1st consumption decile gain welfare by as much as 3.4% of their permanent consumption (709 thousand won annually). Households in the 9th decile lose welfare by as much as 3.4% of their permanent consumption (1,656 thousand won annually).

Despite a potentially large welfare gain from tax reforms, our results should be interpreted with caution because our benchmark model does not take into account the possible capital outflow or the increased administrative costs associated with high income taxes. Indeed an open-economy version of our model indicates that there will be a significant capital flight from high capital income tax rates. A sizable administrative cost due to bureaucracy would also undermine the potential welfare gain from high taxes.

Our results are closely related to those in the existing literature. Aiyagari and McGrattan (1998) developed a heterogeneous agents model with incomplete markets and analyzed the optimal debt policy under the utilitarian social welfare functions. However, while the income tax schedule is linear in their model, we allow for progressive income taxes. HSV (2014) provided a tractable model of optimal tax progressivity. The endogenous labor supply and skill accumulation limits high progressivity—the optimal rate in their model is lower than the current progressivity. Our model embodies capital tax rates and consumption tax rates as well as income tax and focuses on the optimal tax rate for the Korean economy. Our results imply that the optimal tax rate in Korea is much higher and more progressive than the current tax schedule. Chang *et al.* (2015) computed the optimal income tax rate for each of the 31 OECD countries, including Korea.[1] Under the linear income tax and lump-sum transfer, Chang *et al.* found that the optimal income tax rate in Korea is 32%, much higher than the current tax to GDP ratio of 23%. In this paper, we extend the model in Chang *et al.* to incorporate a progressive income tax schedule as well as separate capital and consumption taxes. To our knowledge, this is the first estimate to find the optimal progressivity for the Korean economy based on a quantitative heterogeneous agents general equilibrium model.

The remainder of the paper is organized as follows. Section II documents key statistics about the tax and redistribution policies of Korea and other OECD countries. Section III lays out the benchmark model economy and calibrates to Korean data. In Section IV, we compute the optimal tax reform under the utilitarian social welfare function and examine who will be better off from the optimal tax

[1]We also uncovered the Pareto weights that justify the observed tax rate for each country.

reform. Section V concludes.

II. Data

A. *Tax and Redistribution Policies*

We document some stylized facts about tax and redistribution policies in Korea and the OECD countries. Table 1 summarizes the tax-to-GDP ratios, Gini coefficients, and per capita GDP of 34 OECD countries. The total tax revenue to GDP ratio of Korea is 23%, the third lowest among the OECD countries, whose average is 33%. The second and third columns of Table 1 report the before- and after-tax/transfer income Gini coefficients. (The before-tax income Gini is not available for Turkey, Mexico, and Hungary.) Korea shows the lowest before-tax income Gini (0.34). But, Korea's after-tax income Gini (0.31) is close to the

TABLE 1—KEY STATISTICS FOR THE 34 OECD COUNTRIES, 2010

	Tax/Y (%)	Before Gini	After Gini	Improvement (%)	Wealth Gini	per capita GDP ($)
Australia	25.6	0.469	0.334	28.8	0.636	57,535
Austria	40.9	0.479	0.267	44.3	0.693	45,171
Belgium	42.4	0.478	0.262	45.2	0.655	43,292
Canada	30.5	0.447	0.320	28.4	0.728	47,297
Chile	19.5	0.531	0.508	4.3	0.774	12,727
Czech Republic	32.5	0.449	0.256	43.0	0.743	18,873
Denmark	46.5	0.429	0.252	41.3	0.701	56,428
Estonia	33.2	0.487	0.319	34.5	0.660	14,212
Finland	40.8	0.479	0.260	45.7	0.662	44,134
France	41.6	0.505	0.303	40.0	0.755	39,596
Germany	35.0	0.492	0.286	41.9	0.777	40,418
Greece	31.1	0.522	0.337	35.4	0.714	26,379
Hungary	37.6	...	0.272	...	0.641	12,750
Iceland	33.3	0.393	0.244	37.9	0.663	39,511
Ireland	26.8	0.591	0.266	55.0	0.727	45,921
Israel	30.6	0.501	0.376	25.0	0.783	30,396
Italy	41.5	0.503	0.319	36.6	0.646	33,982
Japan	27.6	0.488	0.336	31.1	0.596	42,918
Korea	23.2	0.341	0.310	9.1	0.726	20,540
Luxembourg	38.0	0.464	0.270	41.8	0.623	102,568
Mexico	18.5	...	0.466	...	0.780	9,189
Netherlands	36.1	0.424	0.288	32.1	0.812	46,783
New Zealand	31.0	0.454	0.317	30.2	0.725	32,757
Norway	42.6	0.423	0.249	41.1	0.779	86,101
Poland	31.3	0.468	0.305	34.8	0.753	12,198
Portugal	30.0	0.522	0.344	34.1	0.725	21,512
Slovak Republic	27.7	0.437	0.261	40.3	0.621	16,073
Slovenia	36.7	0.453	0.246	45.7	0.639	22,938
Spain	31.4	0.507	0.338	33.3	0.662	30,058
Sweden	43.1	0.441	0.269	39.0	0.806	49,375
Switzerland	26.5	0.372	0.298	18.7	0.806	70,523
Turkey	26.2	...	0.409	...	0.842	10,015
United Kingdom	32.8	0.523	0.345	34.8	0.675	36,869
United States	23.7	0.499	0.380	23.8	0.852	48,287
Average	32.8	0.470	0.312	34.8	0.717	37,275
Std. Dev.	7.1	0.050	0.061	10.5	0.069	21,270

Source: Wealth Ginis are obtained from Credit Suisse (2012) and others are from the OECD (2015).

TABLE 2— CORRELATIONS FOR THE 34 OECD COUNTRIES IN 2010

	Before Gini	After Gini	∆ Gini (%)	Tax/Y (%)	Wealth Gini
Before Gini	1.00	0.41	0.26	-0.09	-0.08
After Gini	0.41	1.00	-0.76	-0.70	0.37
∆ Gini (%)	0.26	-0.76	1.00	0.66	-0.33
Tax/Y (%)	-0.09	-0.70	0.66	1.00	-0.24
Wealth Gini	-0.08	0.37	-0.33	-0.24	1.00

Source: Authors' calculations with data from the OECD (2015) and Credit Suisse (2012).

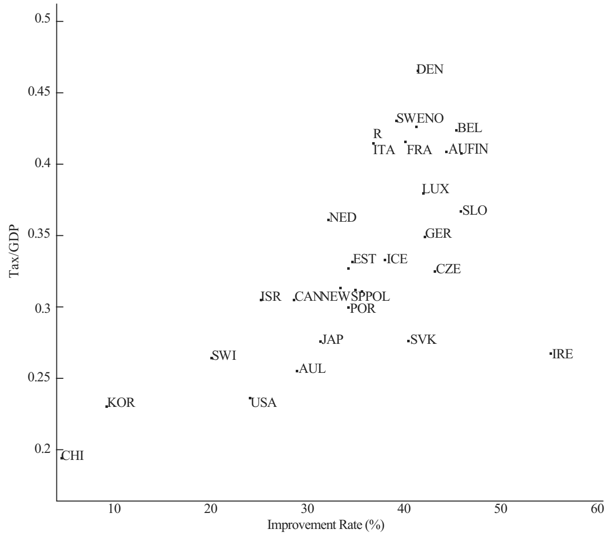

FIGURE 2. TAX/GDP AND IMPROVEMENT RATE

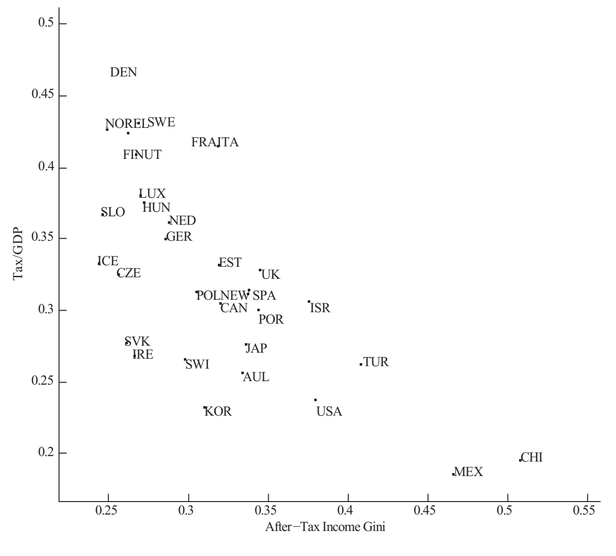

FIGURE 3. TAX/GDP AND AFTER-TAX INCOME INEQUALITY

OECD average. The before-tax income Gini ranges from 0.37 (Switzerland) to 0.59 (Ireland), and the after-tax income Gini from 0.24 (Iceland) to 0.51 (Chile). The fourth column represents the percentage decrease from the before-tax income Gini to after-tax/transfer income Gini coefficients (a measure of the degree of redistribution). In Korea, taxes and transfers reduce income inequality by only 9%, whereas they reduce income inequality by 35% on average among 31 OECD countries. Only Chile (4%) shows a smaller decrease than Korea. These facts imply that Korean currently adopts a "low tax and low transfer policy."

Two income Ginis are, however, modestly correlated with the correlation coefficient of 0.4, indicating varying degrees of redistribution policies across countries. Tax revenues are closely related to redistributions and after-tax income Ginis. As Figure 2 illustrates, the improvement rates of income Ginis are fairly strongly correlated with the tax to GDP ratios (correlation coefficient of 0.65). This is confirmed by Figure 3, which shows a strong negative correlation, -0.70, between the tax to GDP ratio and the after-tax income Gini. Broadly speaking, high taxes are likely to be used for income redistribution purposes and to make incomes more equal.

B. *Tax Structures*

Korea's tax system consists of ten national and eleven local taxes (MOSF 2012). As described in Table 3, national taxes are classified into internal taxes, customs duties, and three earmarked taxes. Local taxes are classified into province taxes and city-county taxes. Table 4 reports the tax revenues (relative to national GDP) of each item. The total tax revenue, including social security contributions, was 23.2% of GDP in 2010 (OECD). Most of the tax revenue comes from individual income taxes (3.3% of GDP), corporate income taxes (3.2%), social security contributions (5.3%), and the value-added tax (4.1%). More detailed information about the major taxes (income taxes, corporation income taxes, and the value-added tax) and social insurance is provided in Appendix A.

Table 5 compares the Korean tax revenue structure to those of the OECD countries. Korea's total tax revenue (23.2% of GDP) is much smaller than that of other OECD countries (average 32.8%). Only Chile (19.5%) and Mexico (18.5%) show lower tax revenues than Korea. The major tax items are similar across OECD countries; individual income taxes, corporate income taxes, social security contributions and taxes on goods and services. The low tax revenues relative to GDP in Korea are mainly due to the low individual income taxes and social security contributions in Korea. The revenues from individual income taxes and social security contributions are 3.3% and 5.3% of GDP, respectively, in Korea. Corresponding figures for the OECD on average are 8.2% and 8.9%, respectively. Also, taxes on goods and services (7.9% of GDP), including value-added tax revenues, are slightly lower than the OECD average (10.7%). The tax revenue from corporate income (3.2% of GDP) is slightly higher than the OECD average (2.8%).

TABLE 3—NATIONAL AND LOCAL TAXES IN KOREA

National Taxes		
	Internal Taxes	
		Individual Income Tax
		Corporate Income Tax
		Gift Tax
		Comprehensive Real Estate Holding Tax
		Value-Added Tax
		Individual Consumption Tax
		Liquor Tax
		Stamp Tax
		Securities Transaction Tax
	Customs Duties	
	Earmarked Taxes	
		Transportation-Energy-Environment Tax
		Education Tax
		Special Tax for Rural Development
Local Taxes		
	Province Taxes	
		Acquisition Tax
		Registration and License Tax
		Leisure Tax
		Local Consumption Tax
		Community Resource and Facility Tax
		Local Education Tax
	City & County Taxes	
		Inhabitant Tax
		Property Tax
		Automobile Tax
		Local Income Tax
		Tobacco Consumption Tax

Source: Ministry of Strategy and Finance (2012).

TABLE 4—TAX REVENUE STRUCTURE IN KOREA, 2010

Tax Items	Revenue (% of GDP)
Total tax revenue	23.2
Taxes on income, profits and capital gains	6.6
Of individuals	3.3
On income and profits	2.7
On capital gains	0.6
Corporate	3.2
Social security contributions	5.3
Employees	2.2
Employers	2.3
Self-employed or non-employed	0.8
Taxes on payroll and workforce	0.1
Taxes on property	2.6
Recurrent taxes on immovable property	0.7
Estate, inheritance and gift taxes	0.2
Taxes on financial and capital transactions	1.7
Taxes on goods and services	7.9
Taxes on production, sale, transfer, etc.	7.6
General taxes (Value added taxes)	4.1
Taxes on specific goods and services	3.5
Taxes on use of goods and perform activities (License tax, automobile tax)	0.3
Other taxes	0.8

Source: OECD database (2015).

TABLE 5— TAX REVENUES OF THE OECD COUNTRIES, 2010

Countries	Total	Individual Income	Corporate Income	Security Cont'n	Payroll	Property	Goods
Australia	25.6	9.8	4.7	0.0	1.3	2.4	7.4
Austria	40.9	9.2	1.9	14.1	2.8	0.5	11.5
Belgium	42.4	12.0	2.6	13.7	0.0	3.1	10.7
Canada	30.5	10.7	3.2	4.7	0.6	3.5	7.5
Chile	19.5	-	-	1.3	0.0	0.7	10.0
Czech Republic	32.5	3.3	3.2	14.6	0.0	0.4	10.8
Denmark	46.5	23.7	2.7	1.0	0.2	1.9	14.8
Estonia	33.2	5.3	1.3	12.8	0.0	0.3	13.3
Finland	40.8	12.1	2.4	12.1	0.0	1.1	13.0
France	41.6	7.0	2.1	16.1	1.3	3.5	10.5
Germany	35.0	8.5	1.5	13.7	0.0	0.8	10.3
Greece	31.1	4.4	2.4	10.9	0.0	1.0	12.1
Hungary	37.6	6.4	1.2	11.8	0.6	1.2	16.0
Iceland	33.3	12.2	0.9	3.9	0.2	2.3	11.7
Ireland	26.8	8.2	2.4	4.3	0.2	1.6	9.9
Israel	30.6	5.6	2.6	5.2	1.2	2.9	12.2
Italy	41.5	11.3	2.7	13.0	0.0	2.0	10.8
Japan	27.6	5.1	3.2	11.3	0.0	2.7	5.2
Korea	23.2	3.3	3.2	5.3	0.1	2.6	7.9
Luxembourg	38.0	8.0	5.9	11.0	0.0	2.7	10.3
Mexico	18.5	-	-	2.8	0.3	0.3	9.7
Netherlands	36.1	8.0	2.0	13.2	0.0	1.4	11.1
New Zealand	31.0	11.7	3.8	0.0	0.0	2.1	12.3
Norway	42.6	10.1	10.0	9.6	0.0	1.2	11.8
Poland	31.3	4.4	2.0	10.9	0.3	1.2	12.3
Portugal	30.0	5.4	2.7	8.7	0.0	1.1	11.8
Slovak Republic	27.7	2.3	2.5	12.0	0.0	0.4	10.1
Slovenia	36.7	5.6	1.8	14.9	0.1	0.6	13.6
Spain	31.4	6.8	1.7	11.8	0.0	2.0	8.4
Sweden	43.1	12.0	3.3	10.8	3.1	1.0	12.7
Switzerland	26.5	8.5	2.7	6.3	0.0	2.0	6.0
Turkey	26.2	3.7	1.9	6.5	0.0	1.1	12.5
United Kingdom	32.8	9.4	2.9	6.2	0.0	4.0	10.1
United States	23.7	7.9	2.3	6.1	0.0	3.1	4.3
Average	32.8	8.2	2.8	8.9	0.4	1.7	10.7

Source: OECD database (2015).

C. *Taxes in the Household Income and Expenditure Survey*

We now examine the detailed tax burdens across households in Korea. According to the Household Income and Expenditure Survey (HIES), the average household in Korea paid 3.5% of its factor income (total income minus public/private transfers) as taxes and 5.6% of their factor incomes as social security contributions in 2010.

Table 6 reports the taxes and social security contributions across various income deciles. The ratio of taxes and contributions to factor income increases gradually, from 7.4% in the third decile of income distribution to 11.2% in the tenth decile, reflecting the progressivity of taxes. (The increase is not uniform owing to differences in household compositions and received transfers.) Even in the tenth decile, the average tax rate is quite low, despite the top statutory income tax rate (41.8%) and social security contribution (4.5% for pensions and 3.035% for health

TABLE 6—HOUSEHOLD INCOME AND TAXES, 2010

Deciles	Factor Income (₩)	Head Age	Household Size	Tax (%)	Tax + Pension (%)	Total Burden (%) Incl. health insur.
Avg.	3,308,404	48.5	3.3	3.5	6.4	9.1
1st	471,064	59.9	2.4	3.7	5.7	12.4
2nd	1,196,617	53.2	2.8	2.2	4.1	7.6
3rd	1,810,447	48.2	3.1	1.8	4.3	7.4
4th	2,376,085	46.9	3.3	2.1	4.7	7.6
5th	2,765,257	46.1	3.4	2.0	4.8	7.8
6th	3,203,106	45.6	3.5	2.2	5.0	7.5
7th	3,779,627	45.4	3.6	2.5	5.6	7.9
8th	4,363,141	46.2	3.6	3.2	6.3	8.7
9th	5,273,345	46.5	3.6	4.0	7.1	9.5
10th	7,833,813	47.1	3.7	6.0	8.9	11.2

Notes: Factor Income = Labor + Business + Capital Income = Total Income − Transfer (public/private)
Total Burden = (Tax + Pension Contribution + Health Insurance)/Factor Income

Source: Household Income and Expenditure Survey.

TABLE 7—EQUIVALIZED HOUSEHOLD INCOMES ACROSS DECILES, 2010

Decile points	Market Income (₩)	Disposable Income (₩)	Net Tax rate (%)
Avg.	1,796,169	1,728,745	0.0375
1st	488,448	620,458	-0.270
2nd	882,314	929,720	-0.053
3rd	1,168,217	1,162,682	0.005
4th	1,415,337	1,376,870	0.027
5th	1,625,759	1,569,030	0.035
6th	1,867,261	1,788,347	0.042
7th	2,160,059	2,045,944	0.053
8th	2,552,677	2,388,744	0.064
9th	3,201,613	2,978,920	0.070

Notes: All incomes are equivalized: divided by the square root of household size.

Source: Household Income and Expenditure Survey.

insurance).[2] This may reflect the fact that various deductions lower the effective tax rate considerably, even for those in the high-income brackets. Surprisingly, while the taxes and contributions paid by households in the first decile (the poorest 10%) are the lowest, their taxes with regard to factor incomes are very high (12.4%). One reason is that in the first decile, the average household size (2.4) is much smaller than the population average (3.3); moreover, the average age of household head (59.9) is much older than the population average (48.5). Because many tax deductions are child related, the tax burden on households without young children would be much greater than the population average. To avoid this issue, we next consider tax rates based on household-size equivalent units.

Table 7 reports the market income, disposable income, and the net tax rate ($1-\frac{disposable\ income}{market\ income}$) based on the equivalized scale (income divided by the square root of the household size) across income deciles.[3] The net tax rate of households

[2]Social security contributions including pension and health insurance are proportional to household income.
[3]In many studies on income inequality, household incomes are often adjusted by household size. For example,

TABLE 8—GINI COEFFICIENTS OF INCOMES, 2010

	2009	2010	2011	2012	2013
Before taxes/transfer	0.345	0.341	0.342	0.338	0.336
After taxes/transfer	0.314	0.310	0.311	0.307	0.302
Percentage Decrease (%)	8.990	9.090	9.060	9.170	10.120

Source: Household Income and Expenditure Survey.

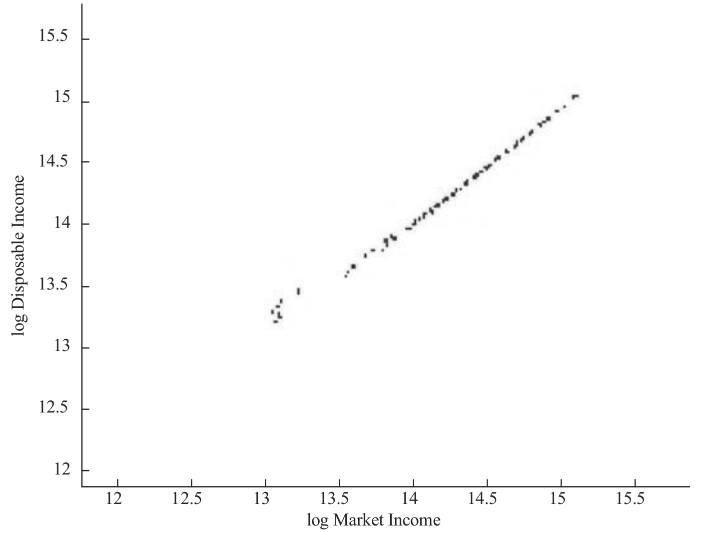

FIGURE 4. MARKET AND DISPOSABLE INCOME

Notes: Data points are from the equivalized income deciles for 2006 to 2013 (HIES).

in the first income decile is now much lower (-27%) than those in other deciles, implying that these households received 27% of their market income as a net transfer in 2010. HIES also reports the Gini coefficients before taxes and transfers (shown in Table 8). Taxes and social transfers reduced the income Gini by approximately 9%-10% in the years 2009-2013.

Summarizing the progressivity of taxes is not simple owing to the complexity of the income tax schedule and various deductions. One practical way is to assume a specific parametric form of tax function with a few parameters. We assume that the individual income tax schedule follows the HSV (2014) type (referred to as the HSV tax function hereafter):

$$\text{Tax} \quad T(y_i) = y_i - \lambda y_i^{1-\tau}$$

$$\text{Disposable income} \quad D(y_i) = \lambda y_i^{1-\tau}$$

$$\log D(y_i) = \log \lambda + (1-\tau) \log y_i$$

both the OECD and Statistics Korea use the square root of the household size as an equivalence measure.

TABLE 9—OLS ESTIMATES FOR THE HSV TAX FUNCTION

	Log(λ)	1 - τ	τ	R^2
Coefficient	1.9418	0.8629	0.1371	0.9942
S. D.	0.1118	0.0079	-	

Source: Household Income and Expenditure Survey.

TABLE 10—TAX RATES: DATA AND ESTIMATION

(UNIT: 10,000 WON/MONTH, %)

Income Decile	1st	2nd	4th	6th	8th	9th
Data (HIES)						
Market income	47	68	142	187	255	320
Net tax rate	-27.02	-5.37	2.72	4.23	6.42	6.96
Estimated HSV						
Net tax rate	-15.71	-6.70	-0.01	3.72	7.76	10.58
Marginal tax rate	0.15	7.93	13.7	16.92	20.41	22.84

Notes: Based on decile points of the equivalized income distribution for 2010. The marginal tax rates are based on the estimated HSV tax function.

In the HSV tax function, two parameters, λ and τ, characterize disposal income, D(y_i), as a function of the household's market income y_i.[4]

We estimate τ and λ based on cross-sectional data. Because tax and transfer data at the individual household level are not available, we use the reported data across income deciles for 2006-2013 as our data points by assuming that the parameters are constant during the sample period. Figure 4 plots the market and disposable incomes at each decile point from 2006 to 2013.[5] Note that both market income and disposable income are equivalized by household size; income is divided by the square root of the household size. The log of disposable income ($log\,D(y_i)$) and the log of market income ($log\,y_i$) appear to be nearly linear, implying that the HSV tax function captures the progressivity of taxes and transfers in the data quite well. Table 9 reports the estimation results after regressing $log\,D(y_i)$ on $log\,y_i$.

Based on this estimated HSV tax function, we can now compute the net tax rates and marginal tax rates across household incomes. Table 10 compares the actual net tax rates in the HIES and those based on the estimated HSV tax function. The estimated tax rates fit relatively well for middle-income families. The net tax rates in the second, fourth, sixth, and eighth deciles are respectively -5.4%, 2.7%, 4.2%, and 6.4% in the HIES. The corresponding rates based on the estimated HSV tax function are -6.7%, 0.0%, 3.7%, and 7.8%. One of the shortcomings of the HSV tax function is its poor approximation at the low-income level. The net tax rate in the first decile in the HIES is -27.0%, whereas the corresponding rate according to the estimated HSV function is -15.7 %.

[4]Disposable income is defined as market income (y_i) minus taxes and contributions plus public trans fer income.

[5]The Statistics Agency of Korea announces equivalized market and disposable incomes for the average of each quintile, and at each decile point from the 1st to the 9th.

III. Model

Our benchmark economy extends Aiyagari's (1994) model to endogenous labor supply and introduces three taxes: progressive income tax, capital tax, and consumption tax.

Households: There is a continuum (measure one) of worker-households who have identical preferences and face an idiosyncratic productivity shock x, which evolves over time according to a Markov process with a transition probability distribution function $\pi_x(x' \mid x) = Pr(x_{t+1} \leq x' \mid x_t = x)$. When a household with labor productivity x_t chooses to work for h_t hours, its labor income is $w_t x_t h_t$, where w_t is the wage rate for the efficiency unit of labor. Households hold assets a_t that yield the real rate r_t. Both labor and capital incomes are liable to progressive taxes of the HSV tax function ($y - \lambda(y)^{(1-\tau)}$). Note that the HSV tax functions include transfers as well as taxes. Households are also liable to a consumption tax at the rate τ_c. A household maximizes its lifetime utility:

$$\max_{\{c_t, h_t\}_{t=0}^{\infty}} \mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t \{\frac{c_t^{1-\sigma} - 1}{1-\sigma} - B \frac{h_t^{1+1/\gamma}}{1+1/\gamma}\},$$

subject to

$$(1+\tau_c)c_t = \lambda(w_t x_t h_t + (1-\tau_k) r_t a_t)^{1-\tau} + a_t - a_{t+1}$$

$$a_{t+1} \geq \underline{a}$$

where c_t is consumption. Parameters σ and γ represent relative risk aversion and labor-supply elasticity, respectively. Capital markets are incomplete in the sense that physical capital is the only available asset for households to insure against idiosyncratic shocks to their productivity, and households face a borrowing constraint: $a_t \geq \underline{a}$ for all t.

In our model, households that own assets pay capital taxes at the rate τ_k separately. These capital taxes are intended to capture corporate income taxes in the data. While the corporate income tax is levied on firms' profit, in our model firms operate in a competitive market yielding zero profits. A perfectly competitive goods market is assumed to avoid a complicated market structure on the production side (see below). Since the assets held by households in our model are the claims on production capital, we interpret the taxes on capital income in our model as a proxy for taxes on stockholders' incomes in the data. Thus, in our model, individual income taxes (HSV tax function) are levied on household capital incomes $(w_t x_t h_t + (1-\tau_k) r_t a_t)$ after paying corporate income taxes. Finally, households differ *ex post* with respect to their productivity x_t and asset holdings a_t, whose cross-sectional joint distribution is characterized by the probability measure $\mu_t(a_t, x_t)$.

Firms: The representative firm produces output through a constant-returns-to-scale Cobb-Douglas technology using capital, K_t, and effective units of labor, $L_t = \int h_t x_t d\mu$. Firms invest I_t and capital depreciates at the rate δ each period:

$$\max_{L_t, K_t} L_t^{\alpha} K_t^{1-\alpha} - w_t L_t - (r_t + \delta) K_t$$

subject to

$$K_{t+1} = (1-\delta)K_t + I_t$$

Government: Using total tax revenue collected from three types of taxes, the government consumes the goods G and transfers the rest of the revenue to households as a lump-sum transfer. The government also balances its budget every period:

$$\int \{\tau_c c_t + T(y_t) + \tau_k r_t a_t\} d\mu(a_t, x_t, e) = G$$

where $T(y_t) = w_t x_t h_t + (1-\tau_k) r_t a_t - \lambda(w_t x_t h_t + (1-\tau_k) r_t a_t)^{1-\tau}$

Recursive Representation: It is useful to consider a recursive equilibrium. Let $V(a,x)$ denote the value function of a household with asset holdings a and productivity x. Then V can be expressed as follows:

$$V(a,x) = \max_{c,h} \left\{ \frac{c^{1-\sigma} - 1}{1-\sigma} - B \frac{h^{1+1/\gamma}}{1+1/\gamma} + \beta \mathrm{E}[V(a', x') \mid x] \right\}$$

subject to

$$(1+\tau_c)c = \lambda(wxh + (1-\tau_k) ra)^{1-\tau} + a - a'$$
$$a' \geq \underline{a}$$

Equilibrium: A stationary equilibrium consists of a value function, $V(a,x)$; a set of decision rules for consumption, asset holdings, and labor supply, $c(a,x)$, $a'(a,x)$, $h(a,x)$; aggregate inputs, K, L; and the invariant distribution of households, $\mu(a,x)$, such that:

1. Individual households optimize: Given w and r, the individual decision rules $c(a,x)$, $a'(a,x)$, $h(a,x)$ and $V(a,x)$ solve the Bellman equation.

2. The representative firm maximizes profits:

$$w = \alpha(K/L)^{1-\alpha}$$
$$r + \delta = (1-\alpha)(K/L)^{-\alpha}$$

3. The goods market clears:

$$\int\{a'(a,x)+c(a,x)\}d\mu+G=F(L,K)+(1-\delta)K$$

4. The factor markets clear:

$$L=\int xh(a,x)d\mu$$

$$K=\int ad\mu$$

5. The government balances the budget:

$$\int\{wxh+(1-\tau_k)ra-\lambda(wxh+(1-\tau_k)ra)^{1-\tau}+\tau_k ra+\tau_c c\}d\mu=G$$

6. Individual and aggregate behaviors are consistent:
For all $A^0\subset\mathcal{A}$ and $X^0\subset\mathcal{X}$,

$$\mu(A^0,X^0)=\int_{A^0,X^0}\left\{\int_{\mathcal{A},\mathcal{X}}1_{a'=a'(a,x)}d\pi_x(x'\mid x)d\mu\right\}da'dx'$$

IV. Quantitative Analysis

A. *Calibration*

The time unit is one year. Workers are not allowed to borrow; $\underline{a}=0$. The labor income share α is 0.64, and the annual depreciation rate of capital δ is 10%. The labor-supply elasticity γ is set to 1. The risk-aversion parameter σ, 1.4, is obtained from Chang *et al.* (2015). The discount factor $\beta=0.939$ is set so that the real interest rate is 6%[6] The disutility for labor $B=6.126$ is chosen to match average working hours, 0.398.[7] The stochastic process for the idiosyncratic productivity shock is assumed to be an AR(1): $x_t=\rho_x x_{t-1}+\varepsilon_t$ where $\varepsilon_t\in N(0,\sigma_x)$. We use the values in Chang and Kim (2008), who estimated them from the panel data of individual wages in the KLIPS data. The estimates are ρ_x=0.8 and σ_x=0.354.

The consumption tax rate, τ_c, is set to the current VAT rate of 10%. The consumption tax revenue in our model is 6.5% of GDP, which is somewhat smaller than the tax revenue on goods and services, 7.9% of GDP in the data (OECD 2010). The capital tax rate τ_k, is set to 24%, so that the capital tax revenue (relative to output) in the model is the same as tax revenue on corporate income in the data (3.2% of GDP). The parameter for the tax progressivity $\tau=0.14$ is

[6]According to the Bank of Korea, average yields of Treasury bonds (3-year), corporate bonds (3-year, AA-), and corporate bonds (3-year, BBB-) between 2000 and 2010 are 5.07%, 6.01%, and 9.93%, respectively. The average inflation rate between 2000 and 2010 is 3.12% (BOK).

[7]Average annual working hours, 2187, from the OECD (2010) are divided by 5,500 hours, which is assumed to be the total amount of discretionary time.

TABLE 11—CALIBRATION

Parameters	Values	Description
(Preference)		
α	0.64	Labor income share
β	0.939	Discount factor (to match r = 6%)
γ	1	Frisch elasticity
B	6.126	Disutility parameter for working (to match h = 0.398)
σ	1.4	Risk-aversion parameter (from Chang *et al*. (2015))
$\underline{a}$	0	Borrowing constraint: no borrowing
(Income process)		
ρ_x	0.800	Persistence of idiosyncratic shock (from Chang and Kim (2008))
σ_x	0.354	Standard deviation of innovation (from Chang and Kim (2008))
(Taxes and Expenditures)		
τ	0.137	Tax progressivity
τ_c	0.100	Consumption tax rate (value-added tax rate = 10%)
τ_k	0.237	Capital tax rate (to match corporation tax revenue = 3.2%)
λ	0.899	Average level of taxation (to match net income tax rate = 3.75 %)
G	0.125	Government consumption/Output

obtained from our estimate based on the HIES. The parameter for the average level of taxation $\lambda = 0.90$ is chosen so that the average net income tax rate in our model is the same as that in the HIES (3.75%). Government consumption, G, is determined by the balanced budget. The government consumption to GDP ratio in our model (12.5%) is slightly smaller that that in the data (13.5% according to the National Income Account 2010).

B. *Steady State*

The before- and after-tax/transfer income Gini coefficients are 0.341 and 0.310, respectively, in the HIES (2010) and 0.390 and 0.357, respectively, according to the Survey of Household Finance and Living Conditions (SHFLC 2011).[8] The income Gini coefficients in our model (0.366 and 0.318, respectively, for before and after tax) fall between those from the HIES and the SHFLC. Table 12 compares the income and wealth shares across quintile groups of the income distribution between the model and the data. The top 20% (the 5th quintile) of households earn 37.3% and 46.4% of total disposable incomes in the HIES and the SHFLC, respectively. The corresponding number in our model is 40.2%. The HIES reports that households in the 1st, 2nd, 3rd, and 4th quintiles earn 6.6%, 13.6%, 18.4%, and 24.0% of total disposable income. The corresponding shares are 3.8%, 9.7%, 16.0%, and 24.2% in the SHFLC. Those in our model are 8.1%, 12.4%, 16.6%, and 22.7%.

The wealth Gini coefficient for Korea is 0.628 according to the SHFLC (2010), whereas it is 0.545 in our model.[9] Table 12 also reports the quintile groups of the

[8]The SHFLC has reported income Gini coefficients before and after tax since 2011.
[9]The HIES does not report information on individual assets.

TABLE 12— INCOME AND WEALTH SHARES

	Quintiles					
	1st	2nd	3rd	4th	5th	Total
Disposable Income						
- HIES	6.6	13.6	18.4	24	37.3	100
- SHFLC	3.8	9.7	16.0	24.2	46.4	100
- Model	8.1	12.4	16.6	22.7	40.2	100
Wealth						
- SHFLC	0.4	4.7	10.6	20.4	64.0	100
- Model	0.7	5.4	13.4	25.7	54.8	100

Source: Household Income and Expenditure Survey (HIES 2010), Survey of Household Finance and Living Conditions (SHFLC 2010).

TABLE 13—STEADY STATE

Variables	Data	Model
Before-tax Gini (BG)	0.340	0.366
After-tax Gini (AG)	0.310	0.318
Improvement Rate (1-AG/BG)	0.091	0.132
Wealth Gini	0.628	0.545
Interest Rate (r)	-	0.060
Wage Rate (w)	-	1.01
Labor Hours (H)	0.398	0.398
Aggregate Output (Y)	-	0.670
Aggregate Capital (K)	-	1.508
Net Tax Rate	0.038	0.038
Consumption Tax / GDP	0.079	0.065
Government Consumption/GDP	0.135	0.125
Capital Tax/GDP	0.032	0.032

Source: Household Income and Expenditure Survey (HIES), Survey of Household Finance and Living Conditions (SHFLC), OECD database

wealth distribution. The SHFLC found that households in the 1st, 2nd, 3rd, and 4th quintiles own 0.4%, 4.7%, 10.6%, 20.4%, and 64.0% of total assets, respectively. The corresponding shares in our model economy are 0.7%, 5.4%, 13.4%, 25.7% and 54.8%, respectively. Income and wealth inequality in our model is higher than that in the HIES, but lower than that in the SHFLC. Overall, the income and wealth distributions in our model economy resemble those from the data quite well.

Table 13 compares the major variables in the data to those in our model. The consumption tax revenue and government consumption in our model are close to those in the data, although we did not target those ratios. Tax revenues on goods and services were 7.9% of GDP (OECD 2013) in 2010; the corresponding rate in our model is 6.5%. Government consumption (13.5% of GDP in 2010) in the National Account (OECD 2014) is similar to that (12.5%) in our model.

According to our calibration strategy, the model economy matches the average net tax rate in the HIES (3.75%). Table 14 compares net and marginal tax rates at decile points between the model and the data. The net tax rate of households in the 1st decile (bottom 10%) is -27.0% in the HIES, and -15.7% according to the estimated HSV tax function. The corresponding figure in our model is -13.9%. The net tax rate in the 9th decile in the HIES is 7.0%, somewhat lower than that in our model (9.5%). The marginal tax rates in the 1st and 9th deciles under the estimated HSV tax function (0.2% and 22.8%) are similar to those in our model (1.7% and 21.9%). In the middle deciles, the marginal tax rates under the estimated HSV tax

TABLE 14—TAX RATES ACROSS INCOME DECILES

Decile Points	1st	2nd	4th	6th	8th	9th
Data: HIES						
Relative income	0.27	0.49	0.79	1.04	1.42	1.78
Net tax rate (%)	-27.02	-5.37	2.72	4.23	6.42	6.96
Data: Estimated HSV						
Net tax rate (%)	-15.71	-6.70	-0.01	3.72	7.76	10.58
Marginal tax rate (%)	0.15	7.93	13.7	16.92	20.41	22.84
Model						
Relative income	0.36	0.46	0.65	0.93	1.40	1.91
Net tax rate (%)	-13.90	-9.96	-4.85	0.00	5.48	9.52
Marginal tax rate (%)	1.70	5.11	9.52	13.77	18.44	21.92

Notes: All incomes are equivalized income at decile points in 2010. Marginal tax rates are based on the estimated HSV tax function. The relative incomes are relative to the population average.

TABLE 15—AVERAGE GROSS TAX RATES (%) OF INCOME DECILES

Income Decile	1st	2nd	4th	6th	8th	9th	10th
HIES	12.4	7.6	7.0	7.5	8.7	9.5	11.2
Model	10.1	7.7	7.2	8.2	10.4	12.4	17.4

Notes: Tax rates in the HIES are the same as those in Table 6; income is not equivalized, and tax rates are taxes and contributions divided by factor income.

function (7.9%, 13.7%, 16.9% and 20.4%) are slightly higher than those in our model (5.1%, 9.5%, 13.8%, and 18.4%). Overall, the marginal tax rates in our model approximate those under the estimated HSV fairly well except for the 1st decile (the bottom 10%) despite a simple parametric functional form.

In order to compare the gross tax rates in our model, we need further assumptions about the transfer because the HSV tax function is defined in terms of net taxes. We assume a lump-sum transfer to all households. In fact, the amount of transfer is actually pretty close to lump-sum in the HIES. The average transfers (public plus private, unequivalized income) are 323,309 won in the HIES (2010), while the average transfers in the 1st and 10th deciles are 341,708 and 372,828.

More specifically, we look for the amount of lump-sum transfer in our model so that the individual income tax to output ratio matches that in the data (income tax and social security contributions to GDP ratio of 8.6%, according to the OECD Tax Revenues 2010). Table 15 compares the average gross tax rates across various income deciles. The gross tax rates in our model resemble those in the HIES well except for the top end of the distribution. The gross tax rate of 11.2% in the 10th decile in the HIES is much lower than that in our model, 17.4%.

C. *Optimal Tax Reform*

In the previous section, we developed a quantitative model that approximates income inequality and tax policies in Korea. We now address the following questions using this model economy: (i) What is the optimal tax rate that maximizes the utilitarian social welfare function? (ii) Who will be better (or worse) off from the fiscal reform to adopt the optimal tax rate?

One of the most important subjects in public finance is to characterize the optimal tax policy. This task often requires appropriately aggregating individual preferences, which is challenging and controversial. A common practice is to use a social welfare function that averages the utility of the population with equal weights (i.e., utilitarian criteria). In the context of our model, the utilitarian social welfare function can be written as:[10, 11]

$$W(\tau,\tau_k)=\int V(a_0,x_0;\tau,\tau_k)d\mu(a_0,x_0;\tau,\tau_k),$$

where $V(a_0,x_0;\tau,\tau_k)$ is the discounted sum of the lifetime utility of a household with asset holdings a_0 and productivity x_0, and $\mu(a_0,x_0;\tau,\tau_k)$ is the distribution of households over (a_0,x_0) in the steady state given tax progressivity τ and a capital tax rate τ_k, i.e.,

$$V(a_0,x_0;\tau,\tau_k)=\mathrm{E}_0\sum_{t=0}^{\infty}\beta^t\left\{\frac{c(a_t,x_t;\tau,\tau_k)^{1-\sigma}-1}{1-\sigma}-B\frac{h(a_t,x_t;\tau,\tau_k)^{1+1/\gamma}}{1+1/\gamma}\right\}$$

We assume that the model economy is at its steady state under the current tax progressivity (τ) and two tax rates (τ_k, τ_c) as reported in Table 13. We then look for the new combination of tax progressivity, τ^*, and capital tax rate, τ_k^*, that maximizes $W(\tau,\tau_{k^*})$, *including* the welfare of households during the transition period to the new steady state.[12] We assume that the consumption tax rate τ_c is fixed at 0.1. We also assume that the government consumption to output ratio *G/Y* is held constant. The average level of taxation, λ, is determined to ensure a balanced budget every period.

We will compute the social welfare gains under the new tax progressivity (τ) and capital tax rates (τ_k). The welfare gain in consumption-equivalence units, Δ, is defined as:

$$\int\sum_{t=0}^{\infty}\beta^t U((1+\Delta)c_0,h_0)d\mu_0(a,x)=\int\sum_{t=0}^{\infty}\beta^t U(c_1,h_1)d\mu_1(a,x)$$

where c_0, h_0, μ_0 are initial steady states and c_1, h_1, μ_1 are those after the reform (including transitions).

Table 16 reports the welfare gains under various tax reforms. Out of 20 combinations we consider around the current values, τ^* = 0.24 and τ_k^* = 0.39 achieve the largest welfare gain—a 0.86% increase in permanent consumption.

[10]This utilitarian social welfare function has been commonly used in the literature, for example, Aiyagari and McGrattan (1998).

[11]Since we assume consumption tax rate is constant in our model, social welfare is a function of tax progressivity τ and the capital tax rate τ_k.

[12]We include the welfare of households during the transition from the current steady state to a new steady state. When a new tax rate is in place in the current steady state, households start re-optimizing their consumption and hours worked. As a result, the corresponding paths of the value functions, $V_t(a_t,x_t;\tilde{\tau}^*,\tilde{\tau}_k^*)$, and the distribution. $\mu_t(a_t,x_t;\tilde{\tau}^*,\tilde{\tau}_k^*)$, will be different from those in the old steady state. Hence, the computation of the optimal tax needs to take into account changes in value functions and distributions during transition periods until the economy reaches a new steady state.

TABLE 16—WELFARE GAINS IN CONSUMPTION EQUIVALENTS

Progressivity (τ)	Capital Tax Rates (τ_k) 0.24	0.29	0.34	0.39	0.44
0.14	0.00	0.08	0.14	0.19	0.21
0.19	0.55	0.61	0.65	0.68	0.68
0.24	0.79	0.83	0.86	**0.86**	0.83
0.29	0.70	0.73	0.73	0.71	0.66

Notes: All numbers are % change (consumption equivalent) from the current steady state.

TABLE 17—CURRENT AND OPTIMAL TAX RATES (%)

Decile Points	1st	2nd	4th	6th	8th	9th
Current State						
Relative Income	0.36	0.46	0.65	0.93	1.40	1.91
Net tax rate	-13.90	-9.96	-4.85	0.00	5.48	9.52
Marginal tax rate	1.70	5.11	9.52	13.77	18.44	21.92
Gross tax rate	8.43	7.32	7.36	8.67	11.21	13.68
Optimal Tax Reform						
Relative Income	0.37	0.47	0.67	0.92	1.37	1.88
Net tax rate	-32.94	-25.44	-15.30	-6.82	2.78	9.73
Marginal tax rate	-1.42	4.30	12.01	18.51	25.83	31.13
Gross tax rate	8.91	7.32	7.65	9.81	13.96	17.9

When converted into 2010 wons, the consumption of all households increases by 300 thousand won every year.[13] Table 17 shows the net and marginal income tax rates under the new steady states.[14] The average net tax rates of income decreases from 3.75% to -0.87% on average due to a more aggressive redistribution. With the increased progressivity, households, except for those in top 10% income distribution, now face lower net tax rates. The marginal tax rates increase with income at a steeper rate. The marginal tax rate of 31.1% in the 9th decile in the new steady state is much higher than 21.9% under the initial steady state. Since the HSV function is defined in terms of net tax burden, we need another assumption in order to determine the gross tax rates across income levels. We assume that the gross tax rate of households at the 2nd decile is fixed in all tax reforms we consider.[15] Table 17 reports the gross tax rates at various decile points under the optimal tax function. The gross tax rates of low-income households change little after tax reform. But those of high-income households increase considerably. For example, the gross tax rate in the 9th decile increases from 13.7% to 17.9%.

Table 18 compares the current steady state and the new steady state under optimal tax reform. The Gini coefficient before tax and transfers (0.356) under optimal tax reform is slightly lower than the current one (0.366). However, the Gini coefficient after tax and transfers decreases from 0.318 to 0.274 after reform. As a result, taxes and transfers reduce the Gini coefficient by 23% under optimal tax reform, which is 13.2% in the current steady state. The tax reform has little effect on wealth distribution; the new wealth Gini (0.536) is similar to the current one

[13]According to the HIES (2010) , the average equivalized income is 1.8 million won per month.

[14]Since the average level of taxation, λ , is changing in transitions, marginal and net tax rates in transitions are different from those in the new steady state

[15]We fix the gross tax rates of households at the 2nd decile point instead of at the 1st decile point because the approximation of the HSV function is known to be poor at the very low-income level.

TABLE 18—CURRENT AND NEW STEADY STATE UNDER OPTIMAL TAX REFORM

Variables	Current Steady State (CS)	New Steady State (NS)	Ratio (NS/CS)
Before-tax Gini (BG)	0.366	0.356	0.97
After-tax Gini (AG)	0.318	0.274	0.86
Improvement Rate (1-AG/BG)	0.132	0.230	1.74
Wealth Gini	0.545	0.536	0.98
Interest Rate (r)	0.060	0.084	1.40
Wage Rate (w)	1.010	0.935	0.93
Labor Hours (H)	0.398	0.384	0.96
Aggregate Output (Y)	0.670	0.591	0.88
Aggregate Capital (K)	1.508	1.159	0.77
Aggregate Consumption (C)	0.436	0.401	0.92
Government Consumption (G)	0.079	0.074	0.94
Net Tax Rate	0.038	-0.009	-
Consumption Tax / GDP	0.065	0.068	-
Government Consumption/GDP	0.125	0.125	-
Capital Tax/GDP	0.032	0.063	-
Income Tax/GDP	0.087	0.107	-

(0.545). Since high tax rates lower after-tax returns on capital, and more social transfers weaken the insurance motive under tax reform, individual savings decrease drastically and the interest rate rises. The capital stock after tax reform is 77% of current steady state, and the corresponding interest rate is now 8.4% (the current rate is 6%). On the contrary, both wage and working hours fall in the new steady state. Low capital stock and labor supply reduce total output by 12%. Aggregate consumption also decreases, but not as much as output. Increases in tax progressivity raise tax revenues on income. However, social transfers increase more than income tax and the net tax rate decreases. Tax revenues on capital income increase from 3.2% in the current steady state to 6.3% in the new steady state.

Figure 5 demonstrates the transition paths from the current to the new steady state under optimal tax reform. All values are relative to the current steady-state level, which is set to 100. Output drops sharply as soon as the new tax reform is in place, and then decreases gradually. Since households reduce savings, aggregate capital falls continuously. Aggregate consumption rises slightly in the beginning as accumulated capital is spent, but goes below the current level in the long run. Working hours drop in the beginning and remain low. The interest rate, which falls in the beginning, keeps rising to 40% higher than the current rate. On the contrary, wages increase in the beginning and then falls.

We now calculate how many households are better off from each tax reform. In computing welfare under tax reform, we include welfare during the transition to the new steady state. Table 19 reports the fraction of households (%) that are better off from each tax reform. Under optimal tax reform ($\tau^* = 0.24$, $\tau_k^* = 0.39$), about 64% of households are better off. If we assume that voting is binary between the current and the new tax scheme, 64% of households will support optimal tax reform.

Figure 6 illustrates the asset and productivity levels at which households are indifferent between the optimal tax reform and the status quo. For comparison with the actual data, we convert the units in our model to 2010 wons (by matching average income in our model to that in the 2010 HIES). Average working hours in our model, 0.398, is also set to the average annual working hours 2,187 in Korea

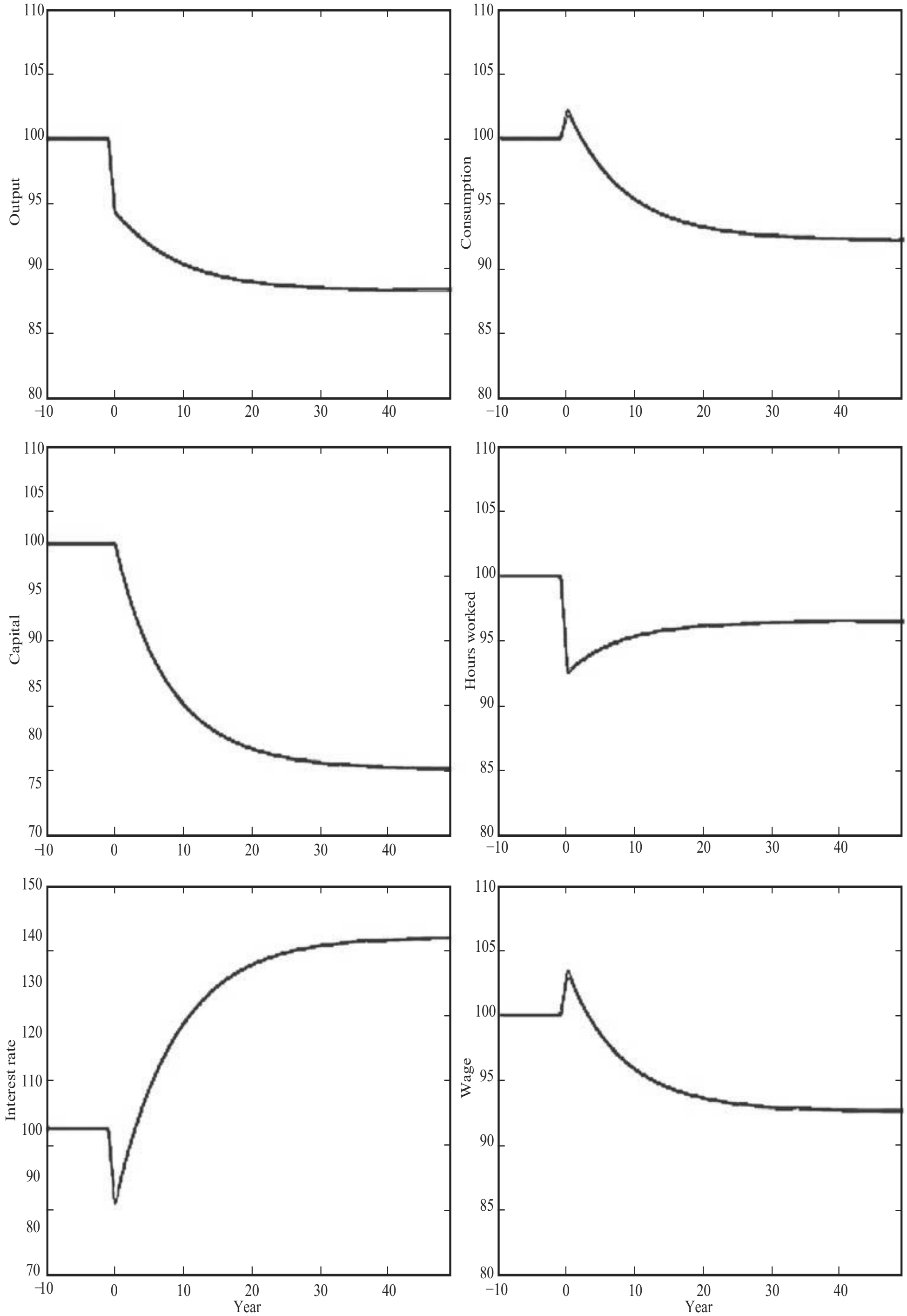

FIGURE 5. TRANSITION PATHS TO THE NEW STEADY STATE

Note: All values are relative to the current steady state, which is normalized to 100.

TABLE 19— FRACTION OF HOUSEHOLDS (%) BETTER OFF FROM TAX REFORMS

Progressivity (τ)	Capital Tax Rates (τ_k) 0.24	0.29	0.34	0.39	0.44
0.14	-	64.4	63.5	62.6	61.5
0.19	79.8	75.5	70.3	67.2	61.5
0.24	72.5	71.1	67.3	**64.4**	62.1
0.29	63.6	61.8	60.1	57.5	55.3

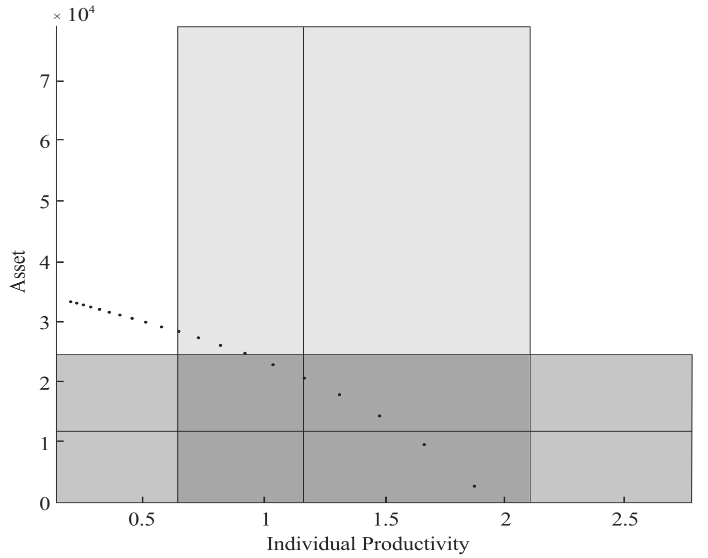

FIGURE 6. ONES BETTER OFF AND WORSE OFF FROM THE OPTIMAL TAX REFORM

Note: Assets and wages are rescaled so that average income in the model matches that in the data.

TABLE 20—WELFARE GAINS AT CONSUMPTION DECILES

Decile Points	1st	2nd	4th	6th	8th	9th
Consumption Equivalence (%)	3.4	2.1	1.3	0.2	-1.4	-3.4
Amount (thousand won)	709	540	404	80	-618	-1,656

(OECD 2010). In Figure 6 households below the dotted line are better off with the optimal tax reform. Clearly, households with low asset and low productivity win from tax reform. (The vertical and horizontal lines in Figure 6 represent the average and ± one standard deviation of assets and individual productivity.[16])

We also report the welfare gains at various consumption deciles under optimal tax reform in Table 20. The welfare gains of a particular household i, Δ_i, in consumption-equivalence units is:

$$\sum_{t=0}^{\infty} \beta^t U((1+\Delta_i)c_{i0}, h_{i0}) = \sum_{t=0}^{\infty} \beta^t U(c_{i1}, h_{i1})$$

[16]The standard deviations of individual productivity are not symmetric, because the wage process is log normal.

where c_{i0}, h_{i0} are the initial steady states and c_{i1}, h_{i1} are those after reform (including transitions) for each individual i. Household in the 1st consumption decile gain 3.4% in terms of permanent consumption. Households in the 2nd, 4th, 6th deciles also gain welfare. However, households in the 8th and 9th deciles lose welfare by as much as 1.4% and 3.4% of their permanent consumption, respectively. When converted into 2010 won units, households in the 1st decile gain 709 thousand won and those in the 9th decile lose 1,656 thousand won.

D. *Robustness*

1. Administrative Costs

In our benchmark model, we assume that there is no administrative cost associated with collecting taxes and transferring resources (or cost associated with bureaucracy). However, collecting tax revenues as well as transferring incomes may require costs. In this section, we introduce some administrative costs of government.

While it is difficult to measure the cost of bureaucracy, according to the OECD, the cost of collection ratio (administrative costs/net revenues) among 32 OECD countries was 1.1% on average in 2010.[17] In the same report, the cost ratio in Korea was 0.81%. Eurostat reports the structure of social protection expenditure among 28 EU countries. Administrative costs account for 3.0% of total expenditure in 2012.[18] Based on these numbers, we now assume that the administrative cost is 4% of total transfers (1% for collecting taxes and 3% for transferring). As a result, total government expenditure becomes $G+0.04\ TR$ where TR is the total amount of transfer.[19]

Table 21 compares social welfare under different tax reforms, now with additional administrative costs. The optimal tax progressivity with administrative costs is the same as that without additional administrative costs, but the optimal capital tax rate is lower without such costs. Raising tax progressivity τ from 0.14 to 0.24 and the capital tax rate τ_k from 0.24 to 0.34 generates the largest social welfare. (The optimal tax without administrative costs is τ=0.24, τ_k=0.39.)

TABLE 21—WELFARE GAINS IN CONSUMPTION EQUIVALENTS WITH ADMINISTRATIVE COSTS

Progressivity	Capital Tax Rates (τ_k)				
(τ)	0.24	0.29	0.34	0.39	0.44
0.14	0.00	0.05	0.10	0.12	0.12
0.19	0.44	0.48	0.50	0.50	0.48
0.24	0.58	0.60	**0.60**	0.58	0.52
0.29	0.38	0.38	0.36	0.31	0.24

Notes: All numbers are % change (consumption equivalent) from the current steady state.

[17]OECD, "Tax Administration 2013: Comparative Information on OECD and Other Advanced and Emerging Economies," p. 180.

[18]Eurostat (online data code: spr_exp_sum)

[19]Note that we assume that $G/Y=\chi$ is fixed.

Welfare gains are as much as 0.60% of permanent consumption, which is 205 thousand in 2010 wons.

2. Capital Outflows

There is widespread concern about possible capital outflows when moving to high capital tax and progressive income tax schedule. To address this, we consider tax reforms in an open economy version by fixing the interest rate at the current steady state 6%. Under perfect capital mobility, the difference between household savings (domestic capital) and aggregate capital implied by the fixed interest rate reflects capital outflows (or inflows). We assume that government consumption is a fixed share of (before-tax) aggregate household incomes.[20] We also assume that only domestic household incomes are subject to the capital tax. Table 22 reports welfare gains under various tax reforms. The optimal tax reform is virtually the same as that in benchmark economies—increasing tax progressivity (τ) to 0.24 and capital tax rates (τ_K) to 0.39.

However, there is a significant capital outflow when the economy moves to high capital tax and more progressive income tax schedule. Table 23 reports the ratio of domestic capital under the new steady state to domestic capital under the current steady state. With optimal tax reform, domestic capital decreases to almost half (47%) of its current level.

TABLE 22— CONSUMPTION EQUIVALENTS UNDER PARTIAL EQUILIBRIUM

Progressivity	Capital Tax Rates (τ_k)				
(τ)	0.24	0.29	0.34	0.39	0.44
0.14	-	0.13	0.22	0.28	0.32
0.19	0.61	0.70	0.76	0.79	0.80
0.24	0.90	0.95	0.99	**1.00**	0.99
0.29	0.86	0.89	0.91	0.91	0.90

Notes: All numbers are % change (consumption equivalent) from the current steady state.

TABLE 23— DOMESTIC CAPITAL/CURRENT CAPITAL UNDER PARTIAL EQUILIBRIUM

Progressivity	Capital Tax Rates (τ_k)				
(τ)	0.24	0.29	0.34	0.39	0.44
0.14	100.0	92.0	84.7	77.9	71.8
0.19	78.4	72.2	66.4	61.2	56.4
0.24	60.2	55.5	51.1	**47.1**	43.5
0.29	45.1	41.6	38.4	35.4	32.8

V. Conclusion

We develop a quantitative general equilibrium model and calibrate it to match the salient features of the Korean economy. With this model, we look for the combination of progressivity in the tax function and the capital income tax rate that

[20] Aggregate output and aggregate incomes are different in an open economy.

maximizes utilitarian social welfare. According to our model, a more progressive income tax schedule increases the average welfare of the society. The marginal income tax rates in the 9th decile should increase from the current 22% to 31%. Also, the optimal capital tax rate (39%) is 15 percentage point higher than the current one. Under optimal tax reform, the average household gains welfare by as much as 0.86% of steady-state consumption, which is approximately 300 thousand won per year in 2010 values. The majority (64%) of households are better off, mostly those with low assets and low productivity. More specifically, households in the 1st consumption decile gain welfare by as much as 3.4% of consumption (709 thousand won per year). But, households in the 9th decile lose welfare by as much as 3.4% of consumption (1,656 thousand won per year).

Despite the potential welfare gain from more progressive and high capital income taxes, we would like to note that our results should be interpreted with caution because our benchmark model does not take into account possible capital outflows or the increased administrative costs associated with high income taxes. An open-economy version of our model does indicate that there will be a significant capital flight from a high capital income tax. Sizable administrative costs would also undermine the potential welfare gains from high taxes.

APPENDIX

A: *Taxes in Korea*

As described in the data section, the tax system in Korea consists of ten national and eleven local taxes. Out of those taxes, three taxes (income tax, corporation tax and value-added tax) account for most tax revenues. In this section, we will describe the detailed tax rates of the three main taxes and social security contributions.

Income Tax: A person, either a resident or a non-resident, is liable to income tax on items of income-derived sources. “Under global taxation, real estate rental income, business income, earned income, and miscellaneous income attributed to a resident are aggregated and taxed progressively. Interest and dividends are subject to tax withholdings” (MOSF 2012, p. 3). Table 24 reports the marginal income tax rates across income brackets. The tax rates on individual income range from 6 percent to 38 percent. When the local income tax is included, the income tax rate ranges from 6.6 percent to 41.8 percent.

TABLE 24— INDIVIDUAL INCOME TAX RATES BY INCOME BRACKETS

Taxable Income (Million Won)	Marginal Tax Rate (%) National	Local	Total
Under 12	6	0.6	6.6
12 - 46	15	1.5	16.5
46 - 88	24	2.4	26.4
88 - 150	35	3.5	38.5
Over 150	38	3.8	41.8

Source: National Tax Service (2015).

Wages and salary incomes are included in taxable income after deductions as specified in Table 25 below. Residents with global income are entitled to annually deduct an amount equivalent to 1.5 million won multiplied by the number of persons in the taxpayer's family (MOSF 2012). The vulnerable (such as the old and the disabled) and households with many dependent children are eligible for additional deductions.

TABLE 25— INCOME TAX DEDUCTION RATE

Total Earnings (Million Won)	Marginal Deduction Rate (%)
Under 5	70
5 - 15	40
15 - 45	15
45 - 100	5
Over 100	2

Source: National Tax Service (2015).

Corporation Tax: A domestic company is liable to tax on its worldwide income, and a foreign company is liable to tax on its Korean-source income (MOSF 2012). According to the National Tax Service, the marginal tax rates are as below: 10% (11% including the local corporation tax) when the tax base is the same as or less than 200 million won, 20% (22% including the local corporation tax) between 200 million won and 20 billion won, and 22% (24.2% including the local corporation tax) over 20 billion won.

TABLE 26— CORPORATE INCOME TAX RATES BY INCOME BRACKETS

Taxable Income	Marginal Tax Rate (%)		
(Million Won)	National	Local	Total
Under 200	10	1	11
200 - 20,000	20	2	22
Over 20,000	22	2.2	24.2

Source: National Tax Service (2015).

Value-Added Tax: A person who engages in the supply of goods and services and a person who imports goods and services are liable to value-added tax (MOSF 2012). The rate of value-added tax is 10% of added value (National Tax Service 2015).

Social Security: In Korea all citizens must subscribe four compulsory insurance plans: National Pension, National Health Insurance, Employment Insurance, and Workers Compensation Insurance. Contributions to the National Pension are 9% of the wages of workers (employer 4.5%, employee 4.5%) or the income of the self-employed (National Pension Service, 2015). For National Health Insurance, wage workers pays 6.07 % of their wages (employer 3.035%, employee 3.035%) as a contribution, and they also pay additional 6.55% of health insurance contributions for Long-term Care Insurance (National Health Insurance Service, 2015). The contributions of the self-employed are determined by income, wealth and economic status. For Employment Insurance, employees pay 0.65% of their wages and employers pay 2.85% of an employee's wage. Contributions for Workers Compensation Insurance vary across industries.

B: *Computational Procedures*

1. Steady-State Equilibrium

The distribution of households, $\mu(a,x)$, is time-invariant in the steady state, as are factor prices. We modify the algorithm suggested by José-Víctor Ríos-Rull (1999) in finding a time-invariant distribution μ. Computing the steady-state equilibrium amounts to finding the value functions, the associated decision rules, and the time-invariant measure of households. We search for (i) the discount factor β that clears the capital market at the given annual rate of return of 6%; (ii) the disutility parameter B to match the average hours worked, 0.398; and (iii) the average levels of taxation λ to match net income tax rates, 3.75%. The details are as follows:

1) Choose the grid points for asset holdings (a) and idiosyncratic productivity (x). The number of grids is denoted by N_a, and N_x, respectively. We use $N_a = 326$, $N_x = 31$. The asset holding a_t is in the range of [0, 50]. The grid points of assets are not equally spaced. We assign more points on the lower asset range to better approximate the savings decisions of households near the borrowing constraint. For idiosyncratic productivity, we construct a grid vector of length N_x whose elements, $ln x_j$'s, are equally spaced on the interval [$-3\sigma_x / \sqrt{1-\rho_x^2}$]. Then, we approximate the transition matrix of idiosyncratic productivity using Tauchen's (1986) algorithm.

2) Pick initial values of β, B, and λ. Given β, B, ρ_x, σ_x, and λ, we solve the individual value functions V at each grid point of individual states. In this step, we also obtain the optimal decision rules for asset holdings $a'(a_i, x_j)$ and labor supply $h(a_i, x_j)$. This step involves the following procedure:

   (a) Initialize value functions $V_0(a_i, x_j)$ for all $j = 1,2,\cdots,N_x$, and $j = 1,2,\cdots,N_x$.

   (b) Update value functions by evaluating the discretized versions:

$$V_1(a_i, x_j) = \max\{u(\frac{\lambda(wh(a_i,x_j)x_j + (1-\tau_k)ra_i)^{1-\tau} + a_i - a'}{1+\tau_c}, h(a_i, x_j))$$

$$+\beta\sum_{j'=1}^{N_x} V_0(a', x_{j'}))\pi_x(x_{j'} \mid x_j)\},$$

where $\pi_x(x_{j'} \mid x_j)$ is the transition probabilities of x, which is approximated using Tauchen's algorithm.

(c) If V_1 and V_0 are close enough for all grid points, then we have found the value functions. Otherwise, set $V_0 = V_1$, and go back to step 2(b).

3) Using $a'(a_i, x_j)$, $\pi_x(x_{j'} \mid x_j)$ obtained from step 3, we obtain the time-invariant measures $\mu^*(a_i, x_j)$ as follows

(a) Initialize the measure $\mu_0(a_i, x_j)$.

(b) Update the measure by evaluating the discretized version of a law of motion:

$$\mu_1(a_{i'}, x_{j'}) = \sum_{i=1}^{N_a}\sum_{j=1}^{N_x} 1_{a_{i'}=a'(a_i, x_j)}\mu_0(a_i, x_j)\pi_x(x_{j'} \mid x_j)$$

(c) If μ_1 and μ_0 are close enough in all grid points, then we have found the time-invariant measure. Otherwise, replace μ_0 with μ_1 and go back to step 3(b).

4) We calculate the real interest rate, individual hours worked, net income tax rate, and other aggregate variables of interest using μ^* and decision rules. If the calculated real interest rate, average hours worked, and net income tax rates are close to the assumed ones, we have found the steady state. Otherwise, we choose a new β, B, λ, and go back to step 2.

2. Optimal Tax Reform

Individual utilities include those in the transition periods from the initial to the new steady state. We compute the value functions and decision rules backwards and the measure of households forward. Computing the transition equilibrium amounts to finding the value functions, the associated decision rules, and the measure of households in each period. The details are as follows:

1) Compute the initial steady state under the current tax rate. Use the algorithm for the steady-state equilibrium.

2) Choose new tax parameters (progressivity τ, capital tax rate τ_k) and compute all transition paths as follows

(a) Compute the final steady state under new tax parameters. Use the algorithm for the steady-state equilibrium. However, the discount factor

β and disutility parameter B are fixed, and we find the real interest rate where the calculated real interest rate is close to the assumed one. The average level of taxation λ is chosen so that calculated total tax revenues are close to the sum of total transfers and government consumption.

(b) Assume that the transition is completed after $T-1$ periods and the economy is in the initial steady state at time 1 and in the final steady state at T. Choose T big enough so that the transition path is unaltered by increasing T.

(c) Guess the capital per effective labor $\{K_t / E_t\}_{t=2}^{T-1}$ and compute the associated $\{r_t, w_t\}_{t=2}^{T-1}$.

(d) Guess the path of average level of taxation, $\{\lambda\}_{t=2}^{T-1}$. Note that the average levels of taxation are all different in each period, since decision rules and measures are different. From backwards, compute the value functions and policy functions for all transition periods by using $V_T(\bullet)$ from the final steady state. Using the initial steady-state distribution μ_1 and the decision rules, find measures of all periods $\{\mu_t\}_{t=2}^{T-1}$.

(e) Based on the decision rules and measures, compute the aggregate variables, tax revenues, transfers and government consumption. If total tax revenues are close to the sum of total transfers and government consumption, we obtain the average level of taxation. Otherwise, choose a new path of the average level of taxation and go back to 2(d).

(f) Compute the paths of aggregated capital and effective labor and compare them with the assumed paths. If they are close enough in each period, we find the transition paths. Otherwise, update $\{K_t / E_t\}_{t=2}^{T-1}$ and go back to 2(c).

3. Choose tax parameters that yield the highest social welfare. This is the optimal tax rate under the utilitarian criteria.

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The Productivity Dispersion of the Korean Manufacturing Industry and Macroeconomic Allocation Efficiency Measures

By JONGIL KIM, DONGKEUN KANG*

According to the macroeconomic allocation efficiency measure, particularly based on the methodology of Hsieh and Klenow (2009), Korea's allocation efficiency in the manufacturing industry deteriorated in the 2000s compared to that in the 1990s. This study compares the potential TFP gain when resource allocation is removed, an indicator of allocation inefficiency according to Hsieh and Klenow (2009), and the productivity dispersion in the Korean manufacturing industry. It finds that the TFP gain may be better explained by TFP dispersions rather than proxies related to factors of distortion. The findings imply that we should investigate the sources of TFP dispersion rather than the sources of distortion to explain increases in the TFP gain (or TFP loss), which is considered as allocation inefficiency in the literature.

Key Word: Misallocation, Total Factor Productivity (TFP), Productivity Dispersion
JEL Code: O11, D24

I. Introduction

Identifying the sources of productivity differences across countries has been an essential subject in studies of economic growth. Recently, numerous theoretical and empirical studies have been devoted to increasing our understanding of differences in productivity levels across countries by exploring the effects of the misallocation of resources on aggregate economic performance, particularly the total factor productivity (TFP). These researchers include Restuccia and Rogerson (2008); Alfaro, Charlton, and Kanczuk (2008), Hsieh and Klenow (2009); and Bartelsman, Haltiwanger and Scarpetta (2013). Their studies introduced the interplay between heterogeneous establishments (plants from now) and productivity in the model and

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argued that misallocations of resources could have a significant effect on productivity and thus on the economic performances of countries.

Restuccia and Rogerson (2008) formulated a version of a growth model which introduced output distortions such as taxes and subsidies, which may be correlated with the productivity parameters of plants.[1] They calculated the effect of distortion based on steady-state calibrations of the U.S. economy and found that distortions which create heterogeneity in the prices faced by individual producers decrease the TFP in the range of 30 to 50 percent. Alfaro, Charlton, and Kanczuk (2008) used a method similar to that of Restuccia and Rogerson (2008) and calculated the effects of misallocations on economic performance levels across countries. They found that the effects of misallocations explains approximately 60% of the log variance of income per worker. They assumed the U.S. economy as relatively undistorted and compared the distortion factors of countries with that of the U.S. Hsieh and Klenow (2009) identified both output and capital distortions and quantified the TFP loss, that is, the potential gain on aggregate TFP, without resource misallocation. Instead of using a calibration technique, they calculated the potential loss of TFP due to misallocations of resources in China and India and found that TFP losses were 30-50% in China and 40-60% in India compared to hypothetical situations in which capital and labor in China and India may be allocated to equalize marginal products as in the U.S.

The essence of these models is that distortion may prevent the equalization of the marginal value of inputs across firms. Roughly speaking, without distortions, plants with higher TFP levels tend to employ more factors of production, which would result in higher TFP. Thus, this type of model was employed to study the effects of size-dependent policies on TFP, as there is a tendency for larger plants to have higher TFP empirically.[2] Guner, Ventura and Xu (2008) studied a simple growth model with an endogenous size distribution of plants and found that policies that reduce the average size of large plants by 20% lead to a reduction in output per plant by as much as 25.6%. They introduced capital distortion correlated with the size of the plant and used a calibration method with different size distributions of plants with regard to TFP.

To summarize the results of these studies, first, larger distortions have large negative effects on productivity. Secondly, distortions that result in reallocations of the factors of production from plants with higher TFP to those with lower TFP are detrimental to productivity. These studies, which raised the importance of resource allocation on TFP, motivated subsequent studies to investigate the effects of resource allocation in individual countries. Bellone and Mallen-Pisano (2013) used the methodology of Hsieh and Klenow (2009) to compare the allocation efficiencies of France and the U.S. They found that the potential TFP gain in France, around 30% in 2005, is less than that in the U.S., which was 42.9% in 1997, and that it stayed at that level without much change between 1998 and 2005. Hosono and Takizawa (2012) and Fuji and Nozawa (2013) also applied the methodology of Hsieh and Klenow (2009) to the Japanese manufacturing industry, finding that the potential gain increased sharply in the 2000s. Before the 2000s, the

[1]Output distortion distorts output prices while capital distortion distorts the rental price of capital.
[2]See Figure 9 of Alfaro, Charlton, and Kanczuk (2008).

potential gain was less than 20%, but it increased to 50% in 2008, implying that there was a sharp rise in allocation inefficiency in Japan starting in the late 1990s.

Several previous works used the methodology of Hsieh and Klenow (2009) to examine the Korean manufacturing industry. Lee, Hwang and Seol (2013) calculated the potential TFP loss, finding that it was 7.6% in 1992 but increased to 25.3% in 2008. Interestingly, the allocation efficiency in Korea continued to decline starting in the 1990s, as in Japan. Ji and Jeong (2015) also used the same methodology and found a similar result, i.e., that the allocation efficiency deteriorated sharply in the 2000s. They aligned the calculation to be consistent with that in Hsieh and Klenow (2009) using the parameter of the U.S. manufacturing industry under the assumption that U.S. manufacturing is relatively less distorted. They found that the potential gains of the Korean manufacturing industry were 50.1% in 1997, 58.4% in 2005 and 73.1% in 2012. These figures are much larger than those in Lee, Hwang and Seol (2013), as the parameters of the production function are different. They blamed the underinvestment of firms with higher productivity levels and the survival of firms which excessively use resources w relative to their productivity level for the deteriorating allocation efficiency. Particularly, they pointed out that large firms and young firms with high productivity levels tended to produce less than the optimal level. Oh (2014) also found results similar to those in the two aforementioned studies, showing that the gap between actual GDP and optimal GDP while assuming efficient allocation increased from less than 30% in 1990 to 40% in 2012.

Is it possible that allocation efficiency in Korea and Japan is much worse than that of U.S. manufacturing while the shares of exports by Korea's and Japan in the world market have increased rapidly relative to the U.S.? This stands in contrast to the implication of the model by Melitz (2003), which provided important ideas about the relationship between intra-industry reallocation and aggregate industry productivity for those engaged in this line of research. According to Melitz (2003), exposure to trade will induce more productive firms to enter the export market and force the least productive firms to exit. Further increases in the industry's exposure to trade may lead to additional inter-firm reallocations toward more productive firms. Is it possible that Korea and Japan's allocation efficiency levels deteriorated sharply in the 2000s, particularly since 2003, while those of other countries such as the U.S. and France remained mostly steady? Why did the problem of zombie firms worsen allocation efficiency suddenly after the ten-year period of stagnation in Japan? Why did Korea's allocation efficiency deteriorate as Japan's did in the 2000s despite the fact that Korea did not have such a prolonged period of stagnation as Japan?

In this study, we attempt to find feasible explanations for the deteriorating allocation efficiency measure, i.e., potential TFP gains, in the last 20 years in Korea's manufacturing industry by looking into the potential TFP gains of the Korean manufacturing industry at the sectoral level rather than the aggregate manufacturing industry. This study will suggest that the TFP gains in the 2000s in Korea may be better explained by the rising TFP dispersion, although resource misallocations may have had a minor effect. Particularly, countries with large export manufacturing industries underwent a significant rearrangement of their industrial production through outsourcing and offshoring starting in the 1990s.

Particularly, manufacturing in East Asia increased in terms of its global production share rapidly, and this new form of international specialization occurred in that region more than anywhere else in the world. Particularly, the rise of Chinese manufacturing played a pivotal role in this process, having an unprecedented impact on Korea's manufacturing industry. As long as we do not understand the patterns and causes of the changing productivity dispersions, it is not a proper judgment to pinpoint rising resource misallocation as a cause of the slowdown in TFP growth in the 2000s based on the indicator of resource allocation developed in recent studies such as that by Hsieh and Klenow (2008).

In the next section, we use the methodology of Hsieh and Klenow (2008) to calculate the degree of distortion in the Korean manufacturing industry. We calculate the potential TFP gains of subsectors of the manufacturing industry along with the aggregate TFP gains possible without distortions. Here, we discuss the basic assumptions and limitations of the model used to compare allocation efficiency levels across countries or at different times.

In section III, we explore the patterns in the productivity dispersions Korea since the 1980s and examine the relationship between the potential TFP gains and TFP dispersions. In section IV, we discuss the possible determinants of the TFP gain in the Korean manufacturing industry as measured by the methodology of Hsieh and Klenow (2009). The conclusion follows in section V.

II. The Degree of Resource Misallocation Measured as Potential Gains based on Hsieh and Klenow (2009)

In this section, we use the methodology of Hsieh and Klenow (2009) to calculate the potential TFP gains in the Korean manufacturing industry and its subsectors when resource misallocation is removed.[3] This methodology is based on the model of monopolistic competition with heterogeneous firms which produce differentiated products.[4] The final good Y of the manufacturing industry is the combination of the output Y_S of S sectors in the industry using a Cobb-Douglas aggregate, $Y=\prod_{s=1}^{S} Y_s^{\theta_s}$, where $\sum_{s=1}^{S} \theta_s = 1$. The output of each sector in the industry is a CES aggregate of M_s differentiated products such that $Y_s=(\sum_{i=1}^{M_s} Y_{s_i}^{\frac{\sigma-1}{\sigma}})^{\frac{\sigma}{\sigma-1}}$.[5] The production function for each product is specified as a Cobb-Douglas function such that $Y_{s_i}=A_{s_i}K_{s_i}^{\alpha_s}L_{s_i}^{1-\alpha_s}$. It is based on the assumption that the capital share, α_s, does not differ across firms but may differ across sectors. From this, we note that the labor and capital income shares of each firm are identical regardless of A_{s_i} as long as there is no distortion. Each firm hires the factors of production, capital and labor, to maximize its profit, and thus the demand for each factor is affected by market distortions. This situation leads to the

[3]Following the presentation of the methodology is an exact reproduction of Hsieh and Klenow (2009).
[4]The model assumes that each firm has a single plant which produces a single differentiated product.
[5]Thus, the demand for each product is $Y_{s_i}=(\frac{P_{s_i}}{P_s})^{-\sigma} Y_s$.

difference in the income shares of firms within a sector.

The model introduces distortions that affect the both capital and labor, as we note the profit of each firm such that $\pi_{s_i}=\left(1\text{-}\tau_{Y_{s_i}}\right)P_{s_i}Y_{s_i}\text{-}wL_{s_i}\text{-}\left(1+\tau_{K_{s_i}}\right)RK_{s_i}$, where P_{s_i}, w, and R are the output price, wage and rental price of capital, respectively. $\tau_{Y_{s_i}}$ denotes the output distortion. A positive values of $\tau_{Y_{s_i}}$ implies the existence of unfavorable factors which restrict the expansion of firms, such as government regulations and higher corporate income taxes. However, a public output subsidy would lower $\tau_{Y_{s_i}}$. $\tau_{K_{s_i}}$ denotes the capital distortion that raises the marginal product of capital relative to labor. A positive $\tau_{K_{s_i}}$ implies the existence of unfavorable factors which increase the cost of capital. An inexpensive policy credit will lower $\tau_{K_{s_i}}$ for firms but difficult access to credit will raise it.

The capital and output distortions, $\tau_{K_{s_i}}$ and $\tau_{Y_{s_i}}$, can be inferred from the condition of profit maximization as $1+\tau_{K_{si}}=(\frac{\alpha_s}{1\text{-}\alpha_s})\frac{wL_{s_i}}{RK_{s_i}}$ and $1\text{-}\tau_{Y_{si}}=(\frac{\sigma}{\sigma\text{-}1})(\frac{1}{1\text{-}\alpha_s})\frac{wL_{s_i}}{P_{s_i}Y_{s_i}}$. Thus, $\tau_{K_{s_i}}$ is the discrepancy between the labor and capital income ratio of a plant relative to what one would expect from the output elasticities with respect to capital and labor. $\tau_{Y_{si}}$ is the discrepancy between a firm's labor income share and output elasticity relative to labor, which equals the labor income share of the sector to which the firm belongs.

Following Foster, Haltiwanger and Syverson (2008), the model distinguishes between physical and revenue productivity. Under monopolistic competition, physical productivity is negatively correlated with output prices, while revenue productivity is positively correlated with output prices. Therefore, the distortions which affect the prices appear in the revenue productivity of firms, $TFPR_{s_i}(=P_{s_i}A_{s_i})$, such that $TFPR_{s_i}=\left(\frac{\sigma}{\sigma\text{-}1}\right)\left(\frac{R}{\alpha_s}\right)^{\alpha_s}\left(\frac{w}{1\text{-}\alpha_s}\right)^{1\text{-}\alpha_s}\frac{(1+\tau_{K_{s_i}})^{\alpha_s}}{(1\text{-}\tau_{Y_{s_i}})}$. Thus, TFPR will not differ across firms without distortion, where more resources will be allocated to firms with higher physical productivity levels to lower their prices, thus causing the revenue productivity differential to disappear. Therefore, when $\frac{(1+\tau_{K_{s_i}})^{\alpha_s}}{(1\text{-}\tau_{Y_{s_i}})}$ is greater than 1, the firm uses fewer resources than it would without distortions.

The sector TFP is expressed as $TFP_s=\left(\sum_{i=1}^{M_s}\left(A_{s_i}\frac{\overline{TFPR_s}}{TFPR_{s_i}}\right)^{\sigma\text{-}1}\right)^{\frac{1}{\sigma\text{-}1}}$, where $\overline{TFPR_s}$ $(=\frac{P_sY_s}{K_s^{\alpha_s}L_s^{1\text{-}\alpha_s}})$ is the geometric average of the average marginal revenue product of capital and labor.[6] The physical TFP can be inferred, as $A_{s_i}=w^{1\text{-}\alpha_s}(P_sY_s)^{-\frac{1}{\sigma\text{-}1}}\frac{(P_{s_i}Y_{s_i})^{\frac{\sigma}{\sigma\text{-}1}}}{K_{s_i}^{\alpha_s}L_{s_i}^{1\text{-}\alpha_s}}$.[7]

[6]Note that $TFPR_{s_i}\propto(MRPK_{s_i})^{\alpha_s}(MRPL_{s_i})^{1\text{-}\alpha_s}\propto\frac{(1+\tau_{K_{s_i}})^{\alpha_s}}{(1\text{-}\tau_{Y_{s_i}})}$

[7]$w^{1\text{-}\alpha_s}(P_sY_s)^{-\frac{1}{\sigma\text{-}1}}$ is not observable but is constant across firms. Thus, relative productivities are not affected by setting this term to 1.

When there is no distortion, the industry TFP becomes $\overline{A}_s$ such that $\overline{A}_s=(\sum_{s_i=1}^{M} A_{s_i}^{\sigma-1})^{\frac{1}{\sigma-1}}$. The potential gain in the sector TFP by removing distortions can be measured as $(\overline{A}_s - TFP_s)/TFP_s$. Finally, the potential gain in the industry TFP can be computed by taking the geometric average of the sectoral TFP gains in the industry weighted by the share of the sector in the industry output. The TFP gain is considered as a measure of allocation inefficiency.

To calculate the TFP gains, we use data from the Statistical Survey on Mining and Manufacturing, which is conducted by the Korea National Statistical Office. The survey provides information on the characteristics of manufacturing plants in Korea with more than four workers up to 2006 and with more than nine workers afterwards. In this study, we use data on plants with more than nine workers from the period of 1991-2011.[8] Output is defined as value-added output. Labor is defined as the total labor compensation, as in Hsieh and Klenow (2009), to take the quality of the workers into consideration. Capital stock is defined as the book value of the fixed capital stock. The capital stock for every year is calculated by taking the average of the book value of the fixed capital stock at the beginning and end of the year.

We classify sectors in the manufacturing industry using the three-digit ISIC level. To be consistent with the assumptions of the model in the analysis of the effects of resource misallocation on productivity, a more disaggregate level of industrial classification is better, as the model used here assumes that the products manufactured by plants in an identical sector are differentiated but substitutable for each other. Foster, Haltiwanger and Syverson (2008) analyzed sectors such as boxes, bread, coffee, gasoline, plywood and sugar, consistent with the spirit of the basic setting of the model in terms of products made by sectors. Lee, Hwang and Seol (2013) and Ji and Jeong (2015) used the data at the four-digit ISIC level, as in Hsieh and Klenow (2008). This paper uses the data at three-digit ISIC level due to our limited access to finer classifications of the manufacturing subsectors. Because this study attempts to calculate the evolutions of TFP gains of sectors in the manufacturing industry, consistency of the industry classification is important. However, aligning industrial classifications at a more disaggregate level is difficult with the data used here.

In this sense, our estimate may overestimate the effects of resource misallocation compared to other studies with more disaggregated levels of classification. However, the analysis at the four-digit ISIC level is still not immune to a similar problem unless we apply the model to a very fine product level of classification.[9] Thus, the indicators of distortion estimated here include not only the effects of distortion on resource allocation in the market but also the effects of unavoidable plant-level heterogeneity caused by intrinsic functional differences in production levels.[10] Thus, the potential gains estimated here may include those stemming

[8]Raw data for the survey are available starting in 1980. However, the quality of the data in the survey in the 1980s is not as good given the relatively small number of plants.

[9]The number of sectors at the three-digit level is close to 60, while there are approximately 170 at the four-digit level. To be strict given the basic assumptions of the model, further disaggregation is necessary.

[10]A functional difference may exist even with the product-level classification because the functional form of production is very simple given that factors such as managerial input and other are omitted.

from intra-sector shifts of resources from subsectors with different levels of TFP relative to the marginal productivity of the resources.

Considering that the industry classification system changed in 1998 and 2007, we aligned the industrial classification to be consistent across periods with a different classification system.[11] In addition, we removed outlier plants by trimming 1% of $log\left(\frac{TFPR_{s_i}}{\overline{TFPR_s}}\right)$ and $log(\frac{A_{s_i}}{\overline{A_s}})$ across industries and set σ to 3 and R to 0.1, as in Hsieh and Klenow (2009).

We estimate the sector capital income share, α_s by subtracting the labor income share from 1, where the labor income share is computed by dividing labor compensation by total value-added, as in Lee, Hwang and Seol (2013). Ji and Jeong (2015) used the capital income share of the U.S. manufacturing industry following the method of Hsieh and Klenow (2009). They applied the capital income share of the U.S. manufacturing industry to India and China by assuming that the U.S. production structure is less distorted. It appears too restrictive to assume the functional specification of production to be identical across countries. As the theory of appropriate technology implies, production technology may differ depending on the relative scarcity of factors in the country and technological level of the sectors.

Figure 1 shows the potential TFP gains ($=\prod_{s=1}^{M_s}((\overline{A}_s - TFP_s)/TFP_s)^{\theta_s}$) from the hypothetical efficient allocation. It was approximately 10 % in the early 1990s and stayed at a similar level until 1997. It then rose sharply to 18 % between 1998 and 2000, when Korea suffered a deep recession due to the economic crisis, after which it went down as the Korean economy recovered from the crisis, and then rose to 24% in 2008. The fluctuation in the TFP gains is not surprising, as these values are sensitive to the business cycle due to the intrinsic rigidity of resource reallocation.

The TFP gains calculated here are somewhat comparable to those of Lee, Hwang and Seol (2013) who reported that the TFP gains in 1992 and 2008 were 7.6% and 25.3%, respectively. These TFP gains are much lower than those in Ji and Jeong (2015), who used the industry capital income share of the U.S. manufacturing industry. They reported that the TFP gains in Korea were 50.1% until the early 2000s and that they increased to 73% in 2012. From this, we know that this measure is quite sensitive to how we measure the industry capital income share and that Hsieh and Klenow (2009) may have overestimated the TFP gains or the degree of resource misallocation of India and China. However, the trend of TFP gains in Ji and Jeong (2015) does not differ greatly from ours. We can therefore conclude that the allocation efficiency in the Korean manufacturing industry has been deteriorating since the 1990s given our comparison of the TFP gains in the 2000s with those in the 1990s.

Ji and Jeong (2015) simulated TFP gains over time with and without the top 10% tail of $log(\frac{\overline{TFPR_s}}{TFPRs_i})$ and found that when we remove the top 10% tail, the TFP gains did not change much over time. They suggested the underproduction of the top

[11]Lee, Hwang and Seol (2013) did not align the industry classification.

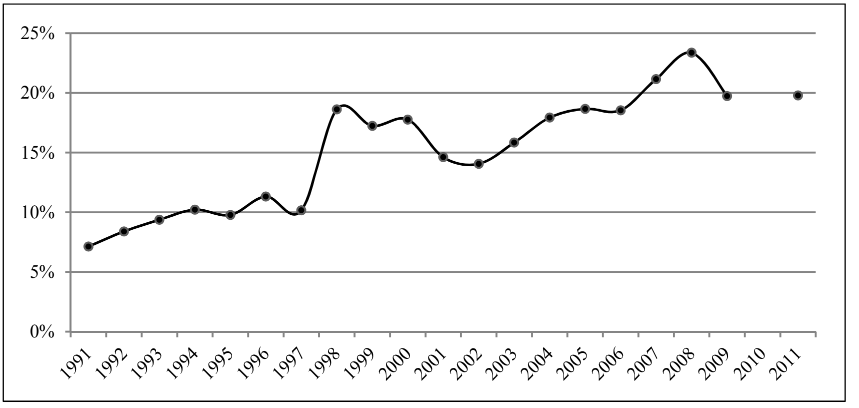

FIGURE 1. POTENTIAL TFP GAINS IN THE KOREAN MANUFACTURING INDUSTRY FOR 1991-2011

Note: The TFP gain in 2010 is not calculated because the raw data are not available for 2010 because the 2010 Total Survey on Establishments, which surveyed the manufacturing industry, did not provide all of the variables needed to compute the TFP gain.

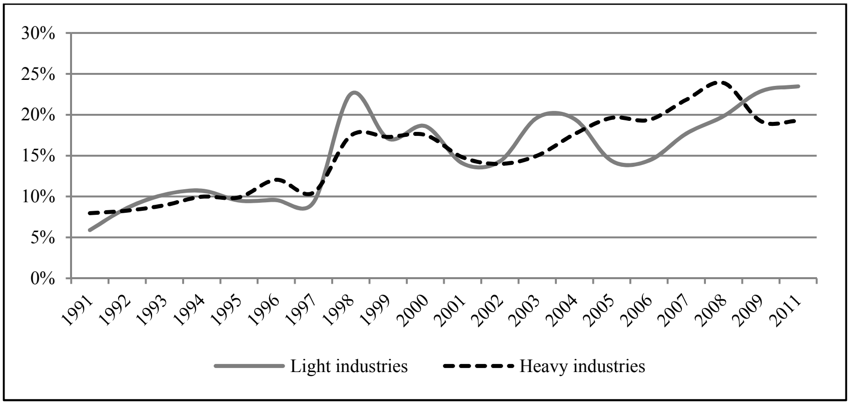

FIGURE 2. POTENTIAL TFP GAINS OF LIGHT AND HEAVY INDUSTRIES

Note: The TFP gain in 2010 is not calculated because the raw data are not available for 2010. The industrial classification is presented in the appendix.

10% productive plants as the major cause of the rise in the TFP gains. They noted the difficult degrees of credit access among young startup firms, the rising market concentration, and the survival of marginal firms which hold excessive resources relative their productivity as plausible factors behind the deterioration of resource allocation.

At this point, we examine the TFP gains of sectors in the Korean manufacturing industry. Because we have more than 50 sectors, we present here industries at a more aggregate level. Figure 2 shows the TFP gains of the light and heavy industries. The TFP gains of both industries show a rising trend over the examined period. The TFP gains of light industries fluctuate more than those of heavy industries. Because the share of heavy industries is much higher than that of light

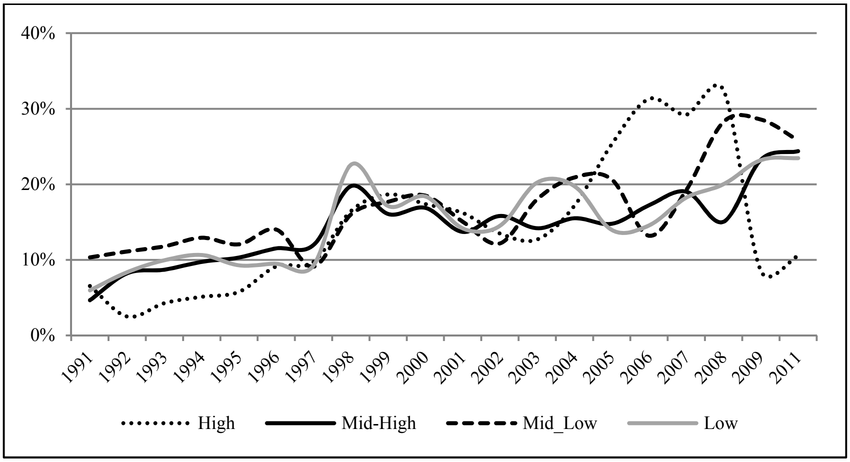

FIGURE 3. POTENTIAL TFP GAINS ACCORDING TO THE LEVEL OF TECHNOLOGY

Note: The TFP gain in 2010 is not calculated because the raw data are not available for 2010. The technology level is based on Hatzichronglue (1997). The industrial classification is presented in the appendix.

industries, the sharp rise in allocation inefficiency since 2003 was driven by the heavy industry sector.

Next, we divide the sectors into four groups according to their technology level based on Hatzichronglue (1997), who classified industries based on the level of R&D intensity. Figure 3 shows the TFP gains of industries with different technology levels. Compared with other groups, the high-tech industry shows the steepest rise in the TFP gain; particularly, the sharp rise in the aggregate TFP gain since 2003 appears to have been driven by the rising TFP gains in the high-tech industry.

Finally, we calculate the TFP gains of different groups of plants based on Pavitt's (1984) taxonomy of innovation modes. In it, firms are categorized according to the sources of technology; the degree of user dependence on innovation; and the appropriation of innovation, such as supplier-dominated, scale-intensive, specialized suppliers, and science-based industries. The innovation mode of industries could bring about different inter-sectoral linkages rather than intra-sectoral linkages. However, the innovation mode usually influences the size distribution of sectors and may serve to differentiate between resource-allocation mechanisms. According to Figure 4, the TFP gains of science-based industries rose sharply starting in 2003, as did those of high-tech industries. This was driven by the rapidly rising TFP gains of the sectors in the electronics industry. The supplier-dominated industry, whose sectors overlap with those of light industries, shows a TFP gain trend similar to that in the light industries. The specialized suppliers industry, which includes machinery, shows a steadily rising trend over time.

From the previous figures pertaining to the trends in TFP gains across different industry groups, we note that the trends in TFP gains differ greatly across industries. We would see a greater variety of patterns of TFP gains, which are considered as indicators of allocation inefficiency across sectors. If we strictly

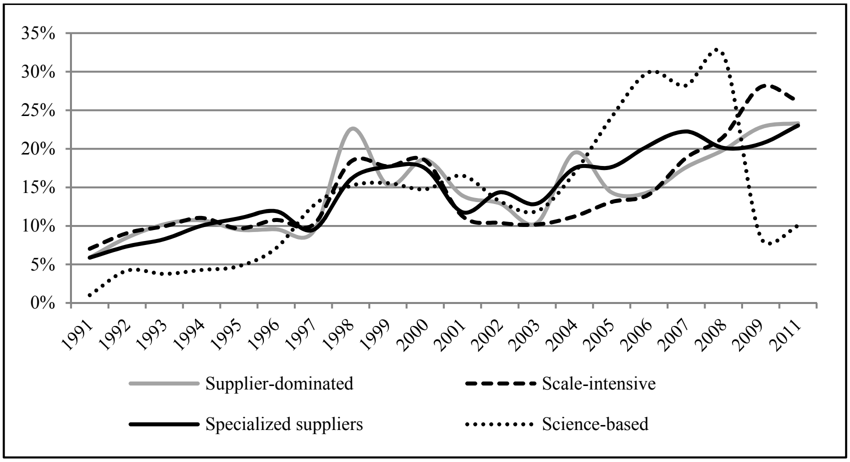

FIGURE 4. POTENTIAL TFP GAINS ACCORDING TO THE INNOVATION MODE

Note: The TFP gain in 2010 is not calculated because the raw data are not available for 2010. The classification of industries by innovation mode is based on Pavitt (1997). The industrial classification is presented in the appendix.

follow the interpretation of the TFP gains from the model as an indicator of allocation inefficiency, the question arises of how the distortions from the size-dependent policies such as special tax treatments or public subsidies to SMEs could result in such different patterns across industries. However, if we examine the heterogeneous industrial dynamics across sectors, the different patterns of the evolution of measured allocation inefficiency are not surprising, as different sectors are exposed to different types of shocks at different times, and allocation inefficiency measured in this way could be temporarily affected by the rigidity of resource reallocation in response to these shocks. Thus, we may ask whether the long-term rise in the TFP gains truly reveals rising allocation inefficiency in the Korean manufacturing industry. To assess this, we investigate long-term productivity trends in the Korean manufacturing industry.

III. Patterns of Productivity Dispersion

In the previous section, we found that the potential TFP gains in Korea are quite different across sectors in the manufacturing industry. In this section, we examine the productivity dispersions of sectors and suggest that they are closely related to the TFP gains.

Figure 5 shows the evolution of the Theil index of labor productivity dispersion of the Korean manufacturing industry for 1980-2011. The dispersion of labor productivity declined until the mid-1990s, though it has steadily increased since 2003. In the short term, it is sensitive to the business cycle and thus rises during recessions. Figure 5 also compares the productivity dispersion of light and heavy industries. The long-term trends for the labor productivity dispersion are similar between light and heavy industries, showing a U-shaped pattern starting in

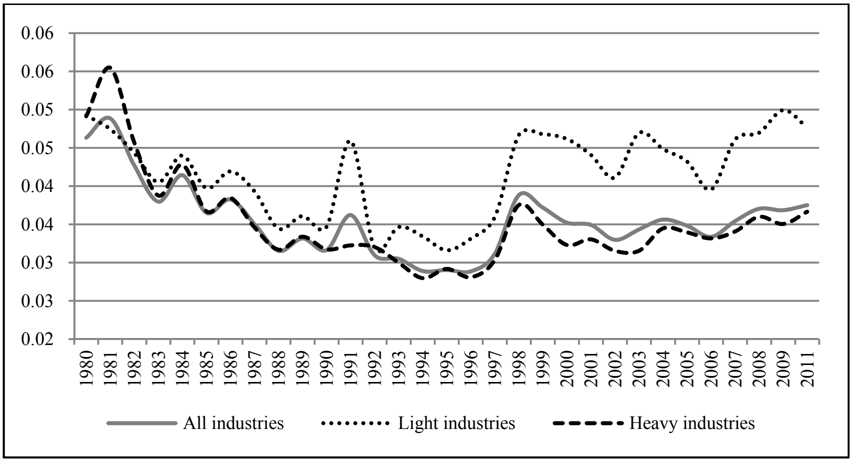

FIGURE 5. LABOR PRODUCTIVITY DISPERSION FOR 1980-2011

Note: Theil index of value-added per worker. The classification of industries is presented in the appendix.

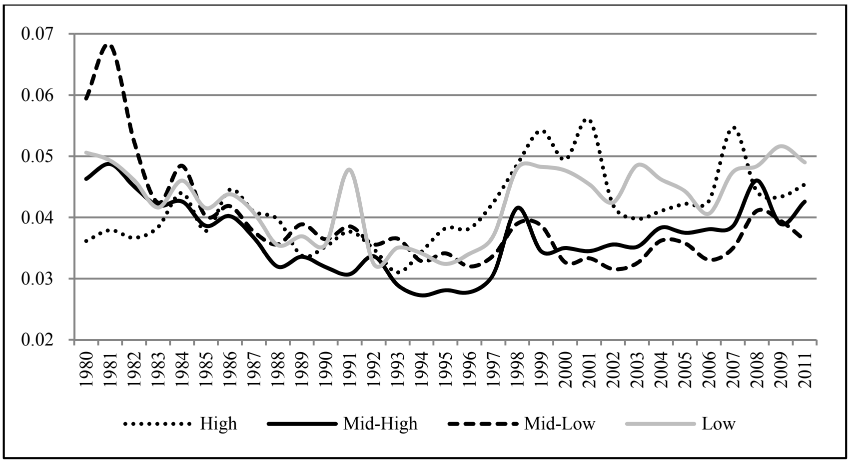

FIGURE 6. LABOR PRODUCTIVITY DISPERSION ACCORDING TO THE TECHNOLOGICAL LEVEL OF THE INDUSTRY

Note: Theil index of value-added per worker. The technology levels of industries are based on Hatzichronglue (1997). The classification of industries is presented in the appendix

the 1980s. However, the productivity dispersion for light industries has been relatively high, sharply increasing in the 2000s.[12] Figure 6 shows the productivity dispersions according to the technology level of industries. The patterns of dispersion over time are quite different across industries with different technological levels. The dispersion in high-technology industries rose in the mid-

[12]There may be many reasons for the differences in productivity across sectors and industries. It is beyond the scope of this paper to investigate these, however. Here, we focus on the various productivity trends across sectors and across specified groups of plants.

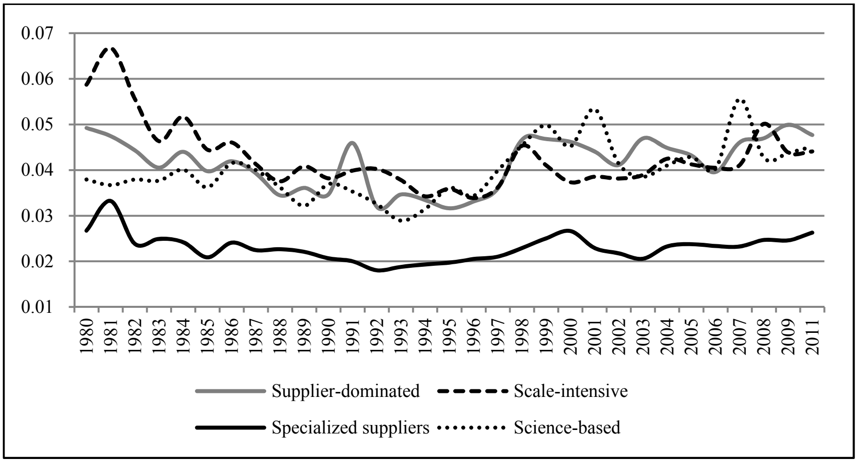

FIGURE 7. LABOR PRODUCTIVITY DISPERSION ACCORDING TO THE INNOVATION MODE

Note: Theil index of value-added per worker. The classification of industries is based on Pavitt (1984) and is presented in the appendix

1990s and remained high. It also showed significant fluctuation in the 2000s. The dispersion in low-tech industries shows a pattern similar to that of high-tech industries. In contrast, the dispersion of what are termed here ‘mid-tech’ industries did not change much, although it shows a rising trend over time. As a result, the differences in dispersion among groups at different technological levels in the 2000s were compared with those in the previous decades. Figure 7 shows the productivity dispersions of different groups of plants based on Pavitt’s (1984) taxonomy of innovation modes. All show a U-shaped trend in the productivity dispersion. However, the dispersion of specialized suppliers remained low throughout these periods. It is notable the dispersion of scale-intensive industries declined sharply in the 1980s.

In sum, the labor productivity dispersions are quite different across industries, although the overall trend for labor productivity shows a U-shaped pattern, declining in the 1980s and rising in the 2000s. Here, we add Figure 8, which shows the productivity dispersion according to the plant size. The result shows quite different patterns across groups of plants of different sizes. The productivity dispersion of large plants with more than 1000 workers has been highest since the 1990s, although it dropped sharply during the 1980s. The dispersion of plants with 300-999 workers also declined sharply until the early 1990s, following the pattern in larger plants but with a time lag. This may be due to the scaling down of firms in light industries and the increasing outward direct investment in these industries during that time.[13] The dispersion of plants with 100-299 rose sharply with the economic crisis in 1997 and remained high afterwards. Smaller plants show relatively smooth patterns of dispersion over time at lower levels of dispersion. The dispersion of small plants with 10-49 workers has been lowest compared to those

[13]If we remove textiles and apparel from the sample, the dispersions of larger plants are similar to those of the other groups.

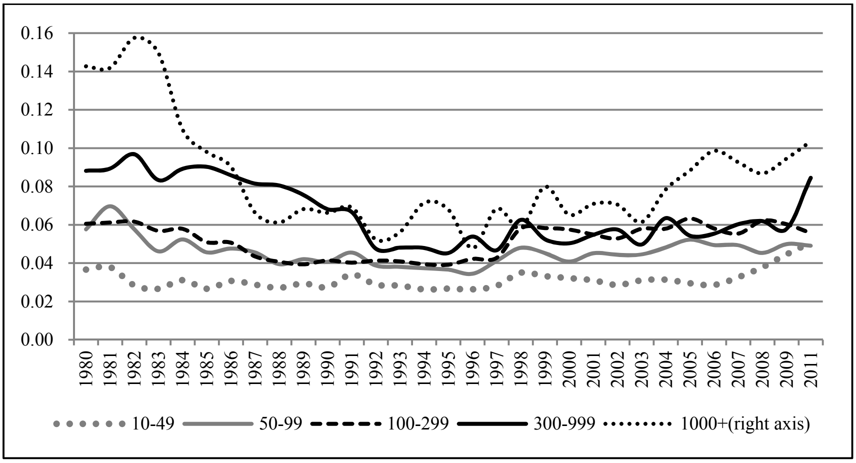

FIGURE 8. LABOR PRODUCTIVITY DISPERSION BY PLANT SIZE

Note: Theil index of value-added per worker. The size of the plants is defined as the number of workers in the plants.

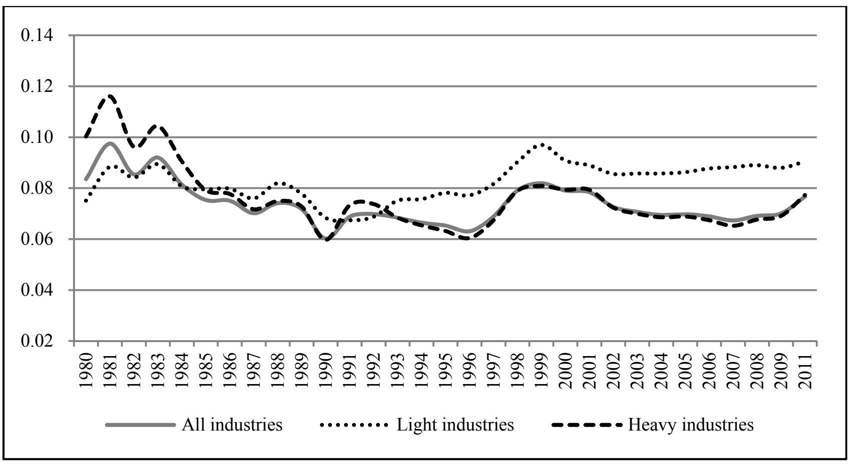

FIGURE 9. CAPITAL INTENSITY DISPERSION FOR 1980-2011

Note: Theil index of capital per worker. Industry classification is presented in the appendix.

of the larger plants, remaining at this level without much change over the period until the mid-2000s.

What drives the long-term evolution of labor productivity dispersion? We decompose the dispersion of labor productivity into the dispersions of TFP and capital intensity while assuming the Cobb-Douglas production function such that $Y_i = A_i K_i^{\alpha_i} L_i^{1-\alpha_i}$, where α_i is the capital income share, which is 1 minus the labor income share of plant i. Figure 9, Figure 10, and Figure 11 show the capital intensity dispersions. First, the capital intensity dispersion is higher than the labor productivity dispersion. It declined in the 1980s, rose during the economic crisis in

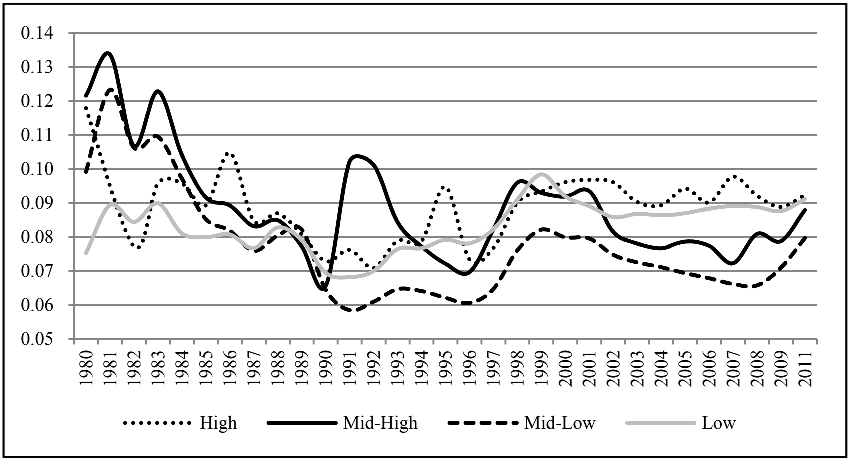

FIGURE 10. CAPITAL INTENSITY DISPERSION ACCORDING TO THE LEVEL OF TECHNOLOGY

Note: Theil index of capital per worker. Industry classification is presented in the appendix.

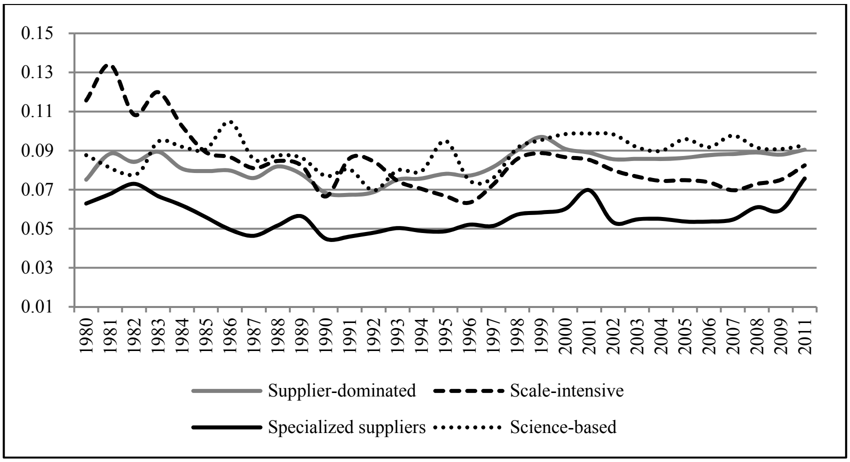

FIGURE 11. CAPITAL INTENSITY DISPERSION ACCORDING TO THE INNOVATION MODE

Note: Theil index of capital per worker. Industry classification is presented in the appendix.

the late 1990s, and declined steadily afterwards. Given that the number of plants in the heavy industries is much greater than that in the light industries, the overall dispersion of the capital intensity is similar to that in the heavy industries. The capital intensity dispersion in light industries is higher than in heavy industries. Second, as the labor productivity dispersion, the patterns of the capital intensity dispersion are also different across industries. Overall, the capital intensity dispersions did not increase much in the 2000s.

Figure 12, Figure 13, and Figure 14 show the TFP dispersions. First, the TFP dispersion of the manufacturing industry shows a clearly rising trend in the 2000s compared to the dispersions of labor productivity and capital intensity. As a result, it shows a U-shaped trend starting in the 1980s. Second, the trends of the TFP dispersion are quite different across industries. The rising trend of the TFP dispersion in the Korean manufacturing industry was driven by the rapidly rising TFP dispersion of the high-tech and low-tech industries. It is noteworthy that the rise in the TFP gains in the previous section was driven by high-tech industries in the 2000s.

From the exploration of the productivity dispersions in the Korean manufacturing industry, we find that the productivity dispersions across industries display quite different patterns in their long-term trends, although the overall trend of the productivity dispersions shows a U-shaped pattern, declining in the 1980s and rising in the 2000s. In terms of appearance, the long-term trend of the labor productivity dispersion appears to have been driven by the TFP dispersion. The capital intensity

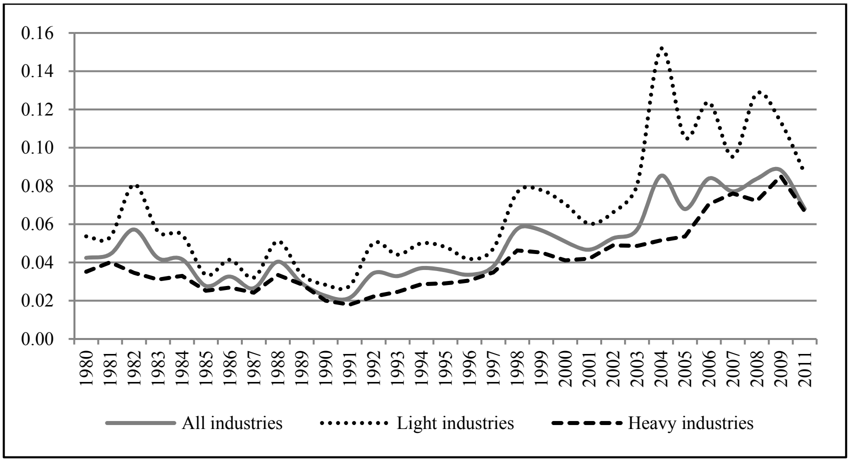

FIGURE 12. TFP DISPERSION

Note: Theil index of TFP. Industry classification is presented in the appendix.

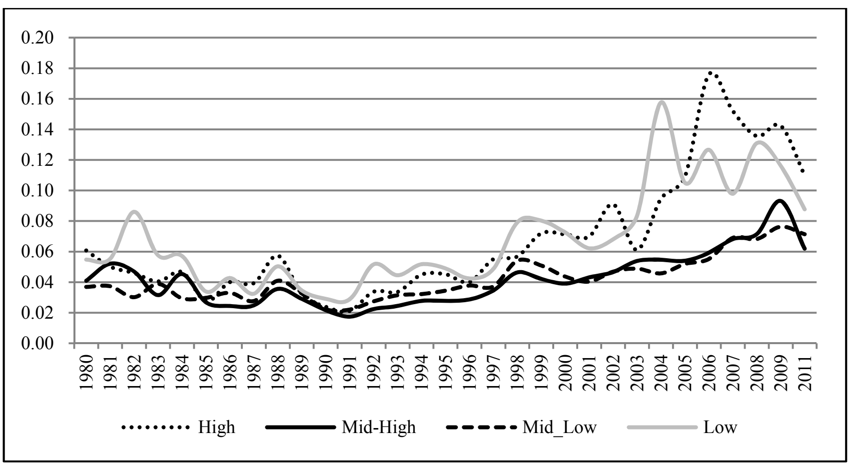

FIGURE 13. TFP DISPERSION ACCORDING TO THE LEVEL OF TECHNOLOGY

Note: Theil index of TFP. Industry classification is presented in the appendix.

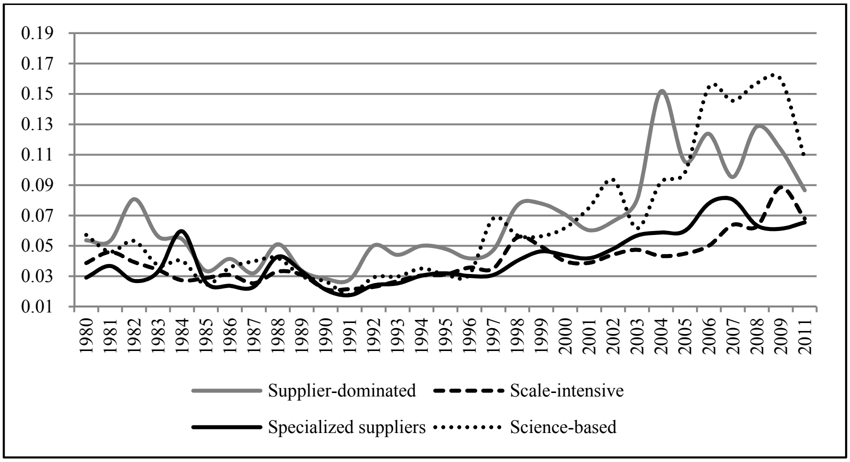

FIGURE 14. TFP DISPERSION BY INNOVATION MODE

Note: Theil index of TFP. Industry classification is presented in the appendix.

dispersions show considerable changes over time, although the capital intensity is more dispersed. Thus, we surmise that the rising TFP gains in the 2000s may be related to the rising TFP dispersions given the similarity in their long-term trends.

IV. Explaining the Rising TFP Gains in the Korean Manufacturing Industry

In this section, we attempt empirically to examine the rising TFP gains by investigating their correlations with the TFP dispersions and factors of allocation distortion. Because we calculate both output and capital distortion ($\tau_{K_{s_i}}$ and $\tau_{Y_{s_i}}$) for each plant, it will be ideal to investigate the relationship between these calculated distortion factors of individual plants and variables related to each plant's tax rates, subsidies, degree of credit access, access to cheap credit, labor rigidity and other factors. However, we do not have plant-level data related to these factors. In addition, because we cannot identify the plants in the raw data, we cannot trace the changes in the distortion factors over time at the plant level. Therefore, we attempt to explain the variations in the TFP gains across sectors by correlating the TFP gains of the sectors with proxies which characterize the factors causing the resource misallocations of sectors.

First, we examine the relationship between the TFP gains and the TFP dispersions across sectors. We estimate from the figures in the previous section that the TFP gains would be positively correlated with the TFP dispersions. Table 1 shows the empirical results of the correlation between the TFP gains and the TFP dispersions. We run an OLS regression by pooling data for the period of 1991-2011 (excluding 2010, when the data are not available) without fixed effects and with sector-specific fixed effects, period-specific fixed effects and both fixed effects in the regression. We find there is a significant correlation between the TFP gains and TFP dispersions. The explanatory power of the TFP dispersion is higher with

TABLE 1—TFP GAINS

	Dependent variable: TFP Gains			
	(1) Pooling	(2) Sector effects	(3) Period effects	(4) Sector & period effects
TFP dispersion	1.586***	2.559***	0.716***	1.728***
Number of obs.	1060	1060	1060	1060
R-squared	0.076	0.542	0.154	0.583
F-statistic	86.749***	22.478***	9.152***	18.953***

Note: ***, ** and * indicate statistical significance at the 1%, 5% and 10% level, respectively. The TFP dispersion is measured by the Theil index.

sector-specific fixed effects than with period-specific fixed effects, implying that the TFP dispersion explains the variations in the TFP gains across periods better than the variations in the TFP gains across sectors. That is, there is a significant difference across sectors other than those explained by the different TFP dispersions across sectors. This may be due to the significantly sharp rise in the TFP gains regardless of the sector when the economy experienced the economic crisis of 1997.

Next, we examine the relationship between the TFP gains and the proxies for the distortions suggested in the literature. It is not easy to find adequate proxies for distortion factors. First, following Meritz (2003), who showed that export exposure reduces resource misallocation, we examined whether sectoral exports are related to TFP gains. Because we do not have the export data of plants in the raw data, we instead compute the ratio of exports to the gross output of the sectors in the I-O table.[14] We expect a negative correlation.[15] Secondly, we choose the concentration ratio (the share of the top three plants in terms of sectoral output), which may affect TFP gains. We expect a positive correlation under the assumption that a concentrated market with less competition is less efficient. Third, we consider the average age of the plants. We expect a positive correlation between the ages of plants and allocation inefficiency. Sectors with a younger age on average would be more active in terms of the entry and exit of plants and may be more efficient with regard to resource allocation. Fourth, we examine the correlation between the average size of the plants (computed as the number of workers divided by number of plants in the sector) and the TFP gains. After the economic crisis of 1997, the number of plants increased while the number of workers decreased.[16] As a result, the sizes of plants in some sectors decreased. According to Guner, Ventura and Xu (2008), a reduction in the plant size may have a negative effect on resource allocation, as size-dependent policy distortions reduce the sizes of plants. Finally, we include the ratio of white collar workers in total employment following Bartelsman, Haltiwanger and Scarpetta (2013), who emphasized the relationship between overhead labor and distortions. The existence of considerable overhead labor acts as a source of friction, which prevents firms from adjusting resource allocation to become efficient in response to productivity changes. We expect that a larger ratio of white collar workers will lead to more inefficiency in the resource

[14]We use the I-O table for 1995 and 2005 and we use export-output ratios in 1995 and 2005 in the regression.

[15]Be reminded that the higher the TFP gains, the higher the allocation inefficiency.

[16]The average size of the plants in manufacturing industry decreased from 48.4 workers in the 1990s (the average of 1992-1997) to 39.9 workers in the 2000s (average of 2002-2007) according to the Survey. The changes in the sizes of plants are quite different across sectors.

allocation (i.e., higher TFP gains).[17] We computed the ratio of white collar workers using data obtained from the Basic Survey of Wage Structure conducted by the Ministry of Labor.[18]

To examine the correlation between the factors of distortions and the TFP gains empirically, we compute the average of the variables for the periods of 1992-1997 and 2002-2007 while excluding years which may be affected by sharp recessions during an economic crisis and run the regression with fixed effects by pooling the data.[19] Table 2 shows the correlation between the plausible determinants of resource inefficiency and TFP gains. The export ratio and the concentration ratio are not significant. The plant size, age and white collar ratio are significant. The sign of the correlation between the plant size and the TFP gains is positive, whereas we expected a negative sign from the theory. The correlation between plant age and TFP gains is not negative, as we expected. The sign of the white collar ratio is consistent with the theory. However, when we run the regressions with these variables while including the TFP dispersion, as shown in column (7), only the TFP dispersion is significant.[20] This finding implies that the variations in the TFP gains across sectors are mainly explained by the variations of the TFP dispersion in the sectors.

From Table 1 and Table 2, we note that the rising TFP gains could be better explained by the rising TFP dispersions than by the deterioration of resource allocation, as implied in the model devised by Hsieh and Klenow (2009). Therefore, we should know why the TFP dispersion increased in the 2000s compared to the 1990s to understand the rising potential TFP gains as measured by the model. The increase in the TFP dispersion indicates that the TFP became more

TABLE 2—DETERMINANTS OF THE TFP GAINS

	Dependent variable: TFP Gains						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
TFP dispersion	2.926***						3.354***
Export ratio		0.001					0.001*
Concentration ratio			-0.126				0.024
Size				0.207***			0.007
Age					-0.079**		-0.023
White collar ratio						0.529***	-0.175
Number of obs.	106	106	106	106	106	106	106
R-squared	0.861	0.748	0.746	0.817	0.769	0.809	0.875
F-statistic	6.054***	2.911***	2.879***	4.368***	3.266***	4.145***	5.665***

Note: ***, ** and * indicate statistical significance at the 1%, 5% and 10% level, respectively. Age is the log of the average age of plants. Size is the log of the average number of workers per plant. The empirical results are from regressions with sector-specific fixed effects.

[17]There could be other distortion factors to consider. For example, following Rajan and Zingales (199), Hosono and Takizawa (2012) tested whether external finance dependence is related to the distortion factor calculated based on the methodology of Hsieh and Klenow (2009). However, we cannot include this factor due to data limitations.

[18]The data are available starting in 1993. Thus, we use the averages for 1993-1997 and for 2002-2007 in the regression.

[19]We also run the regression by pooling data for 1991-2011 and find that size and CR3 are significant but that age is not significant. The sign of CR3 is positive, as expected, but that of size is positive. Moreover, the Theil index of TFP dominates over the other variables when we run the regression together.

[20]We also ran the regressions with TFP dispersion and the subgroups of the factors of distortion, finding that the results did not change much.

differentiated across the plants in the sector. Because we cannot identify the individual plants, it is not easy to distinguish whether the rising TFP dispersion comes from the increasing heterogeneity of TFP shocks to the plants or from the widening TFP gap across the plants over time. If the rising TFP dispersion comes from the rising heterogeneity of shocks, the rising TFP dispersion itself cannot be interpreted as a symptom of resource misallocation. In this case, it reflects the unavoidable rigidity of the plant's resource reallocation in response to temporal TFP shocks. This can differ across sectors and even across plants within sectors depending on the characteristics of the technology and the production process. It is not related to the price distortions faced by a firm. For instance, plants in scale-intensive industries may not easily adjust their capital-output ratios in the short run.

TFP gains measured based on Hsieh and Klenow (2009) could be interpreted as an indicator of allocation inefficiency if the TFP dispersions do not change much over time. If the TFP gains increase even with an unchanged TFP dispersion, we may interpret the rising TFP gains as an indicator of falling efficiency. However, like the Korean manufacturing industry, in which TFP dispersions change greatly, we cannot conclude that the resource allocation became less efficient simply by looking at the rising TFP gains measured by the model. The rising TFP dispersion could be related to structural changes in the production process, including outsourcing and offshoring. For instance, plants could procure intermediate goods in different ways, from domestic producers or foreign producers, and they may also outsource production to other firms through subcontracting in the global production network. With changing networks of production, different plants could face different prices and use different technologies depending on the production network to which they belong. In the long run, the production process tends to become similar across plants if the plants catch up with most efficient firms in networking the production. In Table 3, we examine the correlation between TFP dispersions and outward direct investments of the sectors. The data on outward direct investments were obtained from the internet database of the Korea Export-Import Bank. We find that there is a significant correlation. We also include dummy variables for the technology level and innovation mode of industries, but they are not significant, although this result reflects the relatively large TFP

TABLE 3—DETERMINANTS OF TFP DISPERSIONS

	Dependent variable: Theil Index		
	(1)	(2)	(3)
ODI	0.004***	0.004***	0.004***
Tech2		-0.003	
Tech3		-0.006	
Tech4		-0.005	
PAV2			-0.003
PAV3			-0.003
PAV4			-0.009*
Number of obs.	106	106	106
R-squared	0.108	0.125	0.128
F-statistic	12.606***	3.603***	3.714***

Note: ***, ** and * indicate statistical significance at the 1%, 5% and 10% level, respectively. Tech1, Tech2, Tech3 and Tech4 are low-tech, mid-low tech, mid-high tech and high-tech industry dummies, respectively. PAV1, PAV2, PAV3 and PAV4 are supplier-dominated, scale-intensive, specialized-supplier and science-based industry dummies, respectively. ODI is the log of outward direct investments. We allowed sector-specific random effects in the regressions with dummy variables for technology level and the innovation mode of the industry.

dispersion in low-tech and supplier-dominated industries, such as textiles.

Because this is a simple regression, we cannot tell how outward direct investments increase the TFP dispersion specifically. However, the findings show that aspects of sectoral dynamism in production, such as outward direct investments, may instigate more dispersion in the TFP across plants depending on their positions related to changing situations, such as a rising global production network. A comprehensive study is needed to investigate the rising TFP dispersion, which could be an interesting subject for future study.

V. Conclusion

In this study, we calculate the potential TFP gains for the Korean manufacturing industry following Hsieh and Klenow (2009), who suggested TFP gains as an indicator of resource misallocation. According to this measure, the allocation efficiency of Korea was worse in the 2000s than it was in the 1990s, similar to the findings of other studies using the same methodology. We compared the patterns of the calculated TFP gains for sectors in the manufacturing industry and those of the TFP dispersions and found that there is clear similarity between the two.

We examined the correlation between the calculated TFP gains and the TFP dispersions (the Theil index of the TFP) using panel regressions and found that there is significant correlation between the two variables. We also investigated the correlation between the TFP gains and proxies for distortion factors. The empirical results indicate that the variations of the TFP gain across sectors could be explained by the variations in the TFP dispersion rather than variations in distortion factors. Therefore, we can conclude that the rising TFP gains calculated based on the macroeconomic model linking allocation inefficiency and aggregate TFP do not necessarily imply deteriorating allocation efficiency, at least in case of the Korean manufacturing industry. The Korean manufacturing industry underwent a drastic transformation starting in the mid-1990s, and the dynamics of sectors in terms of technology and production processers such as outsourcing and offshoring may have led to an increase in the dispersion of TFP across the plants within sector. Therefore, we should investigate the causes of the rising TFP dispersions rather than the effects of distortion factors to understand the rising TFP gains calculated by the model of Hsieh and Klenow (2009).

This model suggests an easy-to-apply methodology with a good theoretical background, but one should be concerned with where to apply the model. To be consistent with the theoretical grounds of the model, one should use industries which produce products that are roughly homogeneous with small quality variation, as in Foster, Haltiwanger and Syverson (2008) and Banerjee and Munshi (2004). With disaggregation at the three-digit or four-digit ISIC, which includes various plants which produce highly differentiated products with quite different processes and technologies, the TFP gains measured as an indicator of allocation inefficiency include not only market distortions but also many other factors which may affect the TFP of plants. In this respect, we need further evidence before concluding that the Korean manufacturing industry became more inefficient in terms of resource allocation based on the calculated TFP gains. Given that the

Korean manufacturing industry repositioned itself by actively expanding its outsourcing efforts through a global production network, it is necessary to take into account the dynamics of the industry when interpreting the measures of resource misallocation.

APPENDIX: CLASSIFICATION OF SECTORS

No.	Industries
1	Processing and Manufacturing of Meat, Fishes, Fruit, Oils and Fats
2	Dairy Products and edible Ice Cakes
3	Grain Mill Products, Starches and Starch Products
4	Other Food Products
5	Beverages
6	Spinning of Textiles and Processing of Threads and Yarns
7	Knitted Fabric Mills and Fabric Products
8	Other Made-Up Textile Articles, Except Apparel
9	Sewn Wearing Apparel, Except Fur Apparel
10	Dressing and Dyeing of Fur, Articles of Fur
11	Luggage, Footwear and Similar Products
12	Footwear and Parts of Footwear
13	Sawmilling and Planning of Wood
14	Wood Products
15	Pulp, Paper and Paperboard
16	Printing and Service Activities Related to Printing
17	Reproduction of Recorded Media
18	Refined Petroleum Products
19	Basic Chemicals
20	Other Chemical Products
21	Man-Made Fibers
22	Rubber Products
23	Plastic Products
24	Glass and Glass Products
25	Other Non-metallic Mineral Products
26	Basic Iron and Steel
27	Basic Precious and Non-ferrous Metals
28	Cast of Metals
29	Structural Metal Products, Tanks, Reservoirs and Steam Generators
30	Other Metal Products; Metal Working Service Activities
31	General Purpose Machinery
32	Special-Purpose Machinery
33	Domestic Appliances
34	Computers and Peripheral Equipment
35	Electric Motors, Generators
36	Insulated Wires and Cables, Including Insulated Code Sets
37	Primary Cells and Batteries and Accumulators
38	Electric Lamps and Bulbs
39	Other Electrical Equipment
40	Semiconductor and Electronic Components
41	Telecommunication and Broadcasting Apparatuses
42	Electronic Video and Audio Equipment
43	Instruments and Appliances for Medical, Measuring, Checking, Testing, Navigating, Controlling and Other Purposes, Except Optical Instruments
44	Spectacle, Photographic Equipment and Other Optical Instruments
45	Watches, Clocks and its Parts
46	Bodies for Motor Vehicles; Trailers and Semitrailers
47	Parts and Accessories for Motor Vehicles and Engines
48	Building of Ships and Boats
49	Railway and Tramway Locomotives and Rolling Stock
50	Aircraft, Spacecraft and its Parts
51	Other Transport Equipment
52	Furniture
53	Other Manufacturing n.e.c.

	Level of Technology	Innovation Mode	2digit level
Light Industries	Low-Tech	Supplier-Dominated	Food
			Beverages
			Textiles, Except Apparel
			Apparel, Clothing Accessories and Fur Articles
			Tanning and Dressing of Leather, Luggage and Footwear
			Wood of Wood and Cork
			Pulp, Paper and Paper
			Printing and Recorded Media
			Furniture
	Mid-low		Other Manufacturing
Heavy Industries		Scale-Intensive	Refined Petroleum
			Rubber and Plastic
			Other Non-metallic Mineral
			Basic Metal
			Fabricated Metal , Except Machinery and Furniture
			Other Transport Equipment
		Specialized-supplier	Electrical Equipment
	Mid-high		Other Machinery and Equipment
		Scale-Intensive	Chemicals
			Pharmaceuticals, Medicinal Chemicals and Botanical
			Motor Vehicles, Trailers and Semitrailers
			Other Transport Equipment
	High	Science-based	Medical, Precision and Optical Instruments
			Electronic Components, Computer, Radio, Television and Communication Equipment and Apparatuses

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Effect of Consulting on Microcredit Repayment in Korea†

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This study examines the effect of a one-on-one outsourced pre-lending consulting service on the repayment behavior of microcredit borrowers in Korea with administrative data from the Smile Microcredit Bank. A random change in the cut-off loan amount for mandatory consulting is utilized as an identification strategy. This three-day pre-lending business consulting service is effective in encouraging repayment behavior of existing businesses but it has no significant effect on start-up loans. The effectiveness of the consulting service in deterring delinquency with regard to existing loans is greater among male borrowers than among females.

Key Word: Microcredit, Non-financial Service, Consulting, Loan, Repayment, Arrear
JEL Code: D1, G21, J1, L3, N25

I. Introduction

Since Muhammad Yunus initiated the Grameen Bank in Bangladesh in 1976, several developed countries have introduced microcredit businesses as well to ease financial exclusion in their countries. In Korea, microcredit programs were started around the year 2000 by small non-governmental organizations such as the Joyful Union and the Social Solidarity Bank. After the global financial crisis, around 2010, the Korean government launched various political microcredit products,[1] including the Smile Microcredit Bank (SMB). The SMB provides low-interest loans ranging from 2% to 4.5% to people with poor credit ratings[2] (grades 7-10) or to

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[1]Political microcredit products include the New Hope Loans of commercial banks and the Sunshine Loans of non-bank depository institutions.
[2]The credit rating scheme in Korean ranges from 1-10, where 1 is the best and 10 is the worst.

those with low incomes.[3]

Although the SMB has grown through a government initiative, it is a non-profit organization whose source of funding consists of deposits in dormant accounts and donations. The SMB also provides business development services, as other typical microfinance institutions (MFIs) do. However, some critics argue that the government-led SMB is limited in terms of its business operations. The most salient critiques refer to its lackluster non-financial business development services.

The non-financial business development services include business training, consulting and mentoring. These services are commonly regarded as key functions to support the self-help of borrowers. The SMB requires that some borrowers undergo outsourced three-day one-on-one business consulting. Since the late 2012, it has also operated one-day business training programs in limited regions: Seoul and Busan. Nevertheless, non-financial support by the SMB continues to lag behind that offered by its counterparts in other advanced countries or even in developing countries. Thus, the SMB must strengthen its business development services, but this would require them to incur considerable operating costs. Therefore, a careful study should be conducted to determine how to extend such services; should the bank offer the same services to a larger number of people or should it revise the lineup of its services that are currently available?

As a first step, the current pre-lending consulting services need to be evaluated. To that end, this paper attempts to answer the following questions using administrative data from the SMB. First, could outsourced pre-lending business consulting increase the probability of repaying on time? Second, which borrowers benefit most from consulting? These questions could best be answered with a randomized controlled treatment akin to that in Karlan and Valdivia (2011). However, applying such a randomized controlled treatment in Korea and in other advanced economies is not practically feasible due to ethical issues. Therefore, this method cannot be applied to the current data on SMB borrowers.

Fortunately, however, the SMB has changed the rules pertaining to consulting requirements. Once loan applicants meet the criteria, they must receive one-on-one consulting provided by an outsourced institution before they can take out loans. The SMB has changed the consulting requirement rules at random points in time. Thus, this paper takes an advantage of these random changes to assess the effect of pre-lending consulting on reducing instances of arrears.

In fact, the ultimate long-term goal of MFIs would be to help clients increase their profit or income. Thus, the effects of consulting are best explained by analyzing profits, as in Mel *et al.* (2014) and McKernan (2002). Unfortunately, however, such an analysis is not possible because the SMB has no available information on the business performance or income of its clients. Given that the near-term primary objective of MFIs is to ensure timely repayments, the question as to whether or not a borrower will fall into arrears becomes a key concern for MFIs. Accordingly, it is important to verify whether pre-lending business consulting has any effects on preventing instances of arrears. Furthermore, microcredit users can repay their principle and interest on schedule only when they earn stable income. Therefore, arrears or the lack thereof can be a good indicator of

[3]Potential welfare recipients, welfare recipients, and people eligible for the earned income tax credit (EITC).

the clients' income status. In this sense, it is meaningful to analyze the effects of consulting on repayment behavior. Thus, this paper analyzes the effects of consulting, expanding the literature on business development services provided by MFIs (Mel *et al*. 2014; McKernan 2002; Halder 2003; Karlan and Valdivia 2011).

Moreover, this research can identify the factors behind situations in which a debtor is in arrears as they arise with regard to microcredit in advanced countries, as these factors exhibit distinctly different characteristics from those of developing countries. Microcredit pursues two fundamentally incompatible goals. Thus, it is critical for microcredit institutions to devise an effective repayment management mechanism to ensure their sustainability while at the same time to explore ways to reach out to the financially disadvantaged. Group lending based on social ties and peer monitoring is common in developing countries with advanced microfinance systems. However, this technique is not applicable to urban clients in advanced economies, who tend to be individualistic. In light of such a difference, it is necessary to find an appropriate approach that could work in advanced countries. This paper aims to analyze whether non-financial services such as consulting can promote repayment behaviors in a relatively developed country, Korea. In this context, this research expands on previous investigations in this area (Bhatt and Tang 2002; Deininger and Liu 2009; Papias and Ganesan 2009) that discuss the determinants of repayment in microcredit.

The rest of this paper is organized as follows. Section II provides an overview of the related literature on microcredit in general. Section III briefly introduces the SMB and its consulting services. Section IV describes the empirical model and data. Section V presents the estimation results. Section VI presents the conclusions and policy recommendations.

II. Literature Review

There is a large body of literature which examines the various aspects of microcredit, including its poverty reduction effect (Khandker 2005; Nawaz 2010). Among these studies, this paper is related to those which examine the determinants of repayment of microcredit clients. Cull *et al.* (2007) noted that MFIs are likely to avoid lending to poor clients when they focus primarily on maximizing profits. This implies that it is difficult to attain the two goals of sustainability and outreach simultaneously. Consequently, in microcredit, it becomes very important to understand the determinants of repayment and to establish appropriate incentivizing repayment schemes for disadvantaged clients.

A large theoretical body of work on principal/agent theory shows that joint-liable lending groups strengthen repayment behavior in microcredit (Stiglitz 1990; Besley and Coates 1995), as they facilitate peer monitoring and/or effectively utilize peer selection. Accordingly, the majority of studies on repayment focus on the group lending schemes (Bratton 1986; Zeller 1998; Wydick 1999). However, Sharma and Zeller (1997) find that group lending is particularly effective for low-income households residing in remote areas away from cities. In this respect, most of MFIs in advanced countries and the SMB in Korea do not utilize group lending schemes, where community-based mutual ties are weak.

Several studies have highlighted the effects of other factors on repayment. Field and Pande (2008) find that the repayment period, regardless of whether it is monthly or weekly, does not significant affect repayment. They also show that a monthly repayment schedule would be more cost-efficient. Khandker *et al.* (1995) find that the operational longevity of the branches in the area increases the default rate. They explain that this feature comes from the possible decrease in the marginal profitability of new projects. Zeller (1998) demonstrates that individual characteristics such as gender, youth, and the size of family do not affect repayment behavior.

Although numerous studies have examined the determinants of repayment, the majority utilize data from developing countries, as microcredit originated and was developed mostly in those countries. As a result, little is known about microcredit in developed countries, although its characteristics could be much different from those in developing countries. With U.S. data, Bhatt and Tang (2002) find that instances of arrears decrease when the bank branch and the client's business are located in the same area, and when clients are pressured and supervised with regard to their repayments. However, the sample size in Bhatt and Tang (2002) is quite small. The present paper utilizes an extensive administrative dataset from the SMB in Korea, which is the first empirical study of the SMB in Korea. Thus, this study may extend the scope of microcredit research beyond developing countries.

This paper is also related to literature which examines the effects of non-financial business development services. Most microfinance institutions offer business training and consulting services to increase their clients' self-support capabilities. These non-financial services are considered to be crucial, as they determine the success of microfinance MFIs. Many empirical studies (e.g., Mel *et al.* 2014; McKernan 2002; Halder 2003) suggest that these services have positive effects on clients' business performance or income. McKernan (2002) verifies that the increase in the business profits of clients is attributable to Grameen Bank's training programs, which were designed to teach clients how to use certain types of machinery and to produce products. Halder (2003) discovers that in Bangladesh, women who participated in the BRAC training programs offered there earned higher incomes than those who did not. Mel *et al.* (2014) compare the effect of training only program with combination of business training and cash grants on female enterprises in Sri Lanka. They find that training only increases the profitability of start-ups, not existing firms. However, if cash grants are combined with a training service, the profits of existing firms also increase.

Unlike the above-mentioned studies, this paper examines the effect of consulting on repayment behavior, rather than on business performance. Several studies also provide empirical results on this theme. Karlan and Valdivia (2011) with a randomized control experiment show that regular business education increases the possibility of on-schedule repayment and client retention. Khandker *et al.* (1995) also find that membership training has a positive influence on repayment. Godquin (2004) finds positive effects of basic literacy education and health services on repayments in Bangladesh MFIs. Godquin (2004) explains that the provision of non-financial services helps to develop relationships between MFIs and borrowers, which prevents strategic defaults and increases the ability to repay.

Similarly, a pre-lending business consulting service may also have a positive impact on repayment by SMB borrowers due to the strengthened profitability and greater level of closeness with the SMB. However, the frame of the SMB service differs from that of Godquin (2004) in that the service is not regularly provided and is executed by outsourced institutions. Moreover, the characteristics of borrowers in Korea may differ from those in developing countries. Thus, it should be empirically proven whether a pre-lending business consulting service has positive effects on repayment behavior in Korea.

III. The Consulting Service of the Smile Microcredit Bank

The SMB differs in terms of its structure and characteristics from traditional MFIs in developing or developed countries. The government led its creation and expansion, and a number of large corporate banks and private corporate groups are involved in its activities.[4] In addition, the SMB arranges business consulting services which are provided by an external outsourced consulting institute. A brief explanation of the consulting program is provided below.

A. *Process and Costs*

The SMB requires clients whose loans reach a certain amount to enroll in a business consulting program as a condition of receiving a loan. The SMB outsources the consulting services to the Small Enterprise and Market Service (SEMAS),[5] a quasi-government organization which operates under the Small and Medium Business Administration (SMBA). A client receives one-on-one consulting for three days, and consultant submits a report to the SMB about the feasibility of the client's business. However, it is very rare for consultants to report a negative opinion of the feasibility on the business.[6] Thus, the pre-lending consulting service does not function as a screening process.

The consulting program is paid for in part by a government subsidy (90%) and in part by clients (10%). The fee for clients was 50,000 won for the entire program until 2011, becoming 10,000 won per day in 2012. Previously, SEMAS used to assign consultants randomly to SMB clients, but currently clients can choose a consultant directly from the consultant pool.

B. *Contents*

Because they are one-on-one sessions, the details discussed during the consulting sessions can vary from client to client as well as from consultant to

[4]Five banks (KB, IBK, Shinhan, Woori, and Hana) and six corporate groups (LG, SK, Lotte, Samsung, Posco, Hyundai Motor) operate SMB branches within their donation fund.

[5]SEMAS fosters small enterprises, traditional markets providing education, consulting, and marketing support.

[6]There was only one case up until 2013 for which the consultant assessed the client's business as not feasible. SEMAS consultants may have an incentive not to be harsh on SMB clients, as they are also evaluated by these clients, and their remuneration depends on the average evaluation scores.

consultant. Each session is divided into two groups based on whether the borrower is already running a business or is starting a new one.

For a client who applies for a loan to cover the facility cost and operating expenses of an existing business, consulting sessions focus on presenting a comprehensive diagnostic review of the business. Consultants attempt to find solutions to current and potential problems so as to ensure the success of the business, including an analysis of the business environment, finances, accounting practices, marketing, store management, and customer management.

On the other hand, consulting programs for clients who start new businesses include a feasibility analysis, a location analysis, an examination of matters related to the opening of the store, business administration, customer management, and other matters of which the client should be aware before launching the business.

C. *Rules on Consulting Requirements*

As shown in Table 1, the loan threshold at which pre-lending consulting becomes mandatory has varied from time to time. For operating expense loans, since October of 2010, clients whose loan amounts were 10 million won or more have been required to enroll in the consulting program. However, from May to September of 2010, clients with loans worth 5 million won or more were requested to join the program. The changes to the criteria have been random and can therefore be useful if used to examine a possible link between pre-lending consulting and the probability of a business being in arrears.

For start-up loans, nearly all clients applying for loans had to complete the consulting program regardless of the loan amount. However, between September of 2010 and December of 2011, the consulting requirement applied only to those who borrowed 10 million won or more. Furthermore, start-up business consulting was replaced by the submittal of a business plan during a certain period of time. These inconsistent and random changes can be useful for determining whether the consulting service has a significant impact on preventing or reducing instances of arrears.

TABLE 1— CHANGES IN THE CONSULTING REQUIREMENT CRITERIA

Loan Type	Operating Loan			Loans for Start-ups		
Date of Loans	Under 5 million	5 ~10 million	Over 10 million	Under 5 million	5 ~10 Million	Over 10 million
January 1. 2010 ~ May 16. 2010	X	X	Required	Required	Required	Required
May 17. 2010 ~ September 27. 2010	X	Required	Required	Required	Required	Required
September 28. 2010 ~ December 14. 2011	X	X	Required	X	X	Required
December 15. 2011 ~ May 7. 2012	X	X	Required	Substitutable	Substitutable	Substitutable
May 8. 2012 ~ December 31. 2012	X	X	Required	Required	Required	Required
January 1. 2013 ~ April 22. 2013	X	X	Required	Substitutable	Substitutable	Substitutable
April 23. 2013 ~ June 30. 2013	X	X	Required	Required	Required	Required

Notes: Substitutable indicates that writing up a business plan can be done in lieu of consulting.

D. *How a Consulting Service Affects the Repayment Behavior*

There are three possible mechanisms by which pre-lending consulting may be correlated with the repayment behavior of clients. First, business consulting can have a positive impact on business performance. As a result, the profits of clients who receive consulting are greater than those of clients who do not. If consulting brings positive changes in the attitudes and the styles of doing business, the client's profits may increase. With the increased profits, the client would likely display better repayment behavior than clients who did not participate in the consulting program.

Second, pre-lending consulting can build a sense of solidarity which leads to a stronger sense of responsibility concerning repayment. In other words, even if a client's business performance remains the same, the client may form a sense of attachment to the SMB loan officer during the course of the consulting program, and this attachment may motivate the client to avoid falling behind on repayments. As Godquin (2004) explains, non-financial services may increase the value of the relationship with the MFI and increase the opportunity cost of a strategic default. Although the consulting program is operated by outsourced institutions related the SMB, the consulting program can still build responsibility in clients. Clients may not distinguish the consultant from an SMB employee, and the SMB loan officer may communicate with clients at a deeper level after receiving detailed information from the consultant.

Third, pre-lending consulting may serve as a screening process through which unqualified clients are weeded out. Indeed, it is desirable for this type of screening mechanism to work. Such a filtering process can benefit both existing and new businesses. If an existing business is not profitable and is uncompetitive, closing it down rather than incurring additional loans could be a better choice for the owner. In contrast, if the chance of failure is high for a client who plans to start a new business, it is better to let the client take the time to ensure that everything is ready instead of hurrying and prematurely opening the business. In these situations, the consulting program can help clients make better choices by giving them sufficient time to stop and reconsider their options. However, if such a screening mechanism does exist, this means that there is a selection rule that may have affected the sample.

However, as mentioned earlier, it is very rare for SEMAS consultants to report that clients are ineligible for a loan, and such a screening mechanism is practically non-existent in our sample. Therefore, this research will focus on the first two possible mechanisms: how consulting can improve the client's business performance and how it may build a sense of solidarity.

IV. Empirical Specification and Data

A. *Empirical Specification*

The previous section discussed the characteristics of business consulting with regard to loans from the SMB. In the following basic model, we use logistic regression to estimate the effect of consulting on the probability of repayment behavior:

$$Repayment_i = \alpha + \beta Consulting_i + X_i\gamma + Z_i\delta + \varepsilon_i \tag{1}$$

Here, the dependent variable $Repayment_i$ is a dummy variable which has a value of one when borrower *i* has made regular repayments on time (no arrears), taking a value of zero otherwise. $Consulting_i$ is the key regressor of interest, indicating that the borrower was required to enroll in one-on-one consulting, which is determined by the loan origination timing and the amount of the loan. If one-on-one business consulting has a positive effect on repayment behavior, the coefficient $Consulting_i$ would have a positive value.

X_i is a matrix of control variables. It includes the characteristics of the loans, in this case the amount of the loan and the length of the grace period. During a certain period, the requirement of mandatory consulting for start-up loan applicants could be satisfied instead by the writing of a business plan. Thus, a variable for this type of substitution is also included in the model for start-up loans.

X_i also includes individual characteristics of borrower *i*, in this case the credit score, a dummy variable for male, and the age of the borrower. Credit scores in Korea have a value between one and ten, where the credit score increases when the credit rating worsens. Therefore, a value of ten represents the worst credit rating, and the coefficient of the credit rating is expected to be negative. Sometimes, borrowers do not have a credit rating due to the lack of enough credit history. In this case, we assign a value of eleven, which is inferior to other borrowers with credit ratings, and we add a dummy variable to signify no credit rating. X_i also includes variables pertaining to financial status, such as the log of the average monthly income, the log of the existing total debt at the point of loan application, and the log of the total value of all assets of the borrower.

Additionally, different loan origination times should be controlled, as there would be a tendency of more instances of arrears for older loans with a larger number of payments due. Therefore, a set of control variables, denoted as Z_i, includes the remaining months to maturity and the number of expected payments due. As the effect of different loan origination times could be non-linear, the number of expected payments due is included both as a continuous variable and as several discrete dummy variables.

Moreover, the effects of consulting on repayment may not be the same for all borrowers. For example, the effect of consulting could be greater with borrowers who have more business experience. Thus, we extend the basic regression model with the interaction term $Consulting_i \times W_i$ to capture the effects of consulting on repayment according to the various types of borrowers.

$$Repayment_i = \alpha + (Consulting_i \times W_i)\beta + X_i\gamma + Z_i\delta + \varepsilon_i \quad (2)$$

We formulate several variations of W_i, which is a set of categorical variables. These are gender groups, age groups, and the types of regions based on the business site. For the region, we divide them into three groups: big cities, small cities, and rural areas. Big cities include Seoul and six large metropolitan cities. Rural areas are identified with the administrative township "Eup" or "Myeon," indicating a countryside area.

B. *Data*

The data for the analysis consists of confidential administrative data from the SMB. The raw data consists of all loans originated from January of 2010, when the SMB started to offer microcredit through its branches;[7] it includes client information from loan application documents, such as the gender and credit ratings of the borrowers and the details of their loans. Information about repayment behavior is constructed by comparing the number of actual payments and that of expected payments that must be made until the time of the observation,[8] December of 2012.

Mandatory consulting is only required for clients using standardized products that are commonly offered in all branches; thus, several special products which are offered certain specialized branches are excluded. Among the standardized products,[9] the two most common products are analyzed in this paper, i.e., start-up loans for rent deposits by new businesses and business operating loans for existing businesses.

To construct the sample for the regression, we use loans which were approved from April of 2010 to January of 2012 in order to exclude loans provided immediately after the SMB was launched. This subset is suitable for the analysis because the criteria for the consulting requirement changed for both business operating loans and start-up loans during this period. As a robustness check, we also conducted the same regression with loans that were originated in different periods.

We also exclude loans that are either too small or too large, as the cut-off point for mandatory consulting was established based on the loan amount. In the panel of start-up loans for new businesses, we use the subset of loans between 7 million and 16 million won, as the cut-off point was 10 million won in a certain period. On the other hand, for business operating loans, we use the subset of loans between

[7]The data only contains the clients of the SMB branches, excluding on-lending clients of the traditional market and other microcredit institutions.

[8]The raw data does not include information about how long the loan is overdue or when arrears occurred.

[9]Standardized products include loans for franchises, loans for education, and loans for facilities, but business operating loans and start-up loans are most common.

TABLE 2—SUMMARY STATISTICS

Loan Type	Business Operating Loans (Obs.= 3691)				Start-up Loans (Obs.= 562)			
Variable	Mean	S.D.	Min.	Max.	Mean	S.D.	Min.	Max.
Repayment (Dummy)	0.72	0.45	0	1	0.72	0.45	0	1
Consulting (Dummy)	0.36	0.48	0	1	0.75	0.43	0	1
Loan Amount (Million)	8.54	1.88	3.5	10	11.28	2.36	8	15
Grace Period (Month)	0.43	1.46	0	6	2.04	2.26	0	12
Credit Rating (1~11)	7.69	0.86	2	11	7.62	0.88	4	11
No Credit Rating (Dummy)	0.004	0.06	0	1	0.01	0.10	0	1
Male (Dummy)	0.51	0.50	0	1	0.44	0.50	0	1
Age	44.72	9.68	20	78	40.45	9.39	20	77
Income (Million)	2.41	0.88	0	7.80	2.13	1.24	0	7.50
Total Assets (Million)	31.61	29.36	0	208.50	25.51	22.37	0	130
Existing Debt (Million)	8.98	10.13	0	260	5.80	7.98	0	40.37

3 million and 12 million won, as the cut-off point was 5 million or 10 million won. Robustness tests are also performed by modifying the range of the loan amount.

Outliers are removed from the sample, such as loans to the clients who had more than 8 million won in monthly income, more than 350 million won in assets, or more than 300 million won in debt. Some clients were allowed to roll over their existing loan by taking out a new loan10, and some clients took out loans multiple times. Both such cases are also eliminated.

Summary statistics of the variables used in the empirical analysis are shown in Table 2.

V. Results and Discussion

A. *Business Operating Loans for Existing Businesses*

In this section, we present and interpret the results of the estimation of the impact of participation in pre-lending business consulting on repayment performance. The results of the main regression with business operating loans are presented in Table 3.

Table 3 displays the regression results of four specifications. The first two columns provide the marginal effect and the estimates of the base model. In specification (2), we control for the debt-to-income ratio and the debt-to-assets ratio instead of the log of assets, the log of monthly income and the log of debt. In specification (3), we control for possible non-linear effects with regard to the number of expected payments with several dummy variables instead of a continuous variable. In specification (4) we use dummy variables for the age groups instead of a continuous age variable to control for a possible non-linear effect of age. All results reported are estimated with the logistic regression model.

The results for all specifications show a positive and significant effect of pre-lending business consulting on the repayment behavior of existing entrepreneurs

[10]Roll-over loans are occasionally made to manage repayments, refreshing loans in arrears for a longer period. However, these loans are excluded, as information about the older loans is not available.

TABLE 3— MAIN REGRESSION RESULTS: OPERATING LOANS

	(1)		(2)	(3)	(4)
Variable	Marginal Effect	Estimates	Estimates	Estimates	Estimates
Consulting (Dummy)	0.051**	0.259**	0.263**	0.302***	0.260**
	(0.021)	(0.106)	(0.105)	(0.108)	(0.106)
Loan Amount (Million)	-0.012**	-0.060**	-0.057**	-0.079***	-0.062**
	(0.005)	(0.026)	(0.026)	(0.026)	(0.026)
Grace Period (Month)	-0.014**	-0.069**	-0.064**	-0.113***	-0.067**
	(0.006)	(0.031)	(0.030)	(0.034)	(0.031)
Credit Rating (1~11)	-0.050***	-0.254***	-0.257***	-0.258***	-0.256***
	(0.009)	(0.046)	(0.046)	(0.046)	(0.046)
No Credit Rating (Dummy)	0.299	1.506*	1.512*	1.504*	1.550*
	(0.158)	(0.796)	(0.790)	(0.799)	(0.795)
Male (Dummy)	-0.015	-0.077	-0.082	-0.066	-0.066
	(0.015)	(0.075)	(0.075)	(0.076)	(0.075)
Age	0.001	0.006	0.006	0.006	
	(0.001)	(0.004)	(0.004)	(0.004)	
Log Income (Million)	-0.005	-0.023		-0.022	-0.024
	(0.006)	(0.030)		(0.030)	(0.031)
Log Assets (Million)	0.004**	0.021**		0.019**	0.021**
	(0.002)	(0.009)		(0.009)	(0.009)
Log Existing Debt (Million)	-0.001	-0.003		-0.004	-0.003
	(0.001)	(0.005)		(0.005)	(0.005)
Months left to Maturity	0.006**	0.033**	0.031**	0.051***	0.032**
	(0.003)	(0.015)	(0.015)	(0.017)	(0.015)
No. of Expected Payments	-0.011***	-0.057***	-0.058***		-0.056***
	(0.002)	(0.008)	(0.008)		(0.008)
Debt / Asset			-0.000		
			(0.000)		
Debt / Income			0.000*		
			(0.000)		
Constant		4.153***	4.197***	3.482***	4.278***
		(0.528)	(0.526)	(0.518)	(0.514)
Dummies of Expected payments	x		x	o	x
Dummies of Age Groups	x		x	x	o
Observations	3,691		3,691	3,691	3,691
LogLikelihood	-2128		-2128	-2116	-2125

Notes: Robust standard errors are in parentheses; the dependent variable is repayment. Region-fixed effects are included in all specifications.
*** significant at the 1 percent level.
** significant at the 5 percent level.
* significant at the 10 percent level.

who took out operating loans. According to the marginal effect in the first column, for the average borrower, the probability of repayment without arrears increases by 5% when the borrower enrolls in the consulting service. Thus, enrolling in one-on-one business consulting has an impact similar to an increase of one grade of the credit score on the repayment performance of a typical existing entrepreneur.

This result implies that non-financial services in Korea may enhance the financial performance levels of MFIs through improved repayment behavior, as in developing countries. As the repayment behavior of micro-entrepreneurs is strongly related to the cash flow of the business, it is highly likely that the regression result is caused by the positive impact of the business consulting on the profits of micro-entrepreneurs. If an existing entrepreneur could gain useful ideas or advice from an expert from an objective perspective, the business performance of the borrower will likely improve. Utilizing the microcredit data of developing countries, Mel *et al.* (2014), Halder (2003), and McKernan (2002) also find that non-financial services have a positive impact on the profits of borrowers. However, to clarify this mechanism more directly, an additional analysis with business performance data should be conducted, though this is not available at this point.

On the other hand, the positive impact of one-on-one business consulting can also be explained by the strengthened responsibility of borrowers after in-depth communication prior to receiving a loan. Karlan and Valdivia (2011) find that regular entrepreneurship training has a positive impact on repayment performance and client retention, whereas such a service has little impact on key business outcomes such as revenue or profit levels. Godquin (2004) also finds a positive impact of non-financial services on repayment performance which is not directly related to the performance of the business, such as basic literacy education and access to health services. In the SMB, although consulting is neither regularly nor directly executed by the staff, the experience of sincere communication prior to lending may have strengthened the loyalty of borrowers to the SMB.

In both cases, it is certain that business consulting has a positive impact on the financial stability of the SMB through improved repayment performance. Currently, the recipients of pre-lending consulting for business operating loan are very limited. The consulting requirement applies only to basic products, and loans of less than 10 million won are excluded, even in basic products. Therefore, the SMB must expand its one-on-one consulting service to cover more existing micro-entrepreneurs. This will support the business performance of clients and the repayment management efforts of the SMB.

The coefficients of other variables in Table 3 are reasonable. Credit rating has a negative and significant impact on repayment performance, as a higher credit score signifies an inferior credit rating in Korea. The length of the grace period has a negative and significant coefficient, implying that originating loans without a grace period is a better management strategy for repayment by existing entrepreneurs. Income and existing debt have an insignificant impact, as these factors are already controlled through the credit rating variables.

Table 4 presents the results of the robustness checks, including estimates with pseudo-consulting indicators and estimates with a different subset. Generally, borrowers with the better credit ratings are eligible for larger loan amounts. This can also be applied to the SMB, although the SMB focuses more on borrowers' needs as compared to other typical financial institutions. Thus, we control the size of the loan and the credit rating, and we utilize the period when the cut-off point was randomly changed. However, there remains the possibility that the positive impact of consulting on repayment is a spurious relationship stemming from the fact that borrowers with larger loans tend to be more able to repay them.

To check the robustness further, we create several pseudo-consulting variables. In specification (1) of Table 4, the pseudo-consulting variable represents loans that are greater than 8 million won, and the estimate is insignificant. In specification (2), we use a different pseudo-consulting variable which counterfactually differentiates the period when the cut-off point was changed; this coefficient is also insignificant. Thus, a simple division into large and small amounts cannot determine the source of the impact of consulting on repayment.

In addition, although consulting was mandatory according to the SMB regardless

TABLE 4— ROBUSTNESS CHECKS: OPERATING LOANS

	(1)	(2)	(3)	(4)	(5)	(6)
Pseudo_Consulting1	0.125					
	(0.196)					
Pseudo_Consulting2		0.019				
		(0.136)				
Consulting (Dummy)			0.225**	0.451**	0.261**	0.230**
			(0.109)	(0.177)	(0.106)	(0.100)
Loan Amount (Million)	-0.050	-0.022	-0.054**	-0.103**	-0.064**	-0.038
	(0.048)	(0.020)	(0.026)	(0.043)	(0.026)	(0.024)
Grace Period (Month)	-0.061**	-0.062*	-0.073**	-0.142***	-0.060*	-0.055*
	(0.030)	(0.032)	(0.031)	(0.038)	(0.031)	(0.029)
Credit Rating (1~11)	-0.255***	-0.254***	-0.242***	-0.276***	-0.249***	-0.276***
	(0.046)	(0.046)	(0.047)	(0.065)	(0.046)	(0.044)
No Credit Rating (Dummy)	1.513*	1.517*	1.480*	1.779	1.476*	2.691**
	(0.797)	(0.797)	(0.796)	(1.133)	(0.796)	(1.059)
Male (Dummy)	-0.084	-0.083	-0.086	-0.137	-0.068	-0.001
	(0.075)	(0.075)	(0.076)	(0.112)	(0.076)	(0.071)
Age	0.005	0.005	0.005	0.010*	0.006	0.003
	(0.004)	(0.004)	(0.004)	(0.006)	(0.004)	(0.004)
Log Income (Million)	-0.021	-0.022	-0.023	-0.005	-0.019	-0.015
	(0.030)	(0.030)	(0.031)	(0.041)	(0.031)	(0.028)
Log Assets (Million)	0.021**	0.021**	0.020**	0.022*	0.021**	0.015*
	(0.008)	(0.008)	(0.009)	(0.011)	(0.009)	(0.008)
Log Existing Debt (Million)	-0.003	-0.003	-0.001	0.003	-0.003	-0.001
	(0.005)	(0.005)	(0.005)	(0.008)	(0.005)	(0.005)
Months left to Maturity	0.037**	0.036**	0.033**	0.052***	0.032**	-0.047***
	(0.015)	(0.015)	(0.015)	(0.019)	(0.015)	(0.008)
No. of Expected Payments	-0.050***	-0.051***	-0.054***	-0.140***	-0.057***	0.023
	(0.008)	(0.009)	(0.008)	(0.026)	(0.008)	(0.014)
Constant	3.940***	3.788***	3.961***	6.187***	4.174***	3.548***
	(0.564)	(0.508)	(0.533)	(1.051)	(0.537)	(0.497)
Observations	3,691	3,691	3,576	1,549	3,652	3,691
Log Likelihood	-2131	-2131	-2061	-946.5	-2105	-2305

Notes: Robust standard errors are in parentheses, estimates from the logit regression are represented, and the dependent variable is repayment. Region-fixed effects are included in all specifications.
*** significant at the 1 percent level.
** significant at the 5 percent level.
* significant at the 10 percent level.

of the willingness of the borrower, it is necessary to account for the possibility that borrowers intentionally evade consulting by taking out loans which fall just under the threshold. In specification (3), we construct a new subset in which observations of loan amounts which are slightly under this threshold, when the initial desired amount of the borrower exceeded it, are removed.[11] Even with this subset, main findings do not change.

We also conduct additional robustness tests. In specification (4), we shorten the loan origination period to February of 2011. In specification (5), we change the range of the loan amount of samples, making it between 4 million and 15 million won. In specification (6), we use repayment information as observed six month later, in June of 2013 instead of December of 2012. The results are still positive

[11]When the cut-off amount is 10 million won, we exclude borrowers who take out loans which are between 9.6 million and 10 million won when the originally desired amount was more than 10 million won on the loan application document. Similarly, with the cut-off amount of 5 million won, loans of between 4.6 million and 5 million won are excluded when the initial desired amount was more than 5 million won.

and significant for all specifications, as in the main regression.[12]

B. *The Effect of Consulting according to the Types of Borrowers of Business Operating Loans*

The above-mentioned positive impact of consulting on repayment performance among existing micro-entrepreneurs can vary according to the type of borrower. Thus, we conduct a regression of Equation (2), taking into account interaction terms of consulting variables and each type of borrower. These include gender, age group, and region. Table 5 presents the estimates of the interaction terms.

The first and second columns show that the effect of consulting on repayment performance is greater for male borrowers than for female borrowers. We may interpret this result in light of two possible situations. Firstly, as most consultants are males at the institutions providing the consultations,[13] female borrowers may

TABLE 5— INTERACTION TERMS: OPERATING LOANS

Category		(1)	(2)	(3)	(4)	(5)	(6)
Gender	Consulting x Male	0.324**	0.298**				
		(0.129)	(0.127)				
	Consulting x Female	0.190	0.162				
		(0.133)	(0.130)				
Age Groups	Consulting x 20s			-0.071	-0.097		
				(0.270)	(0.268)		
	Consulting x 30s			0.130	0.108		
				(0.150)	(0.148)		
	Consulting x 40s			0.358***	0.329**		
				(0.133)	(0.131)		
	Consulting x 50s			0.471***	0.435***		
				(0.166)	(0.164)		
	Consulting x 60s			-0.186	-0.228		
				(0.280)	(0.278)		
Business Sites	Consulting x Big City					0.396***	0.257**
						(0.129)	(0.117)
	Consulting x Small City					0.058	0.168
						(0.145)	(0.135)
	Consulting x Rural Areas					0.236	0.292
						(0.213)	(0.207)
	Observations	3,691	3,691	3,691	3,691	3,691	3,691
	Log Likelihood	-2130	-2142	-2126	-2137	-2128	-2142

Notes: Robust standard errors are in parentheses; estimates from the logit regression are represented. The dependent variable is repayment. In all specifications, loan amount, grace period, credit rating, no credit score, gender, age, No. of expected payment, months to the maturity, and constant are included; In specification (1), (3), and (5), log of monthly income, log of assets, log of debt and region fixed effects are added.
*** significant at the 1 percent level.
** significant at the 5 percent level.
* significant at the 10 percent level.

[12]For additional robustness checks, we used several dummy variables for credit ratings instead of a continuous variable to control for a non-linear effect. We also included an interaction term for consulting and the period when cut-off point was changed to control for a possible mean effect of the period itself. The regression results were still consistent.

[13]In 2014, the number of male consultants was 1,012 while the number of female consultants was 206.

not form a sense of solidarity with male consultants in the manner that male borrowers do. Secondly, in Korea, it is common for small businesses to be run by entire families. Thus, a female borrower may have a husband who practically manages the business. In this case, an effective change will not come about after only the female borrower enrolls in the business consulting. Therefore, to provide more effective business consulting, it is suggested to let the all of the business partners to undertake consulting together.

The third and fourth columns indicate that the estimated coefficients of the interaction terms are significant and positive only for borrowers in their 40s and 50s. This result suggests that business consulting is effective for experienced borrowers in their 40s and 50s. As most people hold college degrees in Korea, borrowers under 30 may not have enough experience. On the other hand, borrowers in their 60s have had sufficient time, especially if they start their businesses soon after retirement, which is very common in Korea. Therefore, to promote the effectiveness of consulting on inexperienced borrowers, it is necessary to supplement their insufficient business experience with business training and education as well as one-on-one consulting. Clients who lack experience may find a training program tailored to meet their needs extremely helpful when offered in conjunction with a consulting program.

The fifth and sixth columns show the estimated interaction terms of the consulting indicator and the regions of the business sites. These results show a significant and positive effect only for large cities such as Seoul and the six metropolitan cities. This result may show that the quality of the consultants and the content of the consultations in small cities and in remote rural areas are not as good as they are in large cities. Hence, it is necessary to strengthen the quality of consulting in areas other than large cities.

C. *Start-up Loans for New Business*

The results of the main regression for the group of start-up loans are shown in Table 6. In all specification, borrowers with no credit rating are eliminated in the sample as all of them made full repayment. We present five different specifications, including the base model in the first column. In specification (2), we control for the debt-to-income ratio and the debt-to-assets ratio. In specification (3), we use several dummy variables for the number of expected payments instead of a continuous variable. In specification (4) we use dummy variables for the age groups instead of a continuous age variable. In specification (5), we include the index of substitution, i.e., writing up a business plan instead of enrolling in consulting. In all five specifications, the consulting variable in start-up loans shows a statistically insignificant coefficient, indicating that repayments by new start-ups do not improve with one-on-one pre-lending consultations.

One reason for the insignificance effect of pre-lending consulting could be incomprehension by inexperienced start-ups. Experienced borrowers who receive operating loans for existing firms tend to repay better if they enroll in pre-lending consulting, as in the above results. In contrast, inexperienced borrowers who start new businesses may not be affected by this type of consulting, as they do not fully

TABLE 6— MAIN REGRESSION RESULTS: START-UP LOANS

	(1)	(2)	(3)	(4)	(5)
Consulting (Dummy)	0.004	0.020	0.145	-0.021	0.010
	(0.289)	(0.290)	(0.318)	(0.289)	(0.317)
Substitution (Dummy)					0.025
					(0.517)
Loan Amount (Million)	-0.078*	-0.084*	-0.100**	-0.076	-0.079*
	(0.047)	(0.047)	(0.050)	(0.047)	(0.048)
Grace Period (Month)	-0.066	-0.066	-0.061	-0.062	-0.066
	(0.056)	(0.056)	(0.059)	(0.056)	(0.056)
Credit Rating (1~10)	-0.395***	-0.396***	-0.408***	-0.399***	-0.395***
	(0.124)	(0.123)	(0.131)	(0.124)	(0.124)
Male (Dummy)	-0.425**	-0.420**	-0.414*	-0.393*	-0.425**
	(0.205)	(0.205)	(0.211)	(0.205)	(0.205)
Age	-0.022**	-0.023**	-0.025**		-0.022**
	(0.011)	(0.011)	(0.011)		(0.011)
Log Income (Million)	-0.008		-0.006	-0.009	-0.008
	(0.017)		(0.018)	(0.017)	(0.017)
Log Assets (Million)	0.007		0.010	0.006	0.007
	(0.025)		(0.027)	(0.025)	(0.025)
Log Existing Debt (Million)	0.003		0.002	0.004	0.003
	(0.012)		(0.013)	(0.012)	(0.012)
Months left to Maturity	0.053	0.055*	0.060*	0.050	0.053
	(0.033)	(0.033)	(0.035)	(0.032)	(0.033)
No. of Expected Payments	0.022	0.021		0.023	0.023
	(0.022)	(0.022)		(0.022)	(0.024)
Debt / Asset		0.000			
		(0.000)			
Debt / Income		0.000			
		(0.000)			
Constant	4.646***	4.655***	5.716***	3.976***	4.638***
	(1.313)	(1.312)	(1.439)	(1.249)	(1.322)
Dummies of Expected payment	x	x	o	x	x
Dummies of Age Groups	x	x	x	o	x
Observations	556	556	556	556	556
Log Likelihood	-304.7	-303.8	-293.2	-306.1	-304.7

Notes: Robust standard errors are in parentheses, and the dependent variable is repayment. Estimates from the logit regression are represented. The borrowers with no credit rating are eliminated in the sample as all of them made full repayment.
*** significant at the 1 percent level.
** significant at the 5 percent level.
* significant at the 10 percent level.

understand what the consultants suggest. Mel *et al.* (2014), studying female enterprises in Sri Lanka, find that business training for female enterprises can effectively increase profits, even for new owners. The business training in Mel *et al.* (2014) was very intensive compared to the three-day consulting service of the SMB. The business training service consists of a three-day course on developing business ideas, a five-day course on starting a business,[14] and one day of technical training which varies according to the type of business. Thus, to complement the consulting service for inexperienced start-ups, business training or education sessions may be beneficial.

Moreover, the SMB provides a one-shot service in the initial stage, while the non-financial service in Karlan and Valdivia (2011) continued regularly for one

[14]This covers main aspects of starting a business, including pricing, organization, equipment, other inputs, and financial planning.

or two years. Regular service is not only more advantageous to establish responsibility in clients but also effective at enhancing business performance. As borrowers of start-up loans do not have enough experience or knowledge about their business, they may not sufficiently understand what the consultant suggests or explains. The borrower may also have difficulty when encountering unexpected situations despite any confidence during the initial steps. Thus, to make the business consulting for effective for start-ups, regular check-ups may be required rather than a one-shot pre-lending service.

In all specifications, most variables did not show a significant coefficient, except for credit rating and gender. The coefficient of credit rating is significant and negative, as expected, showing that repayment behavior is degraded as the credit rating becomes poorer (i.e., as the credit score increases). The dummy for male borrower shows a significant and negative coefficient, and this is consistent to earlier findings in the literature which show that female borrowers have display repayment behavior (Kevane and Wydick 2001, Khandker *et al*. 1995; Pitt and Khandker 1998; Sharma and Zeller 1997).

Table 7 shows the results of the robustness test. The first concern was selection error, e.g., when borrowers intentionally avoid consulting by taking out a smaller loan when they originally wanted a larger loan. Thus we remove observations of

TABLE 7— ROBUSTNESS CHECKS: START-UP LOANS

	(1)	(2)	(3)	(4)	(5)
Consulting (Dummy)	-0.184	-0.033	-0.097	0.200	0.138
	(0.310)	(0.286)	(0.621)	(0.341)	(0.274)
Loan Amount (Million)	-0.081*	-0.080*	-0.065	-0.222	-0.069
	(0.047)	(0.046)	(0.079)	(0.168)	(0.045)
Grace period (Month)	-0.060	-0.065	-0.110	-0.111*	-0.091*
	(0.057)	(0.056)	(0.082)	(0.067)	(0.053)
Credit rating (1~11)	-0.272**	-0.241**	-0.437***	-0.222*	-0.003
	(0.116)	(0.112)	(0.160)	(0.128)	(0.110)
Male (Dummy)	-0.477**	-0.414**	-0.829***	-0.474*	-0.448**
	(0.210)	(0.203)	(0.315)	(0.246)	(0.196)
Age	-0.018	-0.019*	-0.014	-0.010	-0.026**
	(0.011)	(0.011)	(0.017)	(0.013)	(0.010)
Log Income (Million)	-0.060	-0.013	-0.156	0.006	-0.027
	(0.087)	(0.017)	(0.142)	(0.107)	(0.081)
Log Assets (Million)	0.032*	0.005	0.034	0.010	0.025
	(0.017)	(0.025)	(0.028)	(0.020)	(0.016)
Log Existing Debt (Million)	-0.007	-0.002	0.003	-0.001	-0.005
	(0.006)	(0.012)	(0.009)	(0.007)	(0.005)
Months left to maturity	0.045	0.044	0.083*	0.112**	0.033
	(0.033)	(0.032)	(0.048)	(0.044)	(0.031)
No. of Expected payments	0.016	0.020	-0.007	0.006	0.009
	(0.023)	(0.022)	(0.054)	(0.028)	(0.021)
Constant	3.972***	3.472***	7.508***	4.181*	1.648
	(1.303)	(1.235)	(2.133)	(2.148)	(1.238)
Observations	529	562	248	413	558
Log Likelihood	-289.3	-310.0	-137.5	-220.2	-327.6

Notes: Robust standard errors are in parentheses, estimates from the logit regression are represented, and the dependent variable is repayment. Region fixed effects are included in all specifications. The borrowers with no credit rating are eliminated except the specification (2).
*** significant at the 1 percent level.
** significant at the 5 percent level.
* significant at the 10 percent level.

borrowers if the loan amount is smaller than the cut-off amount when their initial desired loan amount was larger.[15] In specification (1), we exclude these observations from the sample. Even after removing these observations, the coefficient of the consulting variable remains insignificant.

We also conducted additional robustness tests. In specification (2), we include the borrowers with no credit rating in the sample. In specification (3), we shorten the loan origination period. In specification (4), we change the range of the loan amount of the samples to between 6 and 13 million won. In specification (5), we use the repayment information observed six month later, in June of 2013. The results in these cases are similar to those of the main regression, and the coefficient of consulting remains insignificant in all cases.

VI. Concluding Remarks

This research attempts to determine the effects of pre-lending business consulting on the probability of repayment by analyzing confidential data from the Smile Microcredit Bank in Korea. The SMB has randomly changed the criteria which determine which clients are required to enroll in a three-day one-on-one consulting program. This study utilized this as an identification strategy.

The pre-lending consulting service made a significant difference among clients who were already running a business. Clients who participated in the consulting program had a far lower rate of having their payments go into arrears than those who did not. Given the significant difference in repayment behavior, more clients in receipt of operating loans should undergo this type of consulting program instead of limiting eligibility to clients who borrow 10 million won or more. In addition, financially disadvantaged business owners using other microcredit products should also be encouraged to take the SEMAS consulting program.

In contrast, in the sample of clients who received start-up business loans, no significant differences in behaviors are observed between clients who experienced the pre-lending consulting program and those who did not. Thus, other types of support in addition to the consulting program may be necessary for those starting businesses, as they must carry out extensive preparatory work prior to opening the business. For example, clients should be required to complete an educational program so that they may better understand the details discussed in the consulting sessions. Moreover, post-lending consulting should be provided on a regular basis to give clients timely advice and help them tackle unexpected problems that may arise during the course of running their business.

This research is meaningful in that empirical study of microcredit is scarce in countries other than developing countries. However, more research needs to be done in the future in an effort to determine the direct effect of consulting programs on business performance from a long-term perspective. Furthermore, a randomized control treatment should be conducted so as to increase the validity of the findings in this research.

[15]The borrowers who take out loans which are between 9.6 million and 10 million won are excluded when the originally desired amount was more than 10 million won on the loan application document.

This research looks only at pre-lending consulting outsourced to an external agency, but it would be interesting and necessary to determine how mentoring or consulting directly provided by loan officers and how a group-training program rather than a one-on-one program can change clients' behavior and reduce situations of arrears. Such efforts are left for future work.

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Adoption of Foreign Technologies in Korean Manufacturing Firms: Characteristics and Microfoundations

By JOONGHAE SUH*

The primary goal of this paper is to explore the microeconomic foundation of Korean firms' adoption of foreign technologies. The paper also reviews the overall trend of international technology transfers to Korea. The period covered in this paper is Korea's high growth era, from the 1960s to the 1990s. The works of this paper center on the two questions of what characterizes foreign technologies which had been imported through licensing contracts, and which driving forces expedite technology adoption by firms. The Korean experience provides the context of success in the catch-up growth. The co-movement of technology imports with capital goods imports manifests Korea's effort to improve the technical efficiency toward the world frontier. Underlying this trend are firms' decisions to adopt new technologies. The paper shows that firms respond proactively to wage increases by adopting newer technologies and thus, in turn, increasing employment, which implies the existence of a virtuous interactive mechanism among these factors.

Key Word: Korean manufacturing firms, catch-up growth,
international technology transfer, technology adoption,
microeconomic analysis of economic development
JEL Code: O12, O14, O33

I. Introduction

The effective utilization of foreign technologies is of critical importance for economic growth because, as stated by Keller (2004), for many countries, "Foreign sources of technology account for 90 percent or more of domestic productivity growth." The existence of foreign technologies offers opportunities for catch-up growth, but the effectiveness critically depends upon recipients' efforts with regard to the learning and assimilation of imported technologies. The interplay

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between imported foreign technologies and intensive domestic efforts is common among successful late industrializing economies. The use of foreign technologies is as important for advanced economies as it is for developing countries, as tapping into the world technology pool offers a better chance of success than solely relying on domestic sources.

The experience of Korea is a good case for the role that foreign technologies can play in promoting economic growth in developing economies. As Lall (2003) shows, compared with other high-growth Asian developing economies, Korea's development path is distinctive in her strategy to raise indigenous enterprises by assimilating foreign technologies. Korea's path to build indigenous technological capabilities by promoting domestic firms had been more costly than the path of, for instance, Singapore, which had relied heavily on foreign direct investment and multinational enterprises. However, Korea's path was as effective as the FDI path in the long-run, as the country has realized a superb national innovation system. Presumably, the success of the Korean path crucially depends on the efficiency of the adoption process and the effectiveness of the assimilation of foreign technologies.

The primary goal of this paper is to explore the microeconomic foundation of Korean firms' adoption of foreign technologies. In order to set the context of exploration, the paper also reviews the overall trend of international technology transfers to Korea. As the interplay between foreign technologies and domestic efforts comprises a major part of the evolutionary process of Korea's innovation system, research focusing on technology adoption will unveil clues about the sources of sustained economic growth. In order to organize the study, the works of this paper will center on the two questions of what characterizes foreign technologies which had been imported through licensing contracts, and which driving forces expedite technology adoption by firms.

As the World Bank observed in a recent paper (Correa, Fernandes, and Uregian 2010), microeconomic evidence of the determinants of technology adoption in developing countries is scarce mainly due to data limitations.[1] This paper also faces a similar data problem. The data in this paper are compiled from official reports from the government and from certain surveys done by public organizations. Because it was originally produced for the purpose of, among other purposes, monitoring the process of international technology transfer, the data lacks a considerable amount of important information which is essential for an empirical analysis. In addition, modeling strategies in empirical research are constrained by data limitations. As the adoption and diffusion of technology is a time-intensive and dynamic process, theoretical models need reflect such aspects explicitly. However, because data used in a regression analysis is collected from cross-section survey results, it has many shortcomings. A heuristic approach in which the entire sample is divided into groups with different temporal aspects was used as a compromise. This method is discussed further in section III.

The paper is composed as follows. Section II will make a brief survey of the

[1]Microeconomic, empirical studies of adoption and diffusion have flourished in the areas of agricultural technology and innovation, where data has been abundant (Foster and Rosenzweig 2010). Other fields such as social networks (Banerjee *et al*. 2013), information systems (Venkatesh *et al*. 2007), and medical innovation have shown reasonably good data availability.

literature on technology adoption and diffusion across national borders. Of the numerous studies in this area, the literature survey will summarize the key results of economic studies. Section III will review the general trends in the area of international technology transfer to Korea from the early 1960s to the late 1990s. The covered period is a high-growth era during which Korea successfully pursued state-led industrialization. The main research objective here is to determine the roles of imported technologies and how effectively the imported technologies were used. Section IV investigates the microeconomic foundations of technology adoption by firms. Despite the data limitations and the use of a static model as an analytical framework, this study is expected to shed light on the factors and/or mechanisms that influence adoption decisions by firms. Because theories of technology adoption and diffusion are believed to be well established, a standard summary of the literature is appended after the main text. Section V concludes the paper.

Before going into the main arguments, a qualification of the term 'technology imports', abbreviated as TI, as used in this paper is in order. TI in section III is an English translation of *Gi-Sul-Do-Ip*, a Korean word which means "international technology transfer from abroad in the form of a business contract." Technology adoption also roughly corresponds to an English translation of *Gi-Sul-Do-Ip*. Given that it better highlights firms' decisions to choose new technologies, technology adoption is used in section IV.[2]

II. Studies of Technology Adoption and Diffusion

Technology adoption and diffusion[3] is a significant research area covering a broad range of disciplines. According to Rogers (1995),[4] the early application of a diffusion research approach can be found in anthropology in the 1920s and communications research in the 1940s. Rapidly expanding to various disciplines during the 1950s and 1960s, Rogers (1995) states, diffusion research achieved the status of Kuhn's research paradigm in the 1990s. Although some fields of research matured, the rapid advance of new technologies generates new themes and thereby makes diffusion research ever more active and expanding. Searching with keywords such as diffusion, adoption, innovation and transfer, Sriwannawit and Sandstrom (2015) identified 6,811 publications in the area of diffusion research over the period of 2002-2011. Today's diffusion research covers a broad range of disciplines, from biology and ethnology and to economics, with many overlapping

[2]OECD (1990) defines technology balance of payments with two terms: technology adoption (TA) payments and technology export (TE) receipts. Technology adoption in this paper is equivalent to the OECD's definition of TA at the firm level.

[3]The adoption of technology focuses on the end recipient of the diffusion process, while diffusion refers to all related processes when technology is adopted or rejected by individuals or firms in a society over time (Sriwannawit and Sandstrom 2015). "Adoption" and "diffusion" are used interchangeably in this paper, unless a misunderstanding may arise.

[4]The publication of the first edition of Everett Rogers' book, *Diffusion of Innovations*, in 1962 marks an important junction in diffusion research. Continuously updated until its fifth edition in 2003, the book has been considered as the basic framework of diffusion research. In a conclusive bibliometric review of diffusion research, Sriwannawit and Sandstrom (2015) state that Rogers is the most influential scholar in all subfields of diffusion research combined.

research subfields.

In economics, diffusion research has been used as a means of understanding sources of technological change and productivity growth. Diffusion research in economics can be broadly classified into two groups: firm- or industry-level studies and cross-country studies. Early efforts in economic research primarily sought to understand firms' technology adoption decisions. Since the 1990s, a variety of research has emerged in which the issues addressed are considerably broader (Keller 2008). Early micro-studies ascertained s-shaped diffusion curves and factors affecting the speed of diffusion, and the research framework extended to macro-studies of international technology diffusion. The increasing difficulty facing micro-studies in collecting appropriate data is a partial reason for the prominence of macro-studies in recent years (Comin and Mestieri 2014).

Table 1 summarizes the key findings from prior economic studies of technology diffusion. The literature cited in Table 1 is highly selective, only including review papers or seminal works on the subjects. Early studies conceived the analytical framework as the decisions made by firms, based on cost and expected benefits, regarding whether to adopt an innovation. Mansfield (1982) emphasized the significance of resource costs in international technology transfers. More than a physical investment project, the decision to adopt a type of innovation is accompanied by an uncertain stream of future benefits. In general, firms expecting greater benefits from technology will adopt more rapidly (Jensen 1982), and large firms that are positioned to cope better with future uncertainties as well as risk-loving firms are more likely to adopt earlier (Davies 1979; Reinganum 1983). Research findings also show that firms with greater human capital and more experience tend to adopt earlier while firms with a multinational scope also hasten their adoption of new technologies (Benhabib and Spiegel 2005; Geroski 2000).

In cross-country studies, research has usually been concerned with the barriers and facilitators of international technology diffusion. Among the key research issues are through what channels and to what extent knowledge and technologies are internationally transferred. Trade openness and lower barriers to international trade are in general known to facilitate international technology diffusion (Keller 2004), as firms exposed to foreign competition tend to adopt newer technologies. But technology transfers across borders are generally imperfect with any means of transfer; codified knowledge can relatively easily cross borders, but the tacit dimensions of knowledge are not simple to transfer internationally. Consequently, the effective transfer of, in particular, tacit knowledge, depends on the intensity of the recipient's learning efforts (Caselli and Coleman 2001; Benhabid and Spiegel 2005). Moreover, history matters in international technology diffusion (Comin and Mestieri 2014). One related issue is the implication of localized knowledge spillover in technology diffusion; studies show that geographical proximity to innovation sources promotes technology adoption (Keller 2002). Recent studies also show that the grip of geography is weakened, as advances in ICT substantially lower the transaction costs between regions (Keller and Yeaple 2013).

Unlike research results pertaining to other drivers of international technology diffusion, research on the role of foreign direct investment in international technology diffusion shows mixed results. Blomstrom and Kokko (1998) surveyed the research on technology spillover effects of the activities of multinational firms and

TABLE 1—ECONOMIC STUDIES OF TECHNOLOGY ADOPTION AND DIFFUSION

Drivers	Research papers	General findings
Firm- or industry-level study		
Cost-expected benefits	Mansfield *et al.* (1982), Jensen (1982), Reinganum (1983)	Firms expecting greater benefits from technology will adopt more rapidly.
Firm size	Davies (1979)	Large firms tend to be early adopters.
Absorptive capacity	Benhabib & Spiegel (2005)	Firms with greater human capital and experience are more likely to adopt earlier.
Multinational scope	Meyer (2003), Veugelers & Cassiman (2004)	MNEs are better conduits for international technology transfer than purely domestic firms.
Risk aversion	Geroski (2000)	Risk-loving firms are more likely to adopt earlier.
Cross-country study		
Trade openness	Keller(2004)	Lower barriers to international trade facilitate technology adoption.
Foreign direct investment	Blomstrom & Kokko (1998) Lipsey & Sjoholm (2005)	Greater investments by foreign firms promote technology adoption by domestic firms; mixed results on spillover effect.
Human capital and R&D	Caselli & Coleman (2001), Benhabib & Spiegel (2005)	Countries with greater levels of human capital adopt technologies more rapidly.
Predecessor technologies	Comin & Mestieri (2014)	Countries adopted predecessor technologies are more likely to adopt new technologies.
Geographic proximity	Keller (2002), Keller & Yeaple (2013)	Geographical proximity to the innovation source promotes technology adoption; knowledge transfer is limited by distance.

Source: Comin and Mestieri (2014), Galang (2014), and Keller (2004).

concluded that there is no comprehensive evidence of the exact nature or magnitudes of these effects. Lipsey and Sjoholm (2005) report more positive results of foreign direct investment on technology spillovers. This paper pays special attention to the role of foreign direct investment with regard to international technology diffusion, as the issue is closely related to a country's technologystrategy for industrialization.

III. Korea's Technology Imports

A. *Technology Strategy in Late-industrialization*

Based on the combination of domestic capability building and the attraction of multinational enterprises' production chains, Lall (2003) classified four technology strategies in industrialization among East Asian countries. The autonomous strategy pursued by Korea and Taiwan was based on the development of the capabilities of domestic firms, selectively restricting foreign direct investment (FDI) and actively encouraging technology imports in other forms. The autonomous strategy is clearly different from the FDI-dependent strategies pursued by Singapore and Malaysia in that FDI had been actively promoted as an important policy priority. China and India could leverage large domestic markets to upgrade their import-substituting industries (ISI) along with their global supplier networks. These countries used as the main policy tools trade liberalization and strong export

TABLE 2—INDUSTRIAL TECHNOLOGY STRATEGIES IN EAST ASIA

Strategies	Key features	Countries
Autonomous	Effective restrictions on FDI, active promotion of TI in other forms	Korea, Taiwan
Strategic FDI-dependent	Upgrade MNE activity according to strategic priorities	Singapore
Passive FDI-dependent	Driven by FDI but relying on market forces to upgrade the industrial structure	Malaysia, Thailand, the Philippines
ISI restructuring	Leverage large domestic markets to upgrade import-substituting industries	China, India

Source: Lall (2003).

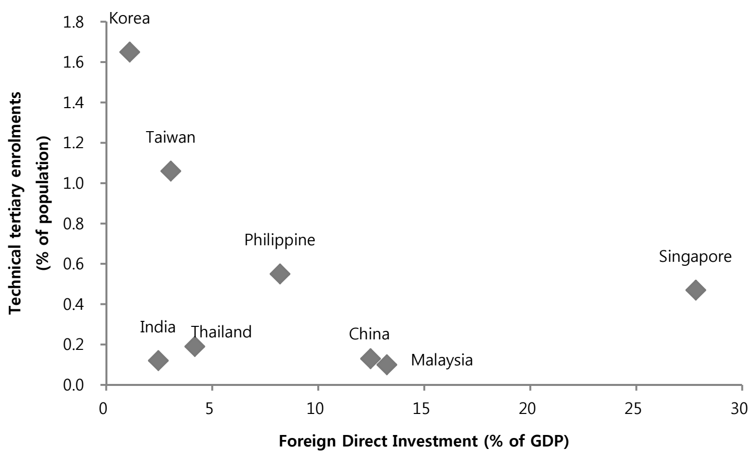

FIGURE 1. FOREIGN DIRECT INVESTMENT VS. TECHNICAL TERTIARY ENROLMENTS IN ASIAN COUNTRIES

Note: Technical tertiary enrollments are as of 1995; foreign direct investments are annual average of 1994-1997.

Source: Lall (2003).

incentives, but they lacked such a coordinated industrial policy as pursued as part of the autonomous strategies of Korea and Taiwan.

Figure 1 shows the differences among these countries in terms of foreign direct investment as a percentage of GDP and technical tertiary enrolment as a share of the population. The latter is used as a proxy indicator of domestic technology capabilities. Korea and Taiwan, which pursued an autonomous strategy, showed very low levels of FDI and high levels of technical tertiary enrolment. Singapore, which that pursued an active FDI-dependent strategy, shows the opposite pattern to Korea and Taiwan, while other countries lie between these two groups of countries.

The advantage of the FDI-dependence strategy is that it allows, as Lall (2003) noted, the bypassing of "the slow and arduous process of building domestic capabilities." Trade and investment in those countries with high FDI are closely related to the activities of multinational enterprises (MNEs). MNEs in general are technologically advanced, with spillover from MNEs being an important source of technological learning for host countries. It is crucial to create a favorable environment for MNEs to undertake more advanced, state-of-the-art activities. Collaboration between MNEs and domestic institutions, including business enterprises, is strongly encouraged, but the outcome of this strategy is mixed, as noted in the previous section. The positive spillover effects from MNEs and FDI frequently fall short of expectations.

Korea did not tread this path. Instead, domestic companies are the main actors for building indigenous technological capabilities. However, it is very costly and time-consuming for developing countries to climb the technological ladder. According to the product life cycle theory, the manufacturing process of various products generally moved overseas only after exporting opportunities of products became limited and the core product technologies reached a mature stage in their development and application (Simon 1991). As shown below, the majority of technologies transferred to Korea were already matured, which implies that product markets are also matured and very competitive. Hence, the key to successful industrialization for Korea lies in the country's ability to take advantage of product life cycle characteristics by relying on mature technologies to manufacture products that are sufficiently cost-effective to compete in both domestic and overseas markets.

B. *International Technology Transfers to Korea*

Selectively restricting foreign direct investment, Korea had encouraged technology imports in other forms. The importation of capital goods embodies the technology and know-how of machine producers. Arm's-length licensing contracts between business enterprises are also popular as a means to trade technologies. Joint ventures, research contracts, reverse engineering, and copying are all possible ways to learn and transfer technologies. Korea has utilized all of these channels.

Out of various channels of technology transfer, this section focuses on what is known as technology imports (TI) in Korea. This is done for two reasons. First, TI highlights the role played by the Korean government in promoting industrial and technological upgrades. Until the late 1980s, the importation of foreign technologies was tightly controlled by the government. A shortage of foreign exchanges to pay for TI was the main reason behind this government control. However, the intervention into TI transactions enabled the government to steer industrial development in a way which fit the national development plan.[5] Second, because the goal of Korea's industrial policy was to build a 'self-sufficient industrial base', which meant to raise domestic companies rather than relying on foreign, multinational companies, effective learning through the importation and assimilation of foreign technologies was a key to accomplish this goal. An analysis of the TI record can unveil the process of the interaction between foreign technologies and indigenous learning efforts.

From 1962 to 1996, the total number of technology imports stands at 9,621

[5]As the rationale of governmental control was to protect infant industries, the policy became more liberal when industries grew.

TABLE 3—TECHNOLOGY IMPORTS TO KOREA, 1962~1996

period	Total number of licensing contract	Amount of royalty payment (in million US$)
1962~1966	33	0.8
1967~1971	285	16.3
1972~1976	434	96.5
1977~1981	1,225	451.4
1982~1986	2,078	1,184.9
1987~1991	3,471	4,359.4
1992~1996	2,095	7,317.7
total	9,621	13,427.0

Source: Ministry of Science and Technology.

cases[6] (See Table 3). As the process of industrialization deepens, the number of TI contracts increases very rapidly, peaking during the period of 1987-1991. As the numbers increased, the payment amounts also continuously increased. Because many contracts contain multi-year payments, the royalty payment amounts increased further, even after the peak in the number of contracts. In addition to the number of contracts and the amounts of royalty payments, official TI records contain information on countries of origin, industrial classifications, and brief descriptions of the technologies. In terms of payments until 1996, 51% were paid to US companies, and 32% to Japanese companies. The U.S. and Japan were the major sources of technology to Korea. An interesting classification is 'types of technologies', which classifies the contents of contracts into the five technologies of technical information,[7] technical assistance,[8] patents, brands, and other types of industrial properties. According to a report published by the Korea Industrial Technology Association (1988), out of 2,407 TI contracts made between 1983 and 1987, 94% of them were made to secure the provision of technical information, whereas 85% contain clauses pertaining to the provision of technical assistance. In addition, the allowance of use of patents and brands accounted for 47% and 23%, respectively. The fact that the majority of TI contracts contain provisions for technical information and technical assistance implies that international technology transfers involve a process of learning and building technological capabilities.

The increasing trends in the numbers or amounts of TI hint at an increasingly important role played by foreign technologies in Korea. However, the official records in the *Annual Report on Technology Imports* are limited in providing further information on how these imported technologies were utilized. In order to

[6]Due to government intervention into TI activities, nearly all transactions that incurred payment in foreign currencies were officially recorded until the late 1990s. The coverage of TI records until the year 1988 is nearly complete due to the approval system under which companies had to operate. The approval system changed became a report system in 1988: companies reported their transaction records directly to the government or via the bank that made the payment transactions. The farther the year from 1988, the more incomplete the TI records become. This partially explains the decrease in the total number of licensing contracts from 1992 and to 1996. As one referee commented, there must be other reasons for the decrease. The OECD (1996) explains that as the Korean economy became more technology-intensive, foreign firms became more reluctant to provide core technologies. This tendency seems to have intensified over time.

[7]Technical information includes non-patented technical know-how: layouts and construction of plants, the installation of machines and tools, assembly and manufacturing procedures and methods, and methods of quality control.

[8]Technical assistance includes such activities as invitations of experts and technical training of engineers, and the dispatching of engineers to licensor companies.

address this issue, it is necessary to find other sources of information. The most direct means of doing this is to search for evidence of how imported technologies were utilized by the companies that entered into TI contracts. A report produced in 1980 stemming from collaborations among three institutions is a good example of this – a very detailed exploration of how imported technologies were used by firms.[9] Another technique is to rely on secondary literature on the themes on TI in Korea. There are a few reliable studies on this. Reports published by three organizations are worth mentioning:[10]

- The Korea Productivity Center (1985): One of the earliest studies of the effect of TI - the main objectives of this study were to identify difficulties faced by Korean companies that had entered into technology licensing contracts with foreign companies and to help them overcome the problems. An analysis was done based on firm-level surveys. Survey questionnaires were sent by mail to 874 companies that had signed TI contracts for the period of 1962-1984. The mail surveys, composed of responses from 287 companies, were complemented with additional visits to conduct interviews with key people at 36 companies.
- The Korea Development Bank (1991): Commissioned by the Ministry of Finance, the KDB conducted the most comprehensive study of the effect of TI. The main part of the study is composed of detailed case studies of the development of technologies in the following ten industrial sectors: electronics, electricity, machinery, chemicals, textiles, materials, ceramics, shipbuilding, pharmaceuticals, and food. The case studies were complemented with mail surveys, the design of which is based on previous works by KPC and KITA. Mail questionnaires were sent to 1,669 companies that had imported foreign technology in the 1980s. In this case, 821 companies replied to the mail surveys. Site-visit interviews at 131 companies were also conducted.
- The Korea Industrial Technology Association (1995): KITA has conducted many surveys. A survey in 1988 assessed 1,080 cases out the 1,408 TI contracts written between 1984 and 1986. The 1988 survey received 432 valid replies. It was generally similar to KPC (1985) in terms of the survey questionnaires, but KITA continued the survey, at three to five year intervals, until the mid-1990s. The 1995 survey is the last in the series. The target of the 1995 survey was 1,670 TI contracts written over the period of

[9]Three organizations collaborated in preparing the report – the Korea Institute of Science and Technology, the Korea Association of Machinery Industry, and the Korea Chamber of Commerce. The report is, to the best of my knowledge, the most comprehensive and detailed *technical* report on TI in Korea.

[10]Due to the importance of TI not only for business enterprises but also for its contribution to industrial development, many public organizations were engaged in work related to the TI of business enterprises. For instance, the Korea Institute of Science and Technology (KIST) established Technology Transfer Support Center in 1976. In addition to the promotion of the transfer of technologies developed by KIST to domestic companies, the Center also helped business enterprises search for appropriate foreign technologies, make favorable contracts, and they assisted in solving problems related to the assimilation of imported technologies (KIST, 2006). Several public organizations published guidebooks on international technology transfers which contained detailed explanations of the process of international technology transfer, including contract templates in English (KIMM. 1987; KITA 1991). In addition, many organizations conducted studies of the effect of TI on, for example, the productivity of firms and the technological progress of industries.

1992 and 1994. The mail survey received 493 valid replies. Although not as comprehensive as the KDB survey of 1991, The KITA survey of 1995 is valuable because it contains the latest information on TI in the early 1990s.

Based on surveys of these three organizations, we devise and answer three questions about the characteristics of TI and its effects on technological developments in Korean industries.

1. Why Import Foreign Technologies Instead of Engage in In-house Development?

All of the surveys cited in Table 4 contain a question about the reasons why the companies opted for importing foreign technologies instead of developing in-house technologies. Out of five answers, the lack of in-house development capabilities accounts for a large share in explaining the reason of TI, at 55% in 1985, 35% in 1991 and 38% in 1995. Reduction of costs and the shortening of technology development time were other main concerns; 20% of companies in the 1985 survey noted these as the main reasons, with 34% in 1991 and 39% in 1995. Only around 10 percent of companies indicated a risk and uncertainty in technology development and improved external credibility as reasons behind technology imports. It is important to note that opposite trends arose between the first and second most important reasons. Over time, companies increasingly place much emphasis on cost reductions and on saving time as the main reasons to pursue TI, because as companies accumulate technological capabilities, they tend to be concerned more with the cost and time elements of technology development.

TABLE 4—REASONS FOR TECHNOLOGY IMPORTS

(UNIT: %)

	Impossible to develop in-house	Reduction of cost & shortening of time	Lowering of risk & uncertainty	Improvement of external credibility	Others
KPC (1985)	55	20	12	9	4
KDB (1991)	35	34	19	7	5
KITA (1995)	38	39	6	6	11

Note: Number of responses in three surveys, KPC (1985) = 287; KDB (1991) = 1,567; KITA (1995) = 440.

2. How Rapidly Did Korea Receive New Technologies from Abroad?

The speed of international technology transfers or diffusion is important because it affects how rapidly follower countries can catch up with frontier countries. A higher speed of technology transfer means a greater chance of catching up. The time lag in the trans-border movement of technology generally becomes longer between advanced and developing countries than it is for countries with similar levels of economic development. Product life cycle theories postulate a typical pattern of international technology transfer with significant time lags according to

TABLE 5—YEARS PAST SINCE AN IMPORTED TECHNOLOGY WAS FIRST DEVELOPED

(UNIT = %)

	Less than 3 years	3-5 years	5-10 years	10-20 years	More than 20 years
KDB (1991)	8	18	30	26	18
KITA (1995)	22	23	26	15	13

Note: KPC (1985) does not contain this question.

the level of economic development. Technologies invented in an advanced country initially move to other countries in similar economic conditions and then later to developing countries that are insufficient with regard to capital and skills.[11] From a sample of 31 US-based firms, Mansfield *et al.* (1982) provide evidence of the number of years between technology transferred overseas and its introduction in the United States. According to them, the age of technology transferred overseas ranges from 5.8 years for an overseas subsidiary in a developed country, 9.8 years for an overseas subsidiary in a developing country, and 13.1 years for licensing or joint ventures. The evidence, consistent with the theory of product life cycle, clearly shows that technologies flow last through licensing or joint venture channels.

Reports from the KDB and KITA discuss how much time passes after imported technology is developed in a foreign country. Because the years are grouped, precise averages are not possible. For the KDB survey, more than half of technologies are aged less than ten years. The imported technologies are younger in the KITA report of 1995, with 45% of imported technologies being less than five years old. With only these two survey results, it is too early to conclude that the time lag of technology between Korea and foreign countries is shortened. However, it is clear that the average number of years of Korea's imported technologies is much shorter than in the findings by Mansfield *et al.* (1982).

In addition to the question of the age of technology, the Korean surveys included an interesting item which showed the differences in the stages of technology development in Korea and in advanced countries. The KDB survey divides the life cycle of technology into the four stages of introduction, growth, maturity, and decay.[12] Each company was asked to check, at the time of importation, at which stage of the life cycle the technology is in Korea and in advanced countries. The survey results found that in Korea, 82 percent of imported technologies were at the stage of introduction, 15 percent were at the stage of growth, and 3 percent were at the stage of maturity. For the life cycle stages of those imported technologies in advanced countries, 11 percent were at the stage of introduction, 31 percent were at the stage of growth, 55 percent were at the stage of maturity, and the remaining 3 percent were at the stage of decay. The difference in the stages of the technology

[11]There are many factors influencing the process of international technology transfer. Rogers (1995) is a very comprehensive and in-depth reference on this issue. The study of Freeman and Soete (1997) contains a chapter on international technology transfers from a catch-up perspective.

[12]KITA (1995) also contains a similar question about the life cycle of technology between Korea and advanced countries, but it divided the issue into six stages, and the terminology is somewhat different from that of KDB (1991). Nonetheless, the pattern of the technology gap found in the KDB survey is nearly identical to that in the KITA survey.

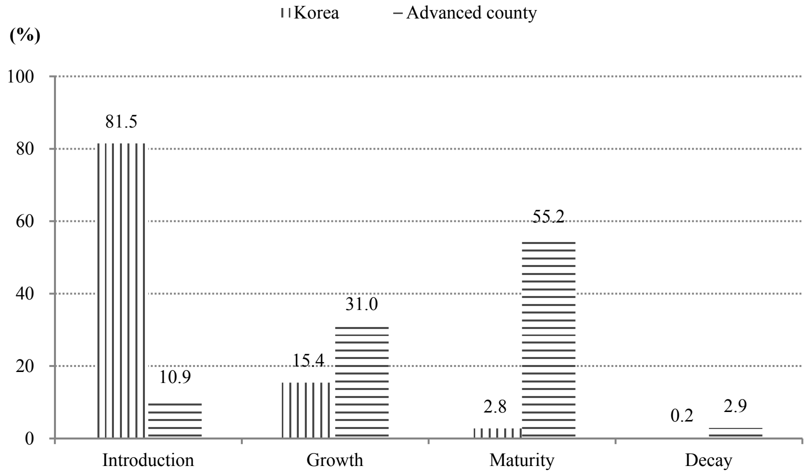

FIGURE 2: LIFE CYCLE OF IMPORTED TECHNOLOGIES

life cycle indicates the existence of a technology gap between Korea and advanced countries, as measured in terms of imported technologies. The KDB survey results are reproduced in Figure 2. The figure shows the existence of a striking technology gap between Korea and advanced countries. It also suggests that imported technologies could be a means to narrow the gap.

3. To What Extent are Imported Technologies Utilized?

The KDB survey contains a very interesting and important section on the use of imported technologies. In order to understand how those imported technologies are used, the survey divided the stages of TI use into the following three areas:

- Primitive stage of application: Under the guidance of the supplier company, imported technologies are applied on site. The solution to technical problems mostly relies on the supplier company.
- Intermediate stage of digestion/absorption: As the technical guidance of the supplier company is becoming complete, engineers make use of the imported technologies. The accumulation of technological capabilities proceeds at this stage.
- Mature stage of improvement/development: Technological capabilities are accumulated such that they are sufficient to develop new products or create technological innovations. When the needs of technology imports arise, core technologies are selectively imported. This allows a company to move up the technology ladder.

The survey shows that as more time elapses from the year of TI, more imported technologies are modified, improved, or become a source of innovation. For those 140 technologies that imported in 1990 (hence, only a year had elapsed from the

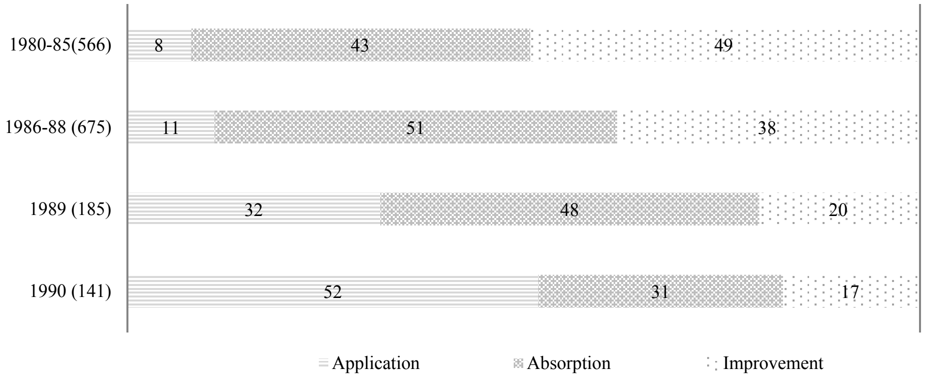

FIGURE 3: STAGES OF USE OF IMPORTED TECHNOLOGIES

Note: Numbers in parentheses are cases of TI made during the year.

Source: KDB (1991).

time of the TI), 52% are at the primitive stage of application, 31% at the intermediate stage of absorption, and 17% at the mature stage of improvement. For those 566 technologies that imported from 1980 to 1985 (hence, roughly 5 to 10 years had passed since the time of TI), only 8 % remained at the primitive stage of application, whereas roughly half of technologies are improved or led to a new innovation. The survey results demonstrate that most imported technologies are well absorbed and assimilated, leading to substantial improvements as compared to the original forms. Narrowing the technological gap between Korea and advanced countries cannot be accomplished only by importing advanced technologies. Narrowing the gap requires a substantial amount of effort by the importing country. Imported technologies are adapted and assimilated. As noted in the replies of nearly two thirds of Korean firms in the KDB survey, imported technologies are adapted and assimilated during the application process.

IV. Microeconomic Analysis on Determinants of Technology Adoption

Using the survey data introduced above, this section will explore the microeconomic foundation of technology adoption. The equilibrium model of technology adoption is used as the research framework, as it is a convenient tool for organizing diverse aspects of technology adoption and diffusion. However, the model must be modified when applied to the survey data in this paper. This section will discuss this in detail. Considerations of factors affecting technology adoption are the standard examples taken from previous studies, except for discussions about the production structures. These are all appended after the main text. Empirical findings will be offered with discussions about the implications of the estimation results.

A. *Equilibrium Model of Technology Adoption*

Starting with the stylized facts expressed by the sigmoid diffusion curve, theories on technology adoption and diffusion aim to identify the underlying mechanisms and factors which explain the diffusion process. This paper posits a firm's technology adoption behavior as a choice problem with the assumption of profit maximizing at an instantaneous moment of time. Accordingly, econometric specification is framed as a probit model of technology choice in a static setting, a variation often known as the equilibrium threshold model of technology adoption.[13]

Firms in equilibrium are assumed to differ in certain characteristics, x_i, affecting the probability of adopting a new technology. As Geroski (2000) states, the trick with equilibrium models of technology adoption is to identify the relevant characteristics x_i. The firm adopts the technology when x_i exceeds a certain threshold level x^*. The probability of firm i adopting a new technology when x_i exceeds x^* can be expressed as follows (notation from Besley and Case 1993),

$$\text{Probability \{adoption by firm } i\} = \varphi(\gamma x_i / \sigma_u),$$

where Φ is a distribution function of the gain of firm I; the gain of the new technology for firm i is parameterized as $\gamma x_i + u_i$, in which u_i denotes the *ex-ante* disturbance shock. In the empirical analysis below, the distribution of the disturbance terms is assumed to follow either a normal or logistic distribution, which produces a probit or a logit model respectively. The coefficients from the logit and probit model estimations are not directly comparable, as they are scaled differently. However, because the curvatures of the normal distribution of the probit and logistic distribution are similar apart from the fact that the logit model has fatter tails, the estimation results are not statistically significantly different.[14]

Because the adoption behavior and diffusion process does involve consideration of the current profit due to the use of the new technologies or the future stream of the expected benefits, the adoption and diffusion process is dynamic in nature. Therefore, applying the probit model in a static setting requires some explanation. One reason is related to the data problem. An ideal approach to modeling adoption behavior is to specify explicitly the dynamic process with the data set suited as such. The data of this paper is far from ideal; it is compiled from a one-time survey of a cross-section of firms that entered into licensing contracts with foreign suppliers. Moreover, the survey questionnaires are lacking many important issues that were required if they had been designed to study adoption behavior. Consequently, the data set is plagued with shortcomings which cannot meet the requirements outlined by Besley and Case (1993). Facing this limitation, the paper opted for the creation of a parsimonious model of adoption behavior based on a

[13]For a comprehensive review of microeconomic models of technology adoption, see Geroski (2000), David (2011) and Foster and Rosenzweig (2010). Comin and Mestieri (2014) offer the latest contribution to the literature on macroeconomic studies of technology diffusion.

[14]An advantage of using the logit model is the accompanying use of odds ratios, which give clearer interpretations of estimates.

short-run, or instantaneous, profit maximization assumption.

The question therefore becomes how well the static model can explain the dynamic process of technology adoption. The model assumes that in response to price changes, firms can reshuffle their production structure so as to maximize profit, with the resulting outcomes reaching Pareto optimality. As the production function itself can move out when the factor price ratio changes, the modeling of profit maximization requires dynamic considerations of changes in technologies. Therefore, a static model can provide a snapshot of technology adoption out of a long-term dynamic process. Moreover, it is difficult to distinguish an instantaneous response from a long-run adjustment. One way to cope with this limitation of a static model is to check the sensitivity of the estimation results with separate regressions, with the criterion of the separation of the entire sample into entries that contain temporal changes. This may be an empirical counterpart to the comparative static approach in economic theory.

B. *Estimation of the Determinants of Technology Adoption*

Data

Variables are selected from the KDB survey. The selection is indeed a result of a compromise between data availability and theoretical requirement, as the KDB survey does not contain many important variables, such as the prices of technologies. The survey questionnaires are mostly composed of multiple-choice questions; hence, the result is what is called categorical data. These categorical data are used as dummy variables. Table 4 provides a summary of the data with brief statistics.

The dependent variable is "year(s) elapsed since the initial time of invention." The survey offers six answers with one choice: 1) within a year, 2) 1~3 year(s), 3) 3~5 years, 4) 4~10 years, 5) 10~20 years, 6) more than 20 years. It is assumed here that firms choose technologies out of time streams. In other words, firms can choose either newer or older technologies, depending on their attributes, with the assumption that newer technologies are better than older ones.[15]

Explanatory variables are composed of six groups. The first group contains variables related to the production structure. Capital intensity, defined as total assets divided by the number of employees, wage per employee, and sales per employee, are used in the regression. These three variables are not compiled directly from the survey but are added by the surveyor based on the KDB's own information about Korean manufacturing firms. The addition after the survey resulted in many missing values in these variables. The values of these three variables are positive and continuous, and they are transformed into logarithms in the estimation.

The remaining five groups of variables are all taken from the survey results. Because the questionnaire items are composed of multiple-choice questions, the

[15]The dependent variable contains a censoring problem, as the observed year is right-censored. Transforming the dependent variable into a categorical data mitigates the censoring problem. This issue will be discussed more in the section on the empirical strategy below.

variables are all transformed into dummy variables.

Firm attributes are composed of three variables. A large firm variable takes a value of 1 if the firm is registered as a large enterprise and 0 if it is a small or medium-sized enterprise. A domestic firm variable has a value of 1 if the firm is a domestic firm, 0 if it is not, such as a multinational firm or a joint venture. The R&D Lab variable asks whether the firm has a R&D laboratory, with a value of 1, or if not, with a value of 0. The R&D Lab variable is a proxy for a firm's level of competence, as discussed as a demand determinant in the appendix. The higher the competence is, the quicker the expected adoption will be. The large firm dummy can be interpreted as an institutional factor. The role played by foreign firms in technology transfers has been one of key research and policy issues. As explained in section II, the empirical evidence shows mixed results.

Three variables compose a group called 'market conditions'. A survey questionnaire asked whether the firm had contacted any other firms before the actual contract, with the answer of either yes or no. This information is used as the Prior contact dummy variable. The Prior contact variable has many connotations. It can imply the existence of a technology market where arm's-length technology transactions occur, it can imply an extensive search effort by firms to find the right partner for a technology transaction, or it suggest the existence of a stable relationship between a licensor and a licensee. With the survey data, it was not possible to distinguish among these; most likely it would be safe to that assume of all these exist. In contrast, the other two variables are easier to interpret. A survey item asked whether the imported technology or a similar form already existed domestically at the time of adoption, with one choice out of five possible answers. The case of domestic non-existence is denoted as the No Existence variable with a value of 1. The Existence variables took a value of 1 when both the adopted technologies and similar forms, implying the potential for replacement, already existed. In addition to a literal interpretation of these two variables, they also show the degree of competition.

All records on technology licensing contracts until the late 1990s contain an entry to fill in regarding which types of technologies are imported. The record template denotes five types: the provision of technological information, the provision of technical assistance such as technical training and the dispatching of experts from the licensor, the allowance of using a patent, the allowance of using a product brand, and the allowance of using other types of industrial property rights. The contract includes at least one of these five types. Excluding the last one, I constructed four dummy variables.

Two countries of origin are included, with the expectation that different origins would result in different adoption behavior. As shown in the estimation results, no differences were found. Industries in the KDB survey are classified into ten types. Three major industries which comprise 65 % of the sample are included as dummy variables. These include chemical, electronics and machinery firms. Industry dummy variables are expected to show the effect of industrial specificity on echnology adoption.[16]

[16]A referee suggested making separate estimations by industry instead of the use of industry dummies. This suggestion is valid, as there are wide differences in the adoption times across industries. (This is shown in

TABLE 6—DESCRIPTIVE STATISTICS

Variable		Number of Observation	Mean	Std. Dev.	Min.	Max
Dependent variable	Year of first invention	1,509	4.2717	1.2047	1	6
Production structure	Capital Intensity	987	10.8963	0.8853	7.8808	14.4107
	Wage	857	7.4173	0.9292	2.0802	12.9337
	Sales	909	10.9044	1.1146	5.3305	16.3593
Firm attributes	Large Firm	1,571	0.6715	0.4698	0	1
	Domestic Firm	1,571	0.7638	0.4249	0	1
	R&D Lab	1,568	0.8393	0.3674	0	1
	Export	1,571	0.3412	0.4743	0	1
Market conditions	Prior Contact	1,550	0.6200	0.4855	0	1
	Non-existence	1,551	0.4049	0.4910	0	1
	Both Existence	1,551	0.1289	0.3353	0	1
Technology Type	Technical Information	1,571	0.9580	0.2007	0	1
	Technical Assistance	1,571	0.9026	0.2966	0	1
	Patent	1,571	0.4920	0.5001	0	1
	Brand	1,571	0.2018	0.4015	0	1
Country of Origin	USA	1,571	0.2425	0.4287	0	1
	Japan	1,571	0.5073	0.5001	0	1
Industries	Chemicals	1,571	0.2247	0.4175	0	1
	Electronics	1,571	0.1572	0.3641	0	1
	Machinery	1,571	0.2654	0.4417	0	1

Empirical Strategy

The threshold model of technology adoption specifies that firms decide to adopt a new technology when their attributes exceed a certain threshold level. The threshold model can be translated into a regression model, where the result of the decision is regressed on the influence of covariates or explanatory variables. The dependent variable is the result of the decision, but the observed counterparts to the result serve as categories.

The choice decision of a firm can be posited as an ordered choice model. The ordered choice model specifies a latent regression $y^* = \gamma x_i + u_i$ with the observed counterpart to y^*, as follows:

$$
\begin{aligned}
y_i \quad &= 0 \text{ if } \; y_i \leq \mu_0, \\
&= 1 \text{ if } \; \mu_0 \leq y_i \leq \mu_1, \\
&\dots \\
&= 5 \text{ if } \; \mu_4 \leq y_i \leq \mu_5.
\end{aligned}
$$

In the above specification, the μ variables are free parameters, where the unit distance between the set of the observed values of y does not carry any significance. Assuming that the variance of the disturbance terms follows a logistic

appendix 2.) I attempted separate regressions by industry and found that some industries, such as the chemical industry, show small differences in the estimated coefficients. However, this did not make a major difference with regard to those reported. For other industries, the estimation was not possible due to the small sample size by industry. Hence, I opted to use industry dummies in the estimation.

distribution posits the estimation equation to be an ordered logit regression equation.[17]

In the threshold estimation model, the firm's choice problem is modeled as an atemporal one. The atemporal estimation model is based on the assumption that firms select technologies out of time streams and that newer technologies are better, as is explained above with regard to the dependent variable in the data section. The assumption is valid when technologies are not monopolized or alternatives to monopolized technologies exist, as in this case, firms can choose out of many options. The KDB survey contains questions which attempt to check this issue. It asked whether the licensor is a monopoly of the imported technology; 201 replies answered positively, and from those, 37 reported the existence of alternatives. From this information, we can infer that 90 percent of imported technologies in the KDB survey are either non-monopolized, or alternatives exist. Based on this observation, the ordered choice model is applied rather than the duration model in which firms make temporal decisions.

The threshold model in this paper intrinsically contains a sample selection problem, as only those firms that imported technologies are included in the sample. The dependent variable contains a censoring problem, as the observed year is right-censored. Transforming the dependent variable into a categorical data mitigates the censoring problem, but the sample selection problem is not corrected econometrically, as the shortage of data does not allow the application of instrumental variables. In practice, sample selection becomes a serious problem when drawing conclusions about the wider population, not only about the subpopulation from which the data was taken (Kennedy 1998). This indicates a reasonable interpretation of the estimation results.

Another critical methodological issue is the omitted variable problem. Ideally, the estimation should include the variable of the price of the adopted technology. Because information about lump-sum payments and royalty rates contained in the survey is varied and incomplete, it cannot be used as an explanatory variable. Consequently, a very important variable is omitted in the regression. One way to circumvent this problem is to assume the price of technology to be a numéraire. Then, the prices of other inputs translate into relative terms. I take this approach here. However, this approach causes another problem. Because Wage is the only price variable in the regression and given that information about the price of capital input is not available, the estimates can also imply in relative terms the price of capital. Acknowledging this problem requires a careful interpretation of the estimation results.

The omitted variable problem also raises doubts about the validity of the modeling strategy used here. A static adoption decision underlies the dynamic diffusion process, and the adoption decision at a given moment of time contains dynamic considerations about the future streams of increased profit or reduced costs. As discussed above about the equilibrium threshold model, the static model is limited with regard to incorporating the dynamic elements of technology adoption, such as the role played by the learning effect. In order to cope with this

[17]Despite the differences in the estimated coefficient, there are no statistical differences when using the Probit and Logit models. I used the OLOGIT and OPROBIT commands from STATA software.

problem, a practical approach is taken here. As some entries in the survey contain temporal questions, the entire sample can be divided into two groups according to the answers to these questions, after which the two regressions show differences. There are two entries of this type: a question on whether employment increased after the technology adoption, and another on whether the company improved the adopted technologies. Though this approach is far from ideal, it is found to be a reasonable empirical counterpart to theoretical comparative static analysis. In line with this approach, two additional separate regressions were utilized. This strategy assumes that the two separate groups are behaviorally different.

Estimation Results

Table 7 summarizes the estimation results using the entire sample. For comparison purposes, the second and the third columns report the Probit and Logit estimation results, respectively. Owing to the different assumptions about the distributions of the disturbance terms, the magnitudes of the estimated coefficients differ but the signs and significance levels of the estimates are nearly identical. Logit estimates can be used to calculate odds ratios, which is a convenient tool for interpreting the estimated coefficients. Hence, in the subsequent estimations, only Logit results are reported.

The dependent variable is coded into six groups of years elapsed since the first invention, with group 1 being the newest and group 6 the oldest. Hence, a negative sign of the estimated coefficients refers to the adoption of newer technologies while a positive sign implies the adoption of older technologies. In order to make the interpretation easy, I calculated the inverse odds ratio, which determines the odds of adopting newer technologies. The last column contains the percentage change in the odds of a one unit change of the explanatory variable. As continuous variables are all in logarithms, a one unit change of, for example, the Wage variable implies a 96% change in wage per labor. The implication for dummy variables is rather awkward, as the doubling of the given state does not change the value of the dummy variable. Nonetheless, it can be interpreted as a strengthening of twice the given status.

Among the three variables representing the production structure, there appears a consistent pattern in Table 7 and in Tables 8-10, as follows. First, the higher the capital intensity, the older the technologies adopted are. Second, the higher the wage, the newer the technologies adopted are. Finally, the sales variable, expected to indicate the market size, does not have statistical significance. The first result is consistent with the fact that investment in machinery and equipment is in general irreversible and the replacement of existing capital stocks incur frequently significant sunk costs to firms. With greater investments in capital stocks, firms tend to delay their adoption of new technologies. An interpretation from an opposite direction is as follows: when a firm's fixed costs of already existing capital stock are low, they will be able to adopt newer technologies. The estimation results and interpretations thereof are aided by the additional regression results in Table 8. The entire sample used in Table 7 is divided into two groups: one in which technology adoption was accompanied with the concomitant importation of machinery and equipment - all these capital goods - and another in which

TABLE 7—REGRESSION USING THE ENTIRE SAMPLE

	Probit	Logit		
		Estimated coefficient	Inverse of Odds ratio	% change in odds
Log Capital Intensity	0.2318***	0.4123***	0.6621***	51.0
	(0.0634)	(0.1092)		
Log Wage	-0.1902***	-0.3267***	1.3864***	-27.9
	(0.0597)	(0.1051)		
Log Sales pl	-0.0629	-0.0859	1.0897	-8.2
	(0.0528)	(0.0883)		
Large Firm	-0.0888	-0.1418	1.1523	-13.2
	(0.1078)	(0.1866)		
Domestic Firm	-0.0875	-0.1648	1.1791	-15.2
	(0.0949)	(0.1651)		
R&D Lab	-0.2406*	-0.4850*	1.6242*	-38.4
	(0.1414)	(0.2536)		
Export	0.0182	0.0325	0.9681	3.3
	(0.0849)	(0.1455)		
Prior Contact	0.1463*	0.2437*	0.7837*	27.6
	(0.0825)	(0.1429)		
Non-existence	-0.4137***	-0.7143***	2.0429***	-51.0
	(0.0845)	(0.1459)		
Both Existence	0.4576***	0.8109***	0.4445***	125.0
	(0.1215)	(0.2114)		
Technical Information	-0.4616**	-0.8455**	2.3288**	-57.1
	(0.2138)	(0.3717)		
Technical Assistance	0.3254**	0.5676**	0.5669	76.4
	(0.1489)	(0.2544)		
Patent	0.0118	0.0152	0.9849	1.5
	(0.0782)	(0.1340)		
Brand	0.1717	0.2736	0.7606	31.5
	(0.1055)	(0.1807)		
USA	0.1512	0.2313	0.7935	26.0
	(0.1114)	(0.1931)		
Japan	0.1348	0.2054	0.8143	22.8
	(0.0972)	(0.1641)		
Chemicals	0.2385*	0.4570**	0.6332**	57.9
	(0.1226)	(0.2145)		
Electronics	-0.4850***	-0.8722***	2.3923***	-58.2
	(0.1207)	(0.2091)		
Machinery	0.2083**	0.3453**	0.7080**	41.2
	(0.0997)	(0.1672)		
LR of Chi2	139.16		143.76	
(p-value)	(0.000)		(0.000)	
Number of Observations	770		770	

importation was not done. In the regression of the former group, the explanatory variable in the production structure did not produce statistically significant results, but in the latter group of no concomitant importation, the pattern is strengthened with statistical significance of 1 percent. The estimation results in Table 8 suggest that existing capital stock becomes a barrier to adopting new technologies; the higher the capital stock, the higher the fixed cost, delaying the adoption of new technology as embodied in new machines.

The second result has multiple interpretations. Literally, it means that high-wage firms tend to adopt newer technologies, with 1.4 times higher odds. On the other hand, as new technologies enable the achievement of high performance and better productivity, causation may flow from new technology to high wages.[18] Moreover,

[18]Liu *et al.* (2001) confirm that the adoption of advanced technology by Taiwan manufacturing firms caused

TABLE 8—IMPORTATION OF FACILITIES AND EQUIPMENT

	Importation accompanied			Importation not accompanied		
	Estimated coefficient	Odds ratio	% change in odds	Estimated coefficient	Odds ratio	% change in odds
Log Capital Intensity	0.2544 (0.2095)	0.7754	29.0	0.4712*** (0.1331)	0.6243***	60.2
Log Wage	-0.1752 (0.1780)	1.1916	-16.1	-0.4561*** (0.1372)	1.5778***	-36.6
Log Sales pl	0.0077 (0.1802)	0.9923	0.8	-0.0589 (0.1042)	1.0607	-5.7
Large Firm	-0.0302 (0.3089)	1.0307	-3.0	-0.1618 (0.2541)	1.1756	-14.9
Domestic Firm	-0.1937 (0.2736)	1.2137	-17.6	-0.1493 (0.2225)	1.1610	-13.9
R&D Lab	-1.5065*** (0.3661)	4.5106***	-77.8	0.5457 (0.3741)	0.5795	72.6
Export	0.2721 (0.2370)	0.7618	31.3	-0.0236 (0.1944)	1.0239	-2.3
Prior Contact	0.3361 (0.2347)	0.7146	39.9	0.1041 (0.1878)	0.9011	11.0
Non-existence	-0.2716 (0.2355)	1.3120	-23.8	-0.9803*** (0.1937)	2.6652***	-62.5
Both Existence	0.8106** (0.3452)	0.4446**	124.9	0.8448*** (0.2736)	0.4296***	132.8
Technical Information	-1.1205* (0.6430)	3.0665*	-67.4	-0.7355 (0.4613)	2.0864	-52.1
Technical Assistance	-0.2462 (0.5392)	1.2791	-21.8	0.8111*** (0.2989)	0.4443***	125.0
Patent	0.1398 (0.2170)	0.8696	15.0	-0.0125 (0.1762)	1.0126	-1.2
Brand	0.3663 (0.3119)	0.6933	44.2	0.3130 (0.2279)	0.7313	36.8
USA	0.5722* (0.3330)	0.5643*	77.2	0.0545 (0.2482)	0.9469	5.6
Japan	0.4196 (0.2639)	0.6573	52.1	0.0839 (0.2186)	0.9195	8.7
Chemicals	0.4086 (0.4120)	0.6646	50.5	0.4683* (0.2663)	0.6261*	59.7
Electronics	-0.8301** (0.3261)	2.2936**	-56.4	-0.9186*** (0.2782)	2.5056***	-60.1
Machinery	0.5285** (0.2617)	0.5895**	69.6	0.1936 (0.2275)	0.8240	21.4
LR of Chi2 (p-value)		55.80 (0.000)			113.96 (0.000)	
Number of Observations		310			460	

because it is not possible to ascertain whether the Wage variable is in relative terms with regard to the prices of capital or technology, the estimates cannot offer clear demarcation. With these limitations in mind, however, we can conjecture about the relationship between factor prices and new technology demand. This interpretation is aided with the estimation results in Table 9. The sample in this table is divided into two groups: one in which employment increased after technology adoption and another with no employment change. The case with increased employment shows a greater effect of wage increases upon new technology adoption: 1.8 times higher against almost no effect and with no increase in employment. It appears that a wage

an increase in wages. Certainly, causality must run in two directions.

TABLE 9—EMPLOYMENT INCREASE AFTER TECHNOLOGY ADOPTION

	Employment increased			Employment not increased		
	Estimated coefficient	Odds ratio	% change in odds	Estimated coefficient	Odds ratio	% change in odds
Log Capital Intensity	0.5642*** (0.1484)	0.5688***	75.8	0.1049 (0.1750)	0.9004	11.1
Log Wage	-0.5749*** (0.1538)	1.7768***	-43.7	-0.1180 (0.1495)	1.1252	-11.1
Log Sales pl	-0.0635 (0.1092)	1.0654	-6.1	-0.0117 (0.1650)	1.0118	-1.2
Large Firm	-0.0091 (0.2576)	1.0092	-0.9	-0.2897 (0.2895)	1.3360	-25.1
Domestic Firm	0.0678 (0.2284)	0.9345	7.0	-0.4483* (0.2537)	1.5657*	-36.1
R&D Lab	-0.3466 (0.3602)	1.4142	-29.3	-0.5619 (0.3802)	1.7541	-43.0
Export	-0.0520 (0.2111)	0.0534	-5.1	0.3726* (0.2168)	0.6889*	45.2
Prior Contact	0.2486 (0.2071)	0.7799	28.2	0.0969 (0.2087)	0.9077	10.2
Non-existence	-1.0317*** (0.2055)	2.8058***	-64.4	-0.3725* (0.2174)	1.4154*	-31.1
Both Existence	0.6387** (0.3119)	0.5280**	89.4	1.0987*** (0.2998)	0.3333***	200.0
Technical Information	-0.5015 (0.5041)	1.6513	-39.4	-1.6307*** (0.5854)	5.1073***	-80.4
Technical Assistance	0.5534 (0.3689)	0.5750	73.9	0.6892* (0.3583)	0.5020*	99.2
Patent	-0.1423 (0.1853)	1.1529	-13.3	0.0977 (0.2039)	0.9069	10.3
Brand	0.3618 (0.2424)	0.6964	43.6	0.1764 (0.2778)	0.8383	19.3
USA	0.1390 (0.2673)	0.8702	14.9	0.3935 (0.2873)	0.6747	48.2
Japan	-0.0124 (0.2274)	1.0125	-1.2	0.4802* (0.2504)	0.6187*	61.6
Chemicals	0.3893 (0.3143)	0.6776	47.6	0.2983 (0.3080)	0.7421	34.8
Electronics	-1.0830*** (0.3070)	2.9533***	-66.1	-1.0226*** (0.3036)	2.7809***	-64.0
Machinery	-0.0254 (0.2327)	1.0257	-2.5	0.5522** (0.2704)	0.5757**	73.7
LR of Chi2 (p-value)		103.20 (0.000)			65.04 (0.000)	
Number of Observations		414			356	

increase stimulates the adoption of new technologies and that this in turn increases the demand for labor. A wage increase induces the adoption of new technologies, but the directions are uncertain. The estimation results cannot shed clear light, but they imply that there is a positive interrelationship between capital-labor complementarity and wage increase — a variation of the skill-biased technical change thesis.

Among the four variables in the firm attribute group, only the R&D Lab dummy variable produces statistically significant estimation results at the 10% level. The estimation results show that the odds of those firms with a R&D lab adopting newer technologies are 1.6 times higher than those without a R&D lab. Other variables, including Large Firm dummy, Domestic Firm dummy and Export dummy, are all statistically insignificant. The effect of the R&D Lab dummy in Table 8 is 4.5 times higher with regard to the odds in the case of the accompanied importation of facilities and equipment.

Three variables in the market condition group all show significant estimation results. These firms that contacted other providers before choosing a contractor tended to import older technologies, only at the 10% level. This estimation results appear to contradict the expectation that firms would make extensive searches for newer technologies. An alternative explanation is as follows: firms would choose older technologies, which may cost less than new ones, in order to minimize the cost of technology adoption. However, without information about the price of the adopted technologies, it is impossible to test which hypothesis is correct. In contrast, the estimates of the other two variables have a clearer interpretation. When adopted technologies did not exist, the odds of adopting newer technologies are twice as high as the other case. This tendency is also confirmed by the estimates of the Both Existence dummy variable. When both domestic technology and imported technology are available, firms tend to import older forms. The estimation results imply that competition to be first in the domestic market prompts the adoption of newer technologies.

Of the five types of technologies, two dummy variables show statistically significant estimation results. The Technical Information dummy variable shows a 2.3 times higher odds, whereas the Technical Service dummy variable shows a 0.6 times lower odds. The effects of the Patent and Brand dummy variables are insignificant. The estimation result hints that intellectual property rights such as patents and brands are protected under law and have much longer life spans than the know-how contained in technical information.

Origin of country does not matter in technology adoption. Technologies originating in the US and Japan appear to be adopted later than in other countries, but the estimates are not statistically significant. However, industries greatly matter with regard to technology adoption. In terms of years elapsed since the first invention, technologies in the electronics industry are adopted much more rapidly and technologies in the chemical or machinery industry are adopted much later than the industry average. These estimation results correspond to the common understanding that the technological life cycle is much shorter in electronics than in the chemical or machinery industry.

The last table contains the estimation results from the separate regressions. The criterion of sample division is three stages of usage of adopted technology, detailed explanation about which was given in the previous section. The later stages imply more advanced states than the earlier stages. I divided the entire sample into two groups, one which remains at the stage of application and the other which is either at the stage of absorption or the stage of improvement. Between these two, the most striking differences appear in the production structure variables of capital intensity and wage. These two variables at the application stage have almost no effect on influencing the speed of technology adoption, but they tend to have very strong effects at the stages of assimilation and improvement. As explained in section II, imported technologies need to be adapted and improved in order to fit the local conditions and thereby achieve higher efficiency. Thus, in order to be closer to the technology frontier or to achieve technical efficiency, substantial post-

TABLE 10—STAGES OF POST-ADOPTION USAGE

	Adopted technologies remain at the stage of application			Adopted technologies are at the stages of assimilation or further development		
	Estimated coefficient	Odds ratio	% change in odds	Estimated coefficient	Odds ratio	% change in odds
Log Capital Intensity	0.5036* (0.2963)	0.6043*	65.5	0.3322*** (0.1256)	0.7173***	39.4
Log Wage	-0.0858 (0.2534)	1.0896	-8.2	-0.4358*** (0.1198)	1.5461***	-35.3
Log Sales pl	-0.3327* (0.1923)	1.3947*	-28.3	0.0657 (0.1160)	0.9364	6.8
Large Firm	-0.4678 (0.5580)	1.5964	-37.4	-0.1900 (0.2060)	1.2092	-17.3
Domestic Firm	-0.3368 (0.4970)	1.4006	-28.6	-0.2400 (0.1795)	1.2713	-21.3
R&D Lab	-0.1656 (0.6309)	1.1801	-15.3	-0.5643** (0.2794)	1.7581**	-43.1
Export	0.1949 (0.4071)	0.8229	21.5	-0.0499 (0.1607)	1.0511	-4.9
Prior Contact	0.8649* (0.4718)	0.4211*	137.5	0.1216 (0.1527)	0.8855	12.9
Non-existence	-1.3901*** (0.4148)	4.0161***	-75.1	-0.5631*** (0.1592)	1.7562***	-43.1
Both Existence	-1.1950 (0.8489)	3.3036	-69.7	1.0150*** (0.2212)	0.3624***	175.9
Technical Information	(omitted due to collinearity)			-0.8029** (0.3782)	2.2321**	-55.2
Technical Assistance	1.1272 (0.7879)	0.3239	208.7	0.4865* (0.2728)	0.6148*	62.7
Patent	0.1814 (0.3905)	0.8341	19.9	-0.0268 (0.1463)	1.0271	-2.6
Brand	-0.1677 (0.5370)	1.1826	-15.4	0.4136** (0.1962)	0.6613**	51.2
USA	1.2256** (0.5160)	0.2936**	240.6	0.1070 (0.2149)	0.8986	11.3
Japan	0.8082* (0.4337)	0.4457*	124.4	0.2028 (0.1819)	0.8165	22.5
Chemicals	0.4501 (0.5530)	0.6376	56.9	0.2913 (0.2413)	0.7473	33.8
Electronics	-1.9074*** (0.6587)	6.7340***	-85.2	-0.7795*** (0.2230)	2.1805***	-54.1
Machinery	0.7911 (0.4877)	0.4534	120.6	0.2493 (0.1823)	0.7793	28.3
LR of Chi2 (p-value)		58.68 (0.000)			11148 (0.000)	
Number of Observations		120			650	

adoption efforts are necessitated. Facing this necessity, high wages prompt much intensive efforts, whereas less capital-intensive firms tend to accelerate their adoption times.

Summary of Empirical Findings

To recapitulate, I could confirm following facts from regression results:

i) Capital intensity serves as an obstacle to the adoption of new technology. High capital intensity levels mean high fixed costs, which leads to higher replacement costs. All of these factors delay the choice of new technologies.

ii) In adopting new technologies, firms are significantly responsive to wages. Due to the limitation of data availability, it was not possible to identify which factor prices are working in which directions.

iii) R&D fastens the adoption of new technologies. Other variables in the firm attribute group - the domestic firms and large firm dummy variables - are not statistically valid. With regard to technology adoption, a firm's capability to adopt, assimilate and improve a foreign technology dominates other firm attributes.

iv) Market conditions work effectively; competition to be first in the domestic market strongly prompts the adoption of new technologies.

v) The time difference in technology adoption among the five aforementioned types of technologies is not strong. Only technology transfer contracts including technical information show a statistically significant tendency to choose newer technologies.

vi) There are substantial differences across industries. Electronics firms tend to adopt newer technologies, a characteristic of the electronics industry in which the life cycle of technology is much shorter than in other industries.

The above list lacks a number of factors that is believed to play important roles in a firm's adoption decision. The expectation on future profits, uncertainty about new technologies and the price information about the technologies are among the omitted variables. Despite these shortcomings, the findings ascertain the notion that technology adoption is mostly induced by economic factors, such as capital intensity, wage levels, and market conditions.[19] Extending this view allows a further conjecture about the relationship between factor prices and technology adoption.

The empirical finding is that when wages rise, firms tend to adopt newer technologies, and this in turn causes an increase in employment. When interpreting new technology adoption as a technical advance, there are two paths for this to occur: 1) the labor-augmenting technical change is labor-biased when capital and labor are gross substitutes, or 2) the capital-augmenting technical change is labor-biased when capital and labor are gross complements.[20] As prior studies of the elasticity of substitution in the Korean economy converge to the consensus of low substitutability,[21] the second path will be the more plausible one. This implies that technical change in Korea was mostly capital-augmenting but with low substitutability between capital and labor, this further creating the demand for labor.

[19]Stefano *et al.* (2012) argue that the technology push and demand pull theses are reinforcing each other.

[20]The usage of terminology is based on Acemoglu (2002). A technical change is either neutral or factor-specific, or both. It is customary to assume no time variation in a neutral technical change. Acemoglu's distinction was made with this assumption due to the impossibility of fully identifying both neutral and factor-specific technical changes. See Carraro and De Cian (2013) for detailed explanations.

[21]Previous studies do not accord squarely, but mostly show that factors are complements rather than substitutes in Korea. Kim (1984) confirms the low substitutability and differences between large firms and SMEs. Kwack (2012) shows the complementarity between human capital and physical capital. Yuhn (1991) argues that the elasticity of substitution between labor and capital in Korean industries is close to unity.

V. Concluding Remarks

The catch-up thesis of economic development states that backward countries can growth more rapidly than advanced countries by borrowing foreign technologies. Catch-up growth, however, is not a universal phenomenon; only a small numbers of countries have been successful. The mere existence of foreign technologies does not guarantee success in industrialization and faster economic growth. Many developing countries become more dependent on foreign technologies rather than successfully constructing their own technology system. The lack of experience in operating modern plants and facilities is the source of operational inefficiency in many developing countries. Rapid changes in certain technologies can prevent developing countries from securing the time to learn from new technologies.

Successful industrialization requires a substantial revision of imported technologies to fit local conditions, through which developing countries increase their technical efficiency and reach out to the world technology frontier. The intensive and extensive assimilation and the improvement of imported foreign technologies are preconditions for a successful path of development. This is the key to shorten the technology gap against advanced countries.

The period covered in this paper is Korea's high growth era, from the 1960s to the 1990s. Structural transformations in various sectors of the economy occurred during this period. Korea's technology system was also fundamentally changed; a notable feature is the rapid increase in private R&D beginning in the early 1980s. The interplay between foreign technologies and indigenous R&D reinforced them both. Even without formal R&D efforts, Korean firms learned to industrialize by adapting and assimilating foreign technologies.

The Korean experience provides the context of success in the catch-up growth. The co-movement of technology imports, expressed in terms of royalty payments, with capital goods imports manifests Korea's effort to improve the technical efficiency toward the world frontier. Underlying this trend are firms' decisions to adopt new technologies. The regression results show that firms respond proactively to wage increases by adopting newer technologies and thus, in turn, increasing employment. In order for this transpire, productivity must increase faster than the rate of wage-hike. Despite some limitations, the microeconomic findings here correspond squarely to macroeconomic trends. With this backdrop, I conjecture that at the microeconomic level, wage increased, the adoption of new technologies, and employment growth are reinforced mutually – a conjecture on the existence of a virtuous interactive mechanism among these factors.

APPENDIX

1. Factors Affecting Technology Adoption

It is the adoption and diffusion process rather than inventions or innovations that ultimately determine the pace of economic growth and the rate of productivity change. According to Rosenberg (1972), the diffusion process has two characteristics: its slowness and the wide variations in the rates of acceptance of different inventions. In this sense, factors affecting technology adoption are of concern to economists and those who interested in the spread of new technologies. Corresponding factors are placed into four categories: the production structure, demand determinants, the supply behavior, and environment factors. Hall and Khan (2003) offer succinct explanations of the last three categories, from which the statements below are taken. Factor in the production structure are added in order to investigate the relationship between production factors and adoption behavior.

1) Production Structure

The assumption of instantaneous profit maximization associated with static equilibrium enables the introduction of an adopted technology as an additional factor of production function. The logic is similar to energy as a production factor (Lann 2010), or clean vs. dirty technologies in environmental economics (Kulmer 2013). The main focus is on how the factor mix and the adoption of technologies respond to changes in factor ratios and other attributes of the production structure.[22]

A firm's adoption of new technologies in general introduces two possible ways to represent it in terms of a production function framework. When firms are undertaking their production activities on the frontier of technical possibilities, raising revenue by increasing production incurs an increase in the cost of production. In contrast, if firms are operating within the production possibility frontier, revenue may increase without increasing the cost. The former case implies that the firm achieves technical efficiency, whereas the latter implies that the firm is technically inefficient.

The distinction between these two cases is important when we consider the effect of factor price changes on the adoption of new, or newer, technologies. When operating on the frontier, factor price changes will affect the level of factor demand, through which the firm will try not to deviate from the frontier. When operating within the frontier, factor price changes will either not affect the factor mix at all or affect it less than when the firm is on the technological frontier. The distinction becomes especially important when modeling technology adoption by a firm. If firms are operating far below the technology frontier, the equilibrium approach may not adequately predict the outcome of the output and factor mix because when firms strive to minimize costs or maximize profit and movement toward the production frontier will not be accompanied with changes in inputs or increases in costs - only appearing as increases in efficiency - it becomes difficult to distinguish technical advances from increased efficiency due to, for instance, better management of resources.

[22] The induced factor demand function from a CES production function can be denoted as $x_i = (\frac{a_i c(p)}{p_i})^{\sigma}$, where $\sigma = \frac{1}{1-\rho}$ represents the constant elasticity of substitution and $c(p) = (\sum_i a_i^{\sigma} p_i^{1-\sigma})^{1-\varsigma}$. The cross-price elasticity of substitution in more than three input cases is not pre-determined but depends on the curvature of the production function (Varian 1993).

2) Demand Determinants

It is apparent that decisions about new technology adoption are made in consideration of the benefits received by user and the costs of adoption. As Rosenberg (1972) argues, the skill level of workers and the state of the capital goods sector are important determinants of technology diffusion to individual firms. If it requires complex new skills or is time-consuming or costly to acquire the required level of competence, or if the initial idea is too advanced relative to the engineering capacity of the industry, then adoption may be sluggish. For example, Caselli and Coleman (2001) investigated computer adoption by OECD countries during 1970 to 1990, and found out that worker aptitude, the openness to manufacturing trade, and the overall investment rate in the country are crucial to the level of investment in computers.

It is also important for firms to be assured of future profits when they make costly investments in new production technologies. In the presence of customer commitment, firms may be able to predict demand and profits more precisely. This helps them to decide whether to adopt new technologies. Helper (1995) uses as a proxy for customer commitment the length of the contract between automotive suppliers and their customers, arguing that this directly affects adoption by providing suppliers guaranteed demand as well as indirectly by extending market share, as there are fewer alternatives for customers in a highly concentrated market.

In addition, network effects are important given today's high degree of interrelation among technologies. This operates both directly and indirectly. Direct network effects arise when a benefit from using a technology increases with the size of the network. Meanwhile, indirect network effects apply when the increase in utility comes from the wider availability of a complementary good, such as "hardware-software," where the availability of software increases as more hardware is sold due to the complementarities between them. In this regard, Saloner and Shepard (1995) investigated commercial banks in United States and found that banks tend to adopt ATMs sooner when they have more branches and a larger value of deposits from customers. However, according to Majumdar and Vankataraman (1998), economies of scale and network effects do not always affect adoption decisions simultaneously. In other words, production economies of scale are more important during the earlier years and weaken over time, while network effects are important during all phases of technology adoption.

3) Supply Behavior

Following Rosenberg (1972), the behavior of suppliers of new technologies both in improving them and in lowering costs over time is essential for adoption. Three important factors on the supply side are identified. First, improvements in the new technology are crucial because the efficiency gain from the new technology is much greater during the enhancement stage than in the initial stage. In some cases, manufacturing capabilities fail realize inventions. Secondly, improvements of old technology are also important, especially when a new innovation is a close substitute for an existing technology because it requires providers of the old technology to make progress or engage in other types of competitive behavior to retain their market position. Thirdly, complementary inputs are critical for the diffusion of new technology. It is often the case that hardware manufacturers, for instance, mobile telephone producers, cooperate with software suppliers such as Microsoft, reaching a deal to produce the software and encourage customers to purchase the hardware products.

4) Environmental and Institutional Factors

The economic literature on incentives for innovative activities has been somewhat contentious since the influential work of Schumpeter and Arrow in 1962. Dorfman (1987) suggests four major arguments with regard to the positive role of the firm size and market share in determining the level of innovative activity. The first two arguments come from Schumpeter. First, firms that are large or with sufficient market share have more incentive to undertake innovations due to the greater expected benefits from new technology and the availability of funds to cover the costs of adoption. Second, larger and more profitable firms are more likely to have the financial resources, human capital, and other resources required to purchase and install a new technology. Third, firms with a large market share are more able to spread the potential risks associated with new projects because they are more able to diversify their technology choice and try out a new technology. Lastly, larger firms adopt new technologies sooner due to the scale-enhancing characteristics of the technologies; it is more feasible for them to spread fixed costs across a larger number of units.

However, large firms with a large market share may also slow down the rate of diffusion. Larger firms tend to have multiple levels of bureaucracy which may impede the decision-making processes for innovation and the hiring of new workers. In addition, as Henderson and Clark (1990) stressed, it is more expensive for older and larger firms to adopt a new technology because they already have numerous resources, including the human capital costs sunk in their old technology and existing architecture.

In a study conducted by Hannan and McDowell (1984) investigating ATM adoption by banks in US, adoption decisions were found to be highly correlated with the prevailing wage rates in the market because ATM machines are substitutes of labor. Therefore, the adoption of a labor-saving technology is more profitable in a market with higher wages. Evidence in the mobile telephone market was also found by Gruber and Verboven (2001) and by Parker and Roller (1997), who claimed that the presence of market competition encourages the adoption of new technologies by lowering prices.

2. The Distribution of Elapsed Time by Industrial Sectors

Industrial sectors (No of firms)	Years elapsed since the initial development (%) Within 3 years	3-5 years	5-10 years	10-20 years	Over 20 years
Electronics (252)	18	26	28	20	8
Electricals (89)	4	17	31	40	8
Machinery (417)	4	13	36	27	20
Chemicals (353)	5	14	29	30	22
Textile (133)	9	23	20	23	25
Metal (99)	7	18	33	29	13
Ceramics (67)	5	19	33	25	18
Shipbuilding (47)	17	9	22	20	32
Pharmaceuticals (40)	16	47	29	3	5
Food (70)	7	19	20	20	25
All (1567)	8	18	30	26	18

Source: KDB (1991).

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