WORKFORCE COMPOSITION AND FIRM PRODUCTIVITY: EVIDENCE FROM TAIWAN

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We study the relationship between workforce composition and firm productivity based on a new employee-employer-matched data set, using an array of workforce characteristics and three alternative measures of firm productivity. While firm age is not essential for the performance of firms, those of smaller size and those in the steel and transportation industries outperform others. Moreover, labor quality, particularly the middle-aged with higher education, contributes significantly to firms' productivity. Furthermore, economic incentives and market competition both play important roles in the performance of firms. Finally, there is an employer-size premium with larger firms paying higher wages and nonwage benefits. (*JEL* C33, D20, J30)

I. INTRODUCTION

Over the past decade, the availability of employee-employer-matched data has created a new wave of research investigating the performance of firms across sections and over time by thoroughly accounting for the economic characteristics of the workforce.[1] Studies based on the U.S.-matched employee-employer data focus on the relationship between workforce composition and firm productivity. A general finding, as particularly highlighted by Haltiwanger, Lane, and Spletzer (1999, 2007), is that workforce composition plays a crucial role for the performance of firms.

Following this research trend, we conduct an empirical investigation of the relationship between workforce composition and firm productivity based on a new employee-employer-matched data set created by ourselves, which consists of 240,000–310,000 employees and 349 firms in Taiwan over the period 1998–2003. Despite its short span and thus limited time series variation, the data are rich for studying various issues concerning workforce composition and firm productivity.

Specifically, we consider a number of characteristics of firms (including firm age, firm size, and the industrial classification) and of the workforce (including most importantly measures of human capital, health capital, and wage dispersion). We construct three different measures of firm productivity: the average product of labor frequently used in the microeconomic literature, the Solow residual conventionally adopted in the macroeconomic literature, as well as the total factor productivity (TFP) based on the Levinsohn and Petrin (2003) approach. Using our newly created data set, we provide a complete balanced panel data analysis of four major issues: (1) whether some types of firms (by firm age, by firm size, or by industry) perform better on average, (2) whether the composition of workforce (including age, human capital, and heath capital) matters for firms' productivity, (3) whether economic incentives (measured by

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1. See, for example, a discussion in Abowd and Kramarz (1999) and Hamermesh (1999).

ABBREVIATIONS

APL: Average Product of Labor
LI: Labor Insurance
TFP: Total Factor Productivity

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intrafirm wage dispersion) and market competition (measured by exportability) play any role in the performance of firms, and (4) whether there is an employer-size premium (in the sense that workers at large firms are overcompensated) or an industry premium (in the sense that workers of equal quality receive greater compensation at certain industries).

The main contributions of our paper are therefore clear-cut. On the one hand, we construct a new employee-employer-matched data set outside America and Europe. The data set is of particular interest because it presents one of the rapidly growing newly developed economies, Taiwan, whose experiences in industrial transformation have been central in development studies. A full examination of the relationship between workforce composition and firm productivity in Taiwan is thus fruitful for understanding a fundamental microeconomic force behind the macroeconomic development of this economy. On the other hand, we propose some modified empirical strategies differing from the current literature, which may be adopted for future studies in related areas. Specifically, we measure firm productivity by the average product of labor, the Solow residuals, and TFP to ensure the robustness of the findings. We also introduce measures for economic incentives and market competition, which are potentially critical for the performance of firms in developing countries. Furthermore, we estimate jointly both productivity and wage regressions, from which we are able to study the employer-size wage premium by controlling an array of workforce and firm characteristics in a systematic fashion.

The main findings of our paper are fourfold. First, while firm age is not essential for the performance of firms, those of smaller size and those in the steel and transportation industries outperform others, in both the average product of labor and the Solow residual measures. Second, labor quality, particularly middle-aged workforce (30–55-yr old) with higher education, contributes significantly to firms' productivity. Third, the significant and positive relationship between wage dispersion and firm productivity is more in line with the tournament theory than the equity and fairness theory. Also, market competition measured by exportability plays a crucial role in the performance of firms. Fourth, there is an employer-size premium with larger firms paying higher wage, cash/noncash dividends, and/or retirement fringe benefits.

The remainder of the paper is organized as follows. Following a brief literature review, we provide a simple illustrative theory of firm productivity in Section II. Section III delineates our empirical model and describes the construction of this new employee-employer-matched data set. In Section IV, we summarize the main results obtained from our panel data analysis and perform an array of robustness analyses. Finally, we conclude the paper and acknowledge the limitations of our study in Section V.

A. *Related Literature*

Concerning the characteristics of the workforce, Black and Lynch (1996) emphasized the importance of human capital for enhancing firms' average product of labor measured by both sales and value added. Haltiwanger, Lane, and Spletzer (1999) found that firms that have higher labor productivity employ a higher fraction of more educated workers, a higher fraction of young and prime-age workers, and a lower fraction of female workers. Similar evidence was also found by Galindo-Rueda and Haskel (2005) for England. Iranzo, Schivardi, and Tosetti (2005) examined the relationship between skill mix and firms' performance. Using a matched Italian employer-employee data set, they report that a firm's productivity is positively associated with the dispersion within occupational groups (production and nonproduction workers) and negatively associated with the skill dispersion between these groups.

Hellerstein, Neumark, and Troske (1999) investigate the roles of age, race, and gender in explaining the wage and productivity differences across the U.S. plants. By jointly estimating the production function and earning equations at the plant level, they find that women are paid significantly less than men, with the wage differentials between men and women being much larger than the productivity differentials. Barrington and Troske (2001) used the New Worker-Establishment Characteristics Database to study the relationship between workforce diversity and productivity. They conclude that establishments with a more diverse workforce are no less productive than those with a more homogeneous workforce.

In contrast with previous studies, we construct a new employee-employer-matched data set containing manufacturing firms and the associated workforce in Taiwan.[2] Moreover, we employ different empirical strategies, examining systematically both firm productivity and worker wage, using three alternative measures of firm productivity as well as taking into account economic incentive and market competition effects that are of particular importance in a developing economy.

II. AN ILLUSTRATIVE THEORY OF FIRM PRODUCTION

We use firm production theory as an organizing framework to conduct our analysis. Consider a representative firm with an owner utilizing two primary inputs, labor (L) and physical capital (K), to produce a good or a service Y during a particular year. Labor is augmented by human capital (H) that is an indicator of the average quality of the workforce. Thus, the effective labor can be specified as $(H_{ijt})^{\beta} L_{ijt}$, where β measures the degree of efficacy in converting labor skills into productive activities. In general, one may refer to $(H_{ijt})^{\beta}$ as the Harrod-neutral technical progress factor.

Let us index industries by j and years by t, and identify a firm by a pair (i,j) indicating the ith firm in industry j. Denoting by A_{ijt} the time-varying firm-specific technological factor, we can thus specify firm (i,j)'s production at time t as:

$$(1) \qquad Y_{ijt} = A_{ijt} F(K_{ijt}, (H_{ijt})^{\beta} L_{ijt}).$$

For illustrative purposes, assume that the production function F is strictly increasing and strictly concave in each of the inputs, K_{ijt} and L_{ijt}, and time invariant, taking the Cobb-Douglass form that satisfies the constant-returns-to-scale property and the Inada conditions (for both primary inputs to be necessary), with the output elasticity of capital denoted by α, where $0 < \alpha < 1$. Due to the constant-return property, one can write the average product of labor (APL) as:

$$\text{APL}_{ijt} = Y_{ijt}/L_{ijt} = A_{ijt} F(K_{ijt}/L_{ijt}, (H_{ijt})^{\beta}). \qquad (2)$$

2. Tsou and Liu (2008) use a similar data set covering both manufacturing and nonmanufacturing firms over a shorter span from 1999 to 2001. They examine a very different issue, establishing a negative effect of wage dispersion on employee turnover.

Further specify the technological factor as:

$$(3) \qquad A_{ijt} = e^{\mu t + \varepsilon} t B_j G_{ijt},$$

where μ is the deterministic rate of technological growth, ε_t is the technology innovation (i.e., the detrended rate of change in technologies), B_j is the time-invariant industry-specific factor affecting firm (i,j)'s production, and G_{ijt} summarizes all other time-varying firm-specific factors.

Finally, denote the worker compensation by W. Assuming perfectly competitive labor markets, workers must be paid at their marginal products:

$$(4) \qquad W_{ijt} = A_{ijt}[\partial F(K_{ijt}, (H_{ijt})^{\beta} L_{ijt})/\partial L_{ijt}].$$

Due the presence of a fixed factor input K_{ijt}, it is expected that $W_{ijt} = (1-\alpha)\text{APL}_{ijt} < \text{APL}_{ijt}$. Notably, however, should the market be noncompetitive or the wages be determined by bargaining, the relationship established in Equation (4) need not hold in general.

III. THE ECONOMETRIC METHODOLOGY

In this section, we will transform the theory into estimatable econometric forms and describe our newly constructed employer-employee-matched data set.

A. The Econometric Model

Let year 0 be the reference time (the starting year of the data set, which is 1998 in our case) and industry 0 be the reference sector (food processing in our case). One can write:

$$\mu(t-1998) + \varepsilon_{t-1998} = \varepsilon_0 + T_t \text{ and}$$

$$(5) \qquad \ln(B_j) = \ln(B_0) + D_j,$$

where T_t is the year dummy and D_j is the industry dummy. Decomposing G_{ijt} into an array of observed controls (X_{ijt}) and unobserved factors (υ_{ij}), we have:

$$(6) \qquad \ln(G_{ijt}) = \gamma X_{ijt} + \upsilon_{ij}.$$

Using Equation (1) under the Cobb-Douglass specification as well as Equations (2), (3), and (5), we can derive the logged level of the average product of labor $\text{LNYL}_{ijt} = \ln(Y_{ijt}/L_{ijt})$ as:

$$\begin{aligned} \text{LNYL}_{ijt} &= \ln(B_0 + \varepsilon_0) + T_t + D_j \\ &\quad + \alpha \ln(K_{ijt}/L_{ijt}) + (1-\alpha)\beta \ln(H_{ijt}) \\ (7) \qquad &\quad + \gamma X_{ijt} + \upsilon_{ij}. \end{aligned}$$

Similarly, we can define the Solow residual as $\text{SOLOW}_{ijt} = \ln(Y_{ijt}) - \alpha \ln(K_{ijt}) - (1-\alpha) \ln(L_{ijt})$ and obtain the following:

$$\begin{aligned} \text{SOLOW}_{ijt} &= \ln(B_0 + \varepsilon_0) + T_t + D_j \\ &\quad + (1-\alpha)\beta \ln(H_{ijt}) + \gamma X_{ijt} + v_{ij}. \qquad (8) \end{aligned}$$

Workers' compensation in logged level (LNW) can also be derived:

$$\begin{aligned} \text{LNW}_{ijt} &= \ln(B_0 + \varepsilon_0 + 1 - \alpha) + T_t + D_j \\ &\quad + \alpha \ln(K_{ijt}/L_{ijt}) + (1-\alpha)\beta \ln(H_{ijt}) \\ &\quad + \gamma X_{ijt} + v_{ij}. \qquad (9) \end{aligned}$$

In theory, Equations (7) and (8) both point to completely analogous measures of firm productivity upon controlling the capital-labor ratio, because $\text{SOLOW}_{ijt} = \text{LNYL}_{ijt} - \alpha \ln(K_{ijt}/L_{ijt})$. In practice, however, they differ in the following aspect: to estimate Equation (6), SOLOW is computed in a restricted regression with other materials (M) used by firms in the production process being included to generate the least squares estimate of the output elasticity of capital:

$$\text{SOLOW}_{ijt} = \ln(Y_{ijt}) - s_{\text{K}} \ln(K_{ijt}) - s_{\text{L}} \ln(L_{ijt}) - s_{\text{M}} \ln(M_{ijt}),$$

where s_{K}, s_{L}, and s_{M} are the expenditure shares of capital, labor, and materials, respectively. One should notice that LNYL and LNW may differ by more than just a constant, $\ln(1-\alpha)$, as indicated in Equations (7) and (9). One reason is that the labor markets need not be perfectly competitive—some workers may in practice be over- or undercompensated. Another is that the production function specification need not be Cobb-Douglas nor satisfy the constant-returns-to-scale property. In our empirical estimation, we will not impose any of such restrictions.

One major concern in the estimation of TFP is the potential endogeneity problem, which may occur when part of the TFP is unobserved by the econometrician but observed by the firm at a time early enough so as to allow the firm to change the factor input decision. To remedy this problem, Olley and Pakes (1996) and Levinsohn and Petrin (2003) use either investment or intermediate inputs as a proxy for unobservable productivity shocks. Lacking a full separation between physical capital investment and financial investment in our data set, we choose to follow the LP approach using either electricity usage or material costs as an indicator for unobserved productivity shocks.[3]

B. The Data

We restrict our analysis to the manufacturing firms listed on the Taiwan Stock Exchange. As pointed out by Gustavo et al. (2006), it is difficult to measure output outside the manufacturing sector. We thus focus our study on manufacturing firms.

Two data sets are used in this study. The first data set is the *Taiwan Economic Journal Data Bank*, which is collected by the Taiwan Economic Journal Corporation. It provides comprehensive information on corporate end-of-year balance sheets and income statements for the firms listed on the Taiwan Stock Exchange, including, more importantly, measures of outputs (sales) and inputs (capital, employment, and other materials). The firms in our study are merged into nine industries according to the classification used by the Taiwan Stock Exchange. These industries include (a) food, (b) plastic and rubber, (c) textile, (d) electronics, (e) chemical, (f) glass, (g) paper, (h) steel, and (i) transportation. Thus, these firms represent well the entire Taiwanese economy with regard to their scopes of production. Because all the firms are listed on the Taiwan Stock Exchange, it is expected that they are larger and better performing enterprises.

The second data set is the Labor Insurance (LI) wage records data, which consists of monthly records of the employment and earnings of almost all individuals who work in Taiwan. Our data contain all workers in each firm in the sample. The LI wage records data set includes the employer's identification code, the monthly wages for the individual, and the individual's demographic information on age, gender, and education. An advantage of our data set is to have individual worker data rather than the workforce average data.[4] In addition to workers' age and gender, we highlight two characteristics: human capital and health capital. The measure of firm-specific INJURY is straightforward: it is a fraction of lost workdays of all employees due to occupational injury/illness

3. While Levinsohn and Petrin (2003) used material inputs, Costello (1993) suggested electricity usage might be a good proxy for productivity in aggregate production.

4. Haskel, Hawkes, and Pereria (2003) point out that many studies in this field are based on workforce average data.

out of total work days—higher INJURY means lower health capital.[5] To compute firm-specific HUMAN CAPITAL, we construct an index aggregating various workers of three different education levels. Specifically, let H_p measure the percentage of primary education (elementary school and junior high school); H_s, the percentage of secondary education (senior high school and junior college); and H_h, the percentage of higher education (university and graduate school). Our HUMAN CAPITAL variable is a weighted aggregator of these fractions:

$$H = (\alpha_p \times H_p + \alpha s \times H_s + \alpha h \times H_h)/ \quad (10) \quad (H_p + H_s + H_h).$$

Following Tallman and Wang (1994), we compute the human capital index using the weighting scheme of $\alpha_p = 1.0$, $\alpha_s = 1.4$, and $\alpha_h = 2.0$.[6]

We construct our matched employer-employee data based on the common recording of the employer's identification code from the two data sets. The unit of our analysis is firm. Our balanced panel contains 349 firms covering the period from 1998 to 2003, with a total of 240,000–310,000 employees. In constructing this balanced panel of matched data, we have lost a negligible number of just 16 firms.

We provide detailed definition and summary statistics of dependent variables, firm controls, and worker controls in Table 1, with workforce composition by years in Table 2 and industry variation in Table 3. Briefly speaking, Table 1 suggests that the variation of sales or Solow residuals (measured by the coefficient of variation) is much greater than that of wages. Among the characteristics of the workforce, injury on the job has the greatest firm variation. Moreover, Table 2 indicates that due partly to the short 6-yr time span, all of these measures have relatively low time variation. Furthermore, Table 3 states that (a) electronics industry hires exceptionally young workers, whereas plastic and rubber as well as paper industries have a much higher fraction of old employees, (b) workers in chemical industry are better educated, (c) the injury rates in glass and steel industries are significantly higher than others, and (d) electronics and textile industries exhibit much greater wage dispersions.[7]

IV. EMPIRICAL EVIDENCE

We are now prepared to conduct simple panel data analysis. Due to the absence of firm-level value-added data, the output of firm i in industry j at year t is measured by the total sales S_{ijt}, so the logged level of sales per worker is denoted by LNSL.

We present our empirical findings in a sequential manner. We begin with firm productivity regressions using the average product of labor, the Solow residual measures, as well as Levinsohn-Petrin productivity. We next summarize evidence from worker compensation regressions, using simply wages, as well as a number of augmented measures by adding cash dividends, noncash dividends, and retirement fringe one by one. Furthermore, we jointly estimate the productivity and worker compensation regressions following the approach adopted by Hellerstein and Neumark (2004).

In each of the productivity and compensation regressions, we consider four specifications. In all specifications, we include firm-specific capital-labor ratios, $\text{LNKL} = \ln(K_{ijt}/L_{ijt})$, and other observed firm-specific characteristics, including firm age, firm size, and single versus multiple plants. Specifically, $X^{ijt} = \{$LNAGE, LARGE FIRM, SMALL FIRM, MULTI$\}$. An increase in the age of firm has two opposing effects on firm productivity: there is a positive learning effect and a negative technology backwardness effect. An increase in firm size also has two opposing effects on firm productivity: a positive effect due to scale economies in production and a negative effect due to higher organization costs. The establishment of multiple plants may promote productivity if the scope of production matters. The effects of these variables on worker compensation need not resemble those on firm productivity, unless the realized wages are paid at workers' marginal products.

In the first specification presented in column (1) of the corresponding tables, we do not include any worker composition controls, H_{ijt}. In the second specification presented in column

5. Unfortunately, we do not have any other better measure of workers' health capital.

6. In our data set, it turns out that all workers have completed at least primary education; thus, $H_p + H_s + H_h = 1$.

7. By examining the firm age distribution, we find that firms in electronics industry are much younger (with more than 60% of them being established after 1978), whereas those in plastic and rubber, glass, paper, and transportation industries are much older (with all firms being established before 1978).

TABLE 1
Variable Definition and Summary Statistics

Variable	Definition	Mean	SD	Minimum	Maximum
Dependent variables					
LNSL	Log (sales/labor) (NT$1,000, 1US$ = 35NT$)	8.784	0.832	3.258	12.426
Solow	Solow residuals	7.649	0.800	1.973	10.999
Levinsohn-Petrin productivity	Levinsohn-Petrin productivity	9.507	0.825	3.733	12.866
LNW	Log (average worker monthly wages) (NT$)	10.400	0.142	9.911	10.660
Firm characteristics					
LNAGE	Log (firm age)	3.121	0.535	0.693	4.060
LNKL	Log (capital/labor) (NT$1,000)	7.849	0.904	3.733	10.812
Large firm	1 if employees >1000, 0 otherwise	0.248	0.432	0.000	1.000
Small firm	1 if employees <250, 0 otherwise	0.232	0.422	0.000	1.000
Multi	1 if multiplant, 0 otherwise	0.179	0.383	0.000	1.000
Wage dispersion	Standard deviation of individual worker wages/mean of individual worker wages at firm level	0.219	0.073	0.000	0.412
Export dummy	1 if foreign sales >0, 0 otherwise	0.978	0.148	0.000	1.000
Plastic and rubber	1 for plastic and rubber industry, 0 otherwise	0.077	0.267	0.000	1.000
Textile	1 for textile industry, 0 otherwise	0.126	0.332	0.000	1.000
Electronics	1 for electronics industry, 0 otherwise	0.567	0.496	0.000	1.000
Chemical	1 for chemical industry, 0 otherwise	0.072	0.258	0.000	1.000
Glass	1 for glass industry, 0 otherwise	0.017	0.130	0.000	1.000
Paper	1 for paper industry, 0 otherwise	0.020	0.140	0.000	1.000
Steel	1 for steel industry, 0 otherwise	0.060	0.238	0.000	1.000
Transport	1 for transportation industry, 0 otherwise	0.011	0.106	0.000	1.000
Worker characteristics					
Male ratio	The percentage of male workers	0.611	0.172	0.130	1.000
Age <30	The percentage of workers under age 30	0.292	0.160	0.000	0.786
Age >55	The percentage of workers above age 55	0.202	0.156	0.000	1.000
Human capital	The human capital index $(1 \times H_p + 1.4 \times H_s + 2 \times H_h)/(H_p + H_s + H_h)$	1.382	0.107	1.149	1.850
Injury	Lost workdays resulting from occupational injury or illness/total employees (days)	0.277	0.511	0.000	9.333
Year dummies					
1999	1 for year 1999, 0 otherwise	0.167	0.373	0.000	1.000
2000	1 for year 2000, 0 otherwise	0.167	0.373	0.000	1.000
2001	1 for year 2001, 0 otherwise	0.167	0.373	0.000	1.000
2002	1 for year 2002, 0 otherwise	0.167	0.373	0.000	1.000
2003	1 for year 2003, 0 otherwise	0.167	0.373	0.000	1.000

Note: 2,094 observations (349 firms in 1998–2003).

(2), we add worker composition characteristics, including gender, age, and education, that is, H_{ijt} = {MALE RATIO, AGE < 30, AGE > 55, HUMAN CAPITAL}. While human capital is expected to enhance firm productivity and to raise worker compensation, gender and worker age may not have unambiguous effects. Particularly in terms of age, while young workers are more adaptive to newer technologies, seasoned workers are more experienced, with greater firm-specific human capital accumulated on-the-job.

In the third specification presented in column (3), we consider an additional workforce control, occupational injury/sick days (INJURY), and an additional firm control measuring economic incentives (measured by within-the-firm

TABLE 2
Workforce Composition by Year

Variable	1998	1999	2000	2001	2002	2003
Male ratio	0.600	0.607	0.611	0.616	0.616	0.615
Age <30	0.347	0.338	0.323	0.293	0.254	0.194
Age >55	0.166	0.182	0.194	0.205	0.220	0.243
Primary education (H_p)	0.298	0.302	0.300	0.290	0.280	0.265
Secondary education (H_s)	0.545	0.542	0.545	0.547	0.548	0.558
Higher education (H_h)	0.157	0.156	0.155	0.163	0.172	0.177
Human capital	1.375	1.373	1.373	1.382	1.391	1.400
Injury	0.307	0.272	0.288	0.278	0.257	0.259
Wage dispersion	0.233	0.232	0.226	0.220	0.210	0.194
Number of firms	349	349	349	349	349	349
Number of workers	258,434	289,878	318,806	300,069	282,858	243,030

TABLE 3
Industrial Variation of Key Variables

Industry	Male Ratio	Age <30	Age >55	Human Capital	Higher Education	Injury	Wage Dispersion
Food	0.586	0.193	0.318	1.382	0.168	0.336	0.229
Plastic and rubber	0.765	0.129	0.381	1.404	0.175	0.389	0.144
Textile	0.496	0.224	0.286	1.286	0.085	0.303	0.238
Electronics	0.573	0.369	0.125	1.398	0.183	0.180	0.239
Chemical	0.667	0.215	0.258	1.419	0.195	0.498	0.202
Glass	0.697	0.214	0.265	1.320	0.096	0.534	0.182
Paper	0.749	0.139	0.371	1.397	0.167	0.467	0.146
Steel	0.838	0.177	0.283	1.373	0.117	0.562	0.164
Transport	0.865	0.179	0.188	1.409	0.156	0.162	0.103

wage dispersion, WAGE DISPERSION). It is expected that more occupational injury/sick days reduce workers' productivity and value. There is, however, no consensus regarding the precise impact of intrafirm wage dispersion on the firm's performance. The tournament models suggest the positive impact of wage dispersion within a firm on the worker's effort (Lazear and Rosen 1981). Since the winner of a promotion tournament is promoted and receives a wage increase, large wage dispersion coincides with large incentives in firms. On the other hand, the equity and fairness theories argue that a compressed wage distribution improves labor relations and stimulates the average worker's effort (Akerlof and Yellen 1990). The empirical evidence is mixed, however. Earlier studies by Cowherd and Levine (1992) and Pfeffer and Langton (1993) support the hypothesis of equity and fairness theories. In contrast, the more recent studies by Winter-Ebmer and Zweimüller (1999), Bingley and Eriksson (2001), Heyman (2005), and Lallemand, Plasman, and Rycx (2007) are in favor of tournament theory.

Finally, the last specification presented in column (4) includes a market competition measure (measured by international exportability, EXPORT DUMMY). There is a small literature illustrating the positive relationship between exportability and productivity in developing countries. For example, such a relationship has been documented using Taiwanese data by Aw and Hwang (1995), Aw, Chung, and Roberts (2000), Liu, Tsou, and Hammitt (1999), and Tsou et al. (2008). Aw and Hwang (1995) suggest that both self-selection and learning play important roles in explaining the linkage between exporting and productivity. However, Liu, Tsou, and Hammitt (1999) and Tsou et al. (2008) conclude that higher productivity among exporters relative to nonexporters does not result from the acquisition or expertise by exposure to the export market, but rather that higher productivity is required to survive in the export market.

TABLE 4
Labor Productivity Regressions

Variable	(1)	(2)	(3)	(4)
Constant	7.0333 (29.72)***	4.3032 (12.08)***	3.8009 (9.11)***	3.5461 (8.14)***
LNAGE	−0.0185 (−0.38)	−0.0156 (−0.29)	−0.0187 (−0.34)	−0.0164 (−0.41)
LNKL	0.2063 (9.75)***	0.1629 (7.37)***	0.1697 (7.48)***	0.1690 (8.48)***
Large firm	0.0356 (0.90)	0.0848 (2.23)*	0.0871 (2.29)**	0.0809 (2.10)**
Small firm	0.3048 (6.30)***	0.2250 (5.14)***	0.2206 (5.00)***	0.2257 (5.76)***
Multi	−0.0445 (−1.19)	−0.0066 (−0.20)	−0.0054 (−0.16)	−0.0060 (−0.15)
Male ratio		0.2727 (2.28)**	0.3780 (2.86)***	0.3723 (2.99)***
Age <30		−1.9201 (−9.52)***	−2.0097 (−9.79)***	−1.9990 (−10.62)***
Age >55		−0.9086 (−5.19)***	−0.8823 (−4.99)***	−0.8877 (−4.91)***
Human capital		2.6384 (13.33)***	2.8257 (13.64)***	2.8584 (14.58)***
Injury			−0.0333 (−1.12)	−0.0340 (−1.13)
Wage dispersion			0.6965 (2.01)**	0.7118 (2.13)**
Export dummy				0.2247 (2.20)**
Plastic and rubber	−0.1899 (−2.46)***	−0.3428 (−5.22)***	−0.3169 (−4.72)***	−0.3294 (−3.71)***
Textile	−0.4290 (−6.41)***	−0.1087 (−1.67)*	−0.0860 (−1.31)	−0.0957 (−1.17)
Electronics	−0.0370 (−0.55)	0.0806 (1.34)	0.0891 (1.50)	0.0746 (0.99)
Chemical	−0.0741 (−0.87)	−0.1528 (−2.04)**	−0.1392 (−1.84)*	−0.1476 (−1.66)*
Glass	−0.9152 (−8.31)***	−0.7685 (−7.26)***	−0.7288 (−6.66)***	−0.7219 (−5.39)***
Paper	−0.0320 (−0.33)	−0.1681 (−1.58)	−0.1361 (−1.27)	−0.1263 (−1.00)
Steel	0.3111 (4.19)***	0.2544 (3.38)***	0.2747 (3.63)***	0.2678 (2.78)***
Transport	1.0311 (6.88)***	0.7049 (4.63)***	0.7518 (4.92)***	0.7431 (4.58)***
$\overline{R}^2$	0.18	0.34	0.34	0.34

Notes: The number of observations is 2,094. All regressions include 5-yr dummies. The reference year is 1998 and the reference industry is food. Values in parentheses are t-statistics. Regressions are estimated by ordinary least squares using heteroskedastic-consistent covariance matrix.

***, **, and *represent statistical significance at 1%, 5%, and 10% level, respectively.

Without further notice, we will regard the last specification as our benchmark setup.

A. *Firm Productivity Estimation*

In Table 4, we summarize regression results on firm productivity measured by APL. First, by comparing the first with the other three specifications, we can see how important workforce composition is in explaining firm productivity as $\overline{R}^2$ increases significantly from .18 to .3 or above. Among the worker characteristics, age and education are most important. Compared to the middle-aged, young workers below age 30 and old workers above age 55 are less productive, implying that on-the-job learning is the dominant force in the early stage, whereas adaptation becomes more important in the later stage. By focusing on the benchmark setup in column (4), a percentage point increase in the young reduces firm productivity by about 2.0%. Conversely, a percentage point increase in the human capital index results in a 2.8% increase in firm productivity. In addition, the productivity effects of firm age and of the establishment of multiple plants are statistically insignificant at the 10% level, which is due to the offsetting effects of learning and technology backwardness. While small firms with less than 250 employees are more productive by about .22%, large firms with more than 1,000 employees perform better than median-sized firms by .08%. The productiveness of small firms is likely due to their flexibility in adapting to the world market. Furthermore, both economic incentive and market competition are important for firm performance. Economic incentive measured by wage dispersion generates approximately a one-for-one positive effect on labor productivity. This result is more in line with the tournament models than with the equity and fairness models. Export-oriented firms on average enjoy 22% higher productivity, which is consistent with the evidence found in Taiwan (Liu, Tsou, and

TABLE 5
Solow Residual Regressions

Variable	(1)	(2)	(3)	(4)
Constant	7.4359 (40.52)***	4.2782 (12.04)***	3.7997 (9.47)***	3.5713 (8.64)***
LNAGE	−0.0001 (−0.01)	0.0334 (0.62)	0.0293 (0.54)	0.0314 (0.79)
Large firm	0.1603 (4.05)***	0.1920 (5.09)***	0.1955 (5.18)***	0.1899 (4.97)***
Small firm	0.2122 (4.44)***	0.1278 (2.94)***	0.1247 (2.84)***	0.1291 (3.33)***
Multi	−0.0407 (−1.11)	−0.0060 (−0.18)	−0.0038 (−0.12)	−0.0044 (−0.11)
Male ratio		0.2197 (1.88)*	0.3372 (2.56)***	0.3317 (2.70)***
Age <30		−1.8427 (−9.32)***	−1.9261 (−9.66)***	−1.9175 (−10.39)***
Age >55		−1.0134 (−6.07)***	−0.9711 (−5.67)***	−0.9769 (−5.56)***
Human capital		2.6672 (14.33)***	2.8657 (14.10)***	2.8943 (14.84)***
Injury			−0.0388 (−1.33)	−0.0395 (−1.32)
Wage dispersion			0.7141 (2.14)**	0.7290 (2.21)**
Export dummy				0.1987 (1.95)**
Plastic and rubber	−0.1881 (−2.48)***	−0.3387 (−5.22)***	−0.3085 (−4.69)***	−0.3195 (−3.62)***
Textile	−0.4274 (−6.54)***	−0.1223 (−2.00)**	−0.0959 (−1.52)	−0.1046 (−1.29)
Electronics	−0.0113 (−0.17)	0.1025 (1.76)*	0.1091 (1.88)*	0.1070 (1.29)
Chemical	−0.0694 (−0.83)	−0.1634 (−2.23)**	−0.1476 (−1.99)**	−0.1551 (−1.75)*
Glass	−0.9134 (−8.21)***	−0.7829 (−7.22)***	−0.7383 (−6.56)***	−0.7324 (−5.50)***
Paper	−0.0198 (−0.20)	−0.1681 (−1.62)	−0.1327 (−1.25)	−0.1241 (−0.99)
Steel	0.3052 (4.36)***	0.2202 (3.14)***	0.2470 (3.46)***	0.2406 (2.52)***
Transport	1.0679 (6.67)***	0.7300 (4.61)***	0.7786 (4.90)***	0.7709 (4.77)***
$\overline{R}^2$	0.12	0.30	0.30	0.30

Notes: The number of observations is 2,094. All regressions include 5-yr dummies. The reference year is 1998 and the reference industry is food. Values in parentheses are *t*-statistics. Regressions are estimated by ordinary least squares using heteroskedastic-consistent covariance matrix.

***, **, and *represent statistical significance at 1%, 5%, and 10% level, respectively.

Hammitt 2001; Tsou et al. 2008).[8] Finally, by examining the coefficients of industry dummies, one can see that firms in steel and transportation industries outperform others.

We conduct similar analysis using the Solow residual (SOLOW) to measure firm productivity and find that our main conclusions remain valid (Table 5). We also perform the analysis with the LP measure of TFP (see Table 6, using electricity usage to proxy unobserved productivity). Most of the main findings are unchanged, except that small firms are no longer better performing than median-sized firms and that wage dispersion is now statistically insignificant. Also, since the measure using electricity usage to proxy unobserved productivity performs better than using material costs as the proxy, we restrict our analysis to the former in the remainder of the paper.

Upon re-running the regressions, we find that, by excluding either industry dummies or worker education variables, the fitness of regressions for firm productivity regressions turns out to be significantly worse.[9]

In summary, firm age is not essential for the performance of firms. Rather, those of smaller size and those in the steel and transportation industries outperform others, in both the average product of labor and the Solow residual measures. Moreover, economic incentives measured by greater wage dispersion and market competition measured by exportability both play significantly positive roles in the performance of firms, which may have useful implications for wage policy and trade policy.

8. We have also considered using the export ratio (a continuous measure) instead of the export dummy. However, this measure is statistically insignificant throughout (and sometimes has a wrong sign). We note that using exportability as a proxy for market competitiveness may suffer a sample selection problem as exporting firms may be more productive to begin with.

9. The fitness of regressions for firm productivity regressions is much worse when industry dummies are excluded, due possibly to unobserved industry heterogeneity related to market competition and within-the-industry production externalities.

TABLE 6
Levinsohn-Petrin Productivity Regressions

Variable	(1)	(2)	(3)	(4)
(A)				
Constant	9.25920 (49.42)***	5.7627 (15.107.58)***	5.5871 (13.57)***	5.2539 (12.55)***
LNAGE	−0.0004 (−0.01)	0.0257 (0.46)	0.0253 (0.45)	0.0284 (0.70)
Large firm	0.3871 (9.65)***	0.4230 (11.01)***	0.4241 (10.97)***	0.4160 (10.74)***
Small firm	0.0807 (1.69)*	−0.0078 (−0.18)	−0.0085 (−0.19)	−0.0021 (−0.05)
Multi	−0.0051 (−0.11)	0.0229 (0.68)	0.0238 (0.70)	0.0229 (0.56)
Male ratio		0.3662 (3.11)***	0.4135 (3.14)***	0.4054 (3.26)***
Age <30		−1.6018 (−8.03)***	−1.6362 (−8.06)***	−1.6237 (−8.68)***
Age >55		−0.7122 (−4.20)***	−0.6921 (−4.02)***	−0.7006 (−3.93)***
Human capital		2.7664 (13.80)***	2.8374 (13.25)***	2.8792 (14.57)***
Injury			−0.0348 (−1.15)	−0.0357 (−1.17)
Wage dispersion			0.2770 (0.84)	0.2987 (0.90)
Export dummy				0.2891 (2.81)***
Plastic and rubber	−0.1536 (−1.83)*	−0.3366 (−4.77)***	−0.3244 (−4.51)***	−0.3404 (−3.81)***
Textile	−0.4284 (−6.15)***	−0.0993 (−1.50)	−0.0898 (−1.33)	−0.1026 (−1.24)
Electronics	−0.0636 (−0.90)	0.0604 (0.96)	0.0618 (0.98)	0.0434 (0.57)
Chemical	−0.0610 (−0.68)	−0.1570 (−2.03)**	−0.1475 (−1.87)*	−0.1584 (−1.76)*
Glass	−0.9161 (−7.98)***	−0.7868 (−6.97)***	−0.7659 (−6.59)***	−0.7572 (−5.61)***
Paper	0.0146 (0.16)	−0.1601 (−1.61)	−0.1445 (−1.43)	−0.1320 (−1.01)
Steel	0.4215 (4.16)***	0.3123 (4.13)***	0.3268 (4.26)***	0.3174 (3.28)***
Transport	1.0652 (6.09)***	0.7241 (4.85)***	0.7395 (4.87)***	0.7283 (4.45)***
$\overline{R}^2$	0.15	0.32	0.32	0.32
(B)				
Constant	10.2860 (67.87)***	6.6939 (19.88)***	6.5984 (15.96)***	6.1990 (14.42)***
LNAGE	0.0326 (0.86)	0.0883 (2.13)**	0.0892 (2.15)**	0.0930 (2.24)**
Large firm	0.7316 (17.3)***	0.7525 (18.94)***	0.7530 (18.94)***	0.7433 (18.68)***
Small firm	−0.1875 (−4.29)***	−0.2690 (−6.67)***	−0.2689 (−6.66)***	−0.2612 (−6.47)***
Multi	0.0072 (0.15)	0.0387 (0.91)	0.0393 (0.93)	0.0383 (0.91)
Male ratio		0.3090 (2.67)***	0.3390 (2.65)***	0.3293 (2.58)***
Age <30		−1.4259 (−7.56)***	−1.4485 (−7.53)***	−1.4336 (−7.46)***
Age >55		−0.7529 (−4.12)***	−0.7371 (−4.02)***	−0.7474 (−4.08)***
Human capital		2.7658 (15.75)***	2.8024 (13.82)***	2.8525 (14.06)***
Injury			−0.0401 (−1.28)	−0.0412 (−1.32)
Wage dispersion			0.1660 (0.48)	0.1921 (0.56)
Export dummy				0.3465 (3.28)***
Plastic and rubber	−0.1663 (−1.70)*	−0.3267 (−3.60)***	−0.3190 (−3.47)***	−0.3382 (−3.68)***
Textile	−0.4643 (−5.15)***	−0.1445 (−1.73)*	−0.1396 (−1.65)*	−0.1549 (−1.83)*
Electronics	−0.0322 (−0.39)	0.0690 (0.89)	0.0686 (0.88)	0.0466(0.60)
Chemical	−0.0769 (−0.77)	−0.1782 (−1.93)*	−0.1692 (−1.83)*	−0.1822 (−1.97)**
Glass	−0.9868 (−6.58)***	−0.8550 (−6.21)***	−0.8389 (−6.04)***	−0.8286 (−5.97)***
Paper	−0.0296 (−0.21)	−0.1887 (−1.45)	−0.1776 (−1.36)	−0.1626 (−1.25)
Steel	0.3803 (3.69)***	0.2891 (2.92)***	0.3018 (3.03)***	0.2905 (2.92)***
Transport	1.0476 (5.89)***	0.7214 (4.34)***	0.7273 (4.32)***	0.7138 (4.25)***
$\overline{R}^2$	0.26	0.39	0.39	0.40

Notes: The number of observations is 2,094. All regressions include 5-yr dummies. The reference year is 1998 and the reference industry is food. Values in parentheses are t-statistics. Regressions are estimated by ordinary least squares using heteroskedastic-consistent covariance matrix.

***, **, and *represent statistical significance at 1%, 5%, and 10% level, respectively.

B. Worker Compensation Estimation

In Table 7, we estimate worker compensation measured by wages based on the four specifications. Similar to the finding from firm productivity regressions, workforce composition is extremely crucial for explaining worker compensations. Our results suggest that labor

TABLE 7
Firm Wage Regressions

Variable	(1)	(2)	(3)	(4)
Constant	9.9929 (252.53)***	9.4008 (241.49)***	10.3626 (287.44)***	10.3851 (283.91)***
LNAGE	0.0205 (3.29)***	−0.0027 (−0.61)	0.0072 (1.91)*	0.0070 (1.85)*
LNKL	0.0377 (10.26)***	0.0130 (5.34)***	0.0012 (0.73)	0.0013 (0.76)
Large firm	−0.0134 (−1.97)**	0.0112 (2.41)**	0.0062 (1.78)*	0.0068 (1.94)**
Small firm	0.0091 (1.35)	−0.0075 (−1.66)*	0.0023 (0.78)	0.0019 (0.63)
Multi	−0.0053 (−0.74)	−0.0017 (−0.33)	−0.0039 (−0.97)	−0.0038 (−0.96)
Male ratio		0.2980 (21.02)***	0.1073 (8.66)***	0.1078 (8.72)***
Age <30		−0.3977 (−18.43)***	−0.2393 (−14.51)***	−0.2402 (−14.54)***
Age >55		−0.0661 (−3.23)***	−0.1038 (−7.22)***	−0.1033 (−7.17)***
Human capital		0.5831 (31.18)***	0.2145 (13.25)***	0.2116 (13.06)***
Injury			−0.0046 (−2.33)**	−0.0045 (−2.30)**
Wage dispersion			−1.2921 (−41.96)***	−1.2935 (−41.92)***
Export dummy				−0.0198 (−2.60)***
Plastic and rubber	0.1158 (7.58)***	0.0371 (3.85)***	−0.0160 (−2.51)***	−0.0149 (−2.34)**
Textile	−0.0462 (−3.14)***	0.0508 (5.04)***	0.0056 (0.86)	0.0065 (0.99)
Electronics	0.0026 (0.19)	0.0336 (3.99)***	0.0140 (2.71)***	0.0153 (2.98)***
Chemical	0.0250 (1.57)	−0.0004 (−0.03)	−0.0143 (−2.08)**	−0.0136 (−1.98)**
Glass	0.0259 (1.26)	0.0423 (2.41)**	−0.0194 (−1.87)*	−0.0200 (−1.94)**
Paper	0.1301 (7.68)***	0.0692 (5.49)***	0.0158 (2.23)**	0.0150 (2.14)***
Steel	0.0452 (2.64)***	−0.0120 (−0.99)	−0.0364 (−4.98)***	−0.0358 (−4.92)***
Transport	0.1981 (11.31)***	0.0807 (6.02)***	−0.0181 (−1.60)	−0.0173 (−1.53)
$\overline{R}^2$	0.25	0.66	0.82	0.82

Notes: The number of observations is 2,094. All regressions include 5-yr dummies. The reference year is 1998 and the reference industry is food. Values in parentheses are t-statistics. Regressions are estimated by ordinary least squares using heteroskedastic-consistent covariance matrix.

***, **, and *represent statistical significance at 1%, 5%, and 10% level, respectively.

quality, particularly middle-aged workforce (30–55 yr old) with higher education or less injury/sick days, contributes significantly to higher wage compensation. The latter finding concerning workers' health conditions is consistent with that in Hamermesh and Wolfe (1990). Additionally, our result concerning a positive effect of the capital-labor ratio on worker compensation suggests Pareto complementarity of the two primary inputs of production. While firm age is inessential for wage compensation, smaller firms pay less compared to the median sized. The presence of an employer-size wage premium has been documented by Bayard and Troske (1999), Troske (1999), and Idson and Oi (1999).

One may inquire whether nonwage compensations behave in a similar fashion. To address this question, we augment the worker wage measure by adding cash dividends, noncash dividends, and retirement fringe one by one. The results are reported in Table 8. As it can be seen clearly, all of our findings continue to carry out.

C. Robustness Analysis

To check the robustness of our findings, we would like to examine what happens if (a) we jointly estimate firm productivity and worker compensation regressions and (b) we include firm fixed effects in our estimation.

Table 9 presents the joint estimation of firm productivity and worker compensation regressions. It is easily seen that the results are very close to those under ordinary least squares (OLS) estimation. By conducting fixed effects estimation, we summarize the results in Table 10. While most of our findings remain unchanged, firms of larger size or with greater wage dispersion may no longer be associated with higher productivity once unobserved firm heterogeneities are controlled.

V. CONCLUSIONS

In this paper, we have examined the relationship between workforce characteristics and firm productivity based on a newly created employee-employer-matched data set. We have

TABLE 8
Firm Wage Regressions with Extra Compensation Added

	Cash Dividend		Cash/Noncash Dividend		Cash/Noncash Dividend and Retirement Fringe	
(1)	(2)	(1)	(2)	(1)	(2)	
Constant	9.9938 (252.31)***	10.3837 (284.29)***	9.9969 (251.25)***	10.3798 (284.06)***	9.9945 (250.98)***	10.3764 (284.04)***
LNAGE	0.0202 (3.22)***	0.0066 (1.77)*	0.0192 (3.03)***	0.0057 (1.55)	0.0198 (3.13)***	0.0060 (1.60)
LNKL	0.0377 (10.27)***	0.0012 (0.75)	0.0377 (10.26)***	0.0012 (0.71)	0.0379 (10.32)***	0.0013 (0.79)
Large firm	−0.0133 (−1.96)**	0.0069 (1.96)**	−0.0130 (−1.91)*	0.0020 (2.06)**	−0.0132 (−1.94)**	0.0072 (2.06)**
Small firm	0.0092 (1.35)	0.0019 (0.63)	0.0094 (1.38)	0.0020 (0.66)	0.0096 (1.40)	0.0020 (0.67)
Multi	−0.0053 (−0.74)	−0.0038 (−0.96)	−0.0053 (−0.75)	−0.0038 (−0.95)	−0.0053 (−0.74)	−0.0038 (−0.95)
Male ratio		0.1084 (8.78)***		0.1081 (8.74)***		0.1085 (8.79)***
Age <30		−0.2411 (−14.61)***		−0.2421 (−14.68)***		−0.2431 (−14.75)***
Age >55		−0.1035 (−7.18)***		−0.1033 (−7.17)***		−0.1007 (−6.97)***
Human capital		0.2133 (13.25)***		0.2185 (13.61)***		0.2200 (13.72)***
Injury		−0.0046 (−2.30)**		−0.0046 (−2.30)**		−0.0046 (−2.33)**
Wage dispersion		−1.2929 (−41.89)***		−1.2728 (−41.86)***		−1.2922 (−41.85)***
Export dummy		−0.0196 (−2.57)***		−0.0193 (−2.53)***		−0.0192 (−2.53)***
Plastic and rubber	0.1158 (7.58)***	−0.0150 (−2.36)**	0.1159 (7.59)***	−0.0151 (−2.37)**	0.1165 (7.62)***	−0.0147 (−2.31)**
Textile	−0.0463 (−3.14)***	0.0066 (1.01)	−0.0464 (−3.15)***	0.0070 (1.08)	−0.0467 (−3.17)***	0.0070 (1.07)
Electronics	0.0026 (0.19)	0.0154 (3.00)***	0.0033 (0.24)	0.0162 (3.16)***	0.0030 (0.22)	0.0163 (3.17)***
Chemical	0.0252 (1.59)	−0.0134 (−1.96)**	0.0254 (1.60)	−0.0133 (−1.94)**	0.0250 (1.57)	−0.0134 (−1.96)**
Glass	0.0257 (1.26)	−0.0200 (−1.95)**	0.0257 (1.26)	−0.0196 (−1.91)*	0.0256 (1.26)	−0.0194 (−1.88)*
Paper	0.1302 (7.68)***	0.0149 (2.13)**	0.1304 (7.69)***	0.0151 (2.15)**	0.1304 (7.65)***	0.0150 (2.13)**
Steel	0.0451 (2.63)**	−0.0360 (−4.94)***	0.0451 (2.64)**	−0.0357 (−4.92)***	0.0449 (2.62)***	−0.0313 (−4.95)***
Transport	0.1992 (11.34)***	−0.0164 (−1.46)	0.1993 (11.36)***	−0.0164 (−1.45)	0.2009 (11.45)***	−0.0146 (−1.30)
$\overline{R}^2$	0.25	0.83	0.25	0.83	0.25	0.83

Notes: The number of observations is 2,094. All regressions include 5-yr dummies. The reference year is 1998 and the reference industry is food. Values in parentheses are t-statistics. Regressions are estimated by ordinary least squares using heteroskedastic-consistent covariance matrix.

***, **, and *represent statistical significance at 1%, 5%, and 10% level, respectively.

TABLE 9
Joint Estimation of Productivity Regressions and Wage Regressions

	Labor Productivity	Firm Wage	Wald tests P Value	Solow Residuals	Firm Wage	Wald tests P Value	Levinsohn-Petrin Productivity	Firm Wage	Wald tests P Value
Constant	3.5461 (8.19)***	10.3851 (270.86)***		3.5713 (8.70)***	10.3818 (270.99)***		5.2539 (12.62)***	10.3912 (271.23)***	
LNAGE	−0.0164 (−0.41)	0.0070 (1.97)**	0.556	0.0314 (0.79)	0.0070 (1.99)**	0.534	0.0284 (0.71)	0.0068 (1.93)**	0.588
LNKL	0.1690 (8.53)***	0.0013 (0.72)	0.000		0.0018 (1.01)			0.0003 (0.19)	
Large firm	0.0809 (2.11)**	0.0068 (2.00)**	0.051	0.1899 (5.00)***	0.0067 (1.98)**	0.000	0.4160 (10.80)***	0.0069 (2.04)**	0.000
Small firm	0.2257 (5.80)***	0.0019 (0.55)	0.000	0.1291 (3.35)***	0.0018 (0.53)	0.000	−0.0021 (−0.05)	0.0021 (0.61)	0.914
Multi	−0.0060 (−0.15)	−0.0038 (−1.06)	0.957	−0.0044 (−0.11)	−0.0039 (−1.08)	0.989	0.0229 (0.56)	−0.0037 (−1.03)	0.511
Male ratio	0.3723 (3.01)***	0.1078 (9.83)***	0.031	0.3317 (2.72)***	0.1073 (9.79)***	0.064	0.4054 (3.28)***	0.1086 (9.91)***	0.016
Age <30	−1.9990 (−10.69)***	−0.2402 (−14.51)***	0.000	−1.9175 (−10.45)***	−0.2410 (−14.56)***	0.000	−1.6237 (−8.73)***	−0.2387 (−14.42)***	0.000
Age >55	−0.8877 (−4.94)***	−0.1033 (−6.49)***	0.000	−0.9769 (−5.59)***	−0.1042 (−6.55)***	0.000	−0.7006 (−3.95)***	−0.1015 (−6.38)***	0.001
Human capital	2.8584 (14.67)***	0.2116 (12.27)***	0.000	2.8943 (14.93)***	0.2115 (12.25)***	0.000	2.8792 (14.66)***	0.2120 (12.29)***	0.000
Injury	−0.0340 (−1.14)	−0.0045 (−1.72)*	0.322	−0.0394 (−1.32)	−0.0046 (−1.72)*	0.238	−0.0357 (−1.18)	−0.0045 (−1.70)*	0.298
Wage dispersion	0.7118 (2.14)**	−1.2935 (−43.90)***	0.000	0.7290 (2.23)**	−1.2922 (−43.87)***	0.000	0.2987 (0.90)	−1.2959 (−43.99)***	0.000
Export dummy	0.2247 (2.22)***	−0.0198 (−2.21)***	0.015	0.1981 (1.96)**	−0.0198 (−2.21)**	0.029	0.2891 (2.83)***	−0.0197 (−2.20)**	0.062
Plastic and rubber	−0.3294 (−3.74)***	−0.0149 (−1.91)*	0.000	−0.3195 (−3.64)***	−0.0149 (−1.90)*	0.001	−0.3404 (−3.83)***	−0.0150 (−1.92)*	0.000
Textile	−0.0957 (−1.17)	0.0065 (0.89)	0.207	−0.1046 (−1.29)	0.0063 (0.87)	0.167	−0.1026 (−1.25)	0.0068 (0.94)	0.179
Electronics	0.0746 (1.00)	0.0153 (2.31)**	0.425	0.0965 (1.30)	0.0154 (2.33)**	0.272	0.0434 (0.58)	0.0150 (2.27)**	0.705
Chemical	−0.1476 (−1.67)*	−0.0136 (−1.73)*	0.127	−0.1551 (−1.76)*	−0.0136 (−1.73)*	0.106	−0.1584 (−1.77)*	−0.0135 (−1.72)*	0.102
Glass	−0.7219 (−5.42)***	−0.0200 (−1.70)*	0.000	−0.7324 (−5.53)***	−0.0201 (−1.71)*	0.000	−0.7572 (−5.64)***	−0.0197 (−1.67)*	0.000
Paper	−0.1263 (−1.01)	0.0150 (1.35)	0.256	−0.1241 (−1.00)	0.0149 (1.34)	0.261	−0.1320 (−1.04)	0.0151 (1.37)	0.241
Steel	0.2678 (2.78)***	−0.0358 (−4.20)***	0.002	0.2406 (2.53)***	−0.0361 (−4.23)***	0.003	0.3174 (3.30)***	−0.0352 (−4.13)***	0.000
Transport	0.7431 (4.61)***	−0.0173 (−1.21)	0.000	0.7709 (4.80)***	−0.0173 (−1.21)	0.000	0.7283 (4.48)***	−0.0173 (−1.21)	0.000
R^2	0.35	0.83		0.31	0.83		0.33	0.83	

Notes: The number of observations is 2,094. All regressions include 5-yr dummies. The reference year is 1998 and the reference industry is food. Values in parentheses are *t*-statistics. Regressions are estimated by ordinary least squares using heteroskedastic-consistent covariance matrix.

***, **, and *represent statistical significance at 1%, 5%, and 10% level, respectively.

TABLE 10
Productivity and Firm Wage Regressions–Fixed Effect Estimation

Variable	Labor Productivity	Solow Residuals	Levinsohn-Petrin Productivity	Firm Wage	Firm Wage with Cash Dividend Added	Firm Wage with Cash/ Noncash Dividend	Firm Wage with Cash/ Noncash Dividend and Retirement Fringe
LNAGE	0.9374 (13.58)***	1.0125 (15.12)***	1.2291 (18.65)***	0.0467 (5.07)***	0.0485 (5.27)***	0.0474 (5.16)***	0.0473 (5.15)***
LNKL	0.1803 (8.15)***			0.0133 (4.80)***	0.0134 (4.84)***	0.0136 (4.91)***	0.0139 (5.03)***
Large firm	−0.0877 (−2.37)**	−0.0470 (−1.29)	0.0123 (0.34)	0.0138 (2.80)***	0.0137 (2.78)***	0.0139 (2.83)***	0.0137 (2.77)***
Small firm	0.1958 (7.01)***	0.1512 (5.54)***	0.0914 (3.41)***	−0.0040 (−1.06)	−0.0042 (−1.12)	−0.0039 (−1.06)	−0.0036 (−0.96)
Multi	−0.0882 (−1.36)	−0.0897 (1.41)	−0.0805 (−1.28)	−0.0078 (−0.91)	−0.0081 (−0.94)	−0.0081 (−0.93)	−0.0080 (−0.92)
Male ratio	0.7631 (4.31)***	0.7192 (4.22)***	0.8771 (5.23)***	0.1913 (8.11)***	0.1927 (8.18)***	0.1949 (8.28)***	0.1945 (8.26)***
Age <30	0.0449 (0.33)	0.0951 (0.71)	0.2668 (2.02)**	−0.2349 (−12.87)***	−0.2331 (−12.84)***	−0.2327 (−12.78)***	−0.2328 (−12.78)***
Age >55	0.1994 (1.12)	0.0736 (0.43)	0.0254 (0.15)	−0.0479 (−2.02)**	−0.0482 (−2.04)**	−0.0463 (−1.96)**	−0.0444 (−1.88)*
Human capital	0.9457 (4.32)***	0.7545 (3.55)***	0.4911 (2.35)**	0.3076 (10.55)***	0.3082 (10.58)***	0.3121 (10.73)***	0.3112 (10.69)***
Injury	0.0116 (0.80)	0.0117 (0.82)	0.0101 (0.72)	0.0004 (0.23)	0.0005 (0.25)	0.0005 (0.26)	0.0005 (0.25)
Wage dispersion	−0.8583 (−3.18)***	−0.8389 (−3.17)***	−0.8090 (−3.10)***	−0.9391 (−26.11)***	−0.9395 (−26.16)***	−0.9387 (−26.17)***	−0.9393 (−26.15)***
Export dummy	0.0857 (1.73)*	0.0901 (1.86)*	0.0956 (2.00)**	−0.0082 (−1.24)	−0.0084 (−1.27)	−0.0081 (−1.24)	−0.0079 (−1.19)
R^2	0.92	0.92	0.92	0.95	0.95	0.95	0.95

Notes: All regressions include firm fixed effects and 5 yr dummies. Figures in parentheses are *t*-statistics.
***, **, and *represent statistical significance at 1%, 5%, and 10% level, respectively.

constructed a new employee-employer-matched data set, which is one of the very first of such a kind in developing countries. We have measured firm productivity not only by the conventional average product of labor measure but also by the Solow residuals. We have introduced measures for economic incentives and market competition as well as jointly estimated both productivity and wage regressions so as to study more rigorously the employer-size wage premium. We have found that firms of smaller size outperform others, in both the average product of labor and the Solow residual measures. Labor quality, particularly middle-aged workforce with higher education, contributes significantly to firms' productivity. Both economic incentives and market competition play significantly positive roles in the performance of firms. The positive and significant relationship between intrafirm wage dispersion and firm productivity provides evidence in favor of the tournament models. An employer-size compensation premium is present, where larger firms overcompensate their employees relative to the corresponding productivity.

To conclude, we would like to acknowledge the limitations of our analysis, particularly in terms of (a) the nature of our sample, which includes only relatively larger and better performing firms that may overestimate firm productivity and (b) the short time span of our data, which makes a complete dynamic panel analysis impossible. Along these lines of research, one may conduct further study on other issues using this matched data set. For example, it is possible to investigate the relationship between worker turnover and firm productivity. Another potential interesting avenue of future work is to examine whether workforce diversity in job attributes or gender mix may affect the performance of firms and to explore whether worker compensation may be decomposed into firm-pure and worker-pure effects following Abowd, Kramarz, and Margolis (1999).

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