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Is Taiwan's Workforce Underpaid? Evidence from Marginal Product of Labor Estimates at the Company Level*

Tobias Haepp**
Postdoctoral Researcher
National School of Development, Peking University

Ping-Lung Hsin
Associate Professor
Graduate Institute of National Development, National Taiwan University

ABSTRACT

We analyze whether the production factor labor is underpaid in Taiwan by estimating the gap between the marginal product of labor and factor compensation based on profit and output data from publicly listed companies. Our results show that marginal product of labor growth has outpaced remuneration growth during the past two and a half decades, implying that Taiwan's workforce is increasingly underpaid. In contrast, capital overpayment has increased, especially in the manufacturing sector. We find that the degree of underpayment is larger for workers with university education, who are predominantly from younger cohorts, while the productivity-compensation-gap is smaller and sometimes negative for workers whose highest educational attainment is a high school degree. In companies with a young workforce, the degree of underpayment is higher and rents are allocated to capital owners. Workers from the low education group are overpaid in companies with an older workforce and long tenure structure.

Key Words: labor productivity, wages, factor compensation, decoupling

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** Corresponding author, E-mail: haepp@pku.edu.cn
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I. Introduction

During the recent decades of rapid economic growth, industrial restructuring and an expansion of higher education, the productivity of Taiwanese workers has risen remarkably. According to data from the Taiwanese statistical authority, labor productivity in the industrial sector rose by 78.0% between 1982 and 1992, and has continued to rise by 59.7% and 52.6% during the two subsequent decades until 2012. Sustained growth in labor productivity with a slight reduction in the growth rates over time can be attested for the three decades.

This positive trend in labor productivity differs markedly from the development of wages during the same time span. Towards the end of the Taiwanese economic miracle, hourly real wages in the industrial sector approximately doubled between 1982 and 1992, but this growth soon slowed down to about 20.4% for the following decade. During the most recent decade of stagnating wage growth, average real wages dropped by about 2.7% between 2002 and 2012.

A closer inspection of the trends in wage growth as depicted in Figure 1 reveals two turning points in 1993 and 2001, and the development of Taiwanese wages can therefore be divided into three phases: (1) rapid growth before 1994, (2) moderate growth between 1994 and 2001, and (3) stagnating or negative wage growth since 2002. Using 1982 as base year, one can observe that the index of labor productivity has outpaced the wage index roughly in 1997 and the gap between the two indicators has since then continued to widen. The divergence between wages and average labor productivity suggests that a decoupling between the two indicators has taken place in recent decades.[1]

From a theoretical point of view, wages do not necessarily follow developments in average labor productivity. In fact, microeconomic theory predicts that compensation allocated to each factor of production should be closely related to its *marginal* product rather than its *average* product. This has been termed marginal productivity theory and is arguably one of the most widespread concepts in economic work.[2] Our analysis therefore aims to trace how the marginal output contribution of the factor labor has evolved in Taiwan, how its time path differs

1 The incidence of decoupling between wages and labor productivity is not unique to the Taiwanese economy. See, for example, Pessoa and van Reenen (2013) for an analysis of decoupling in the US and UK economies.

2 Tests of marginal productivity theory date back at least to the work of Handsaker and Douglas (1938), Bronfenbrenner and Douglas (1939) and Gunn and Douglas (1940; 1942).

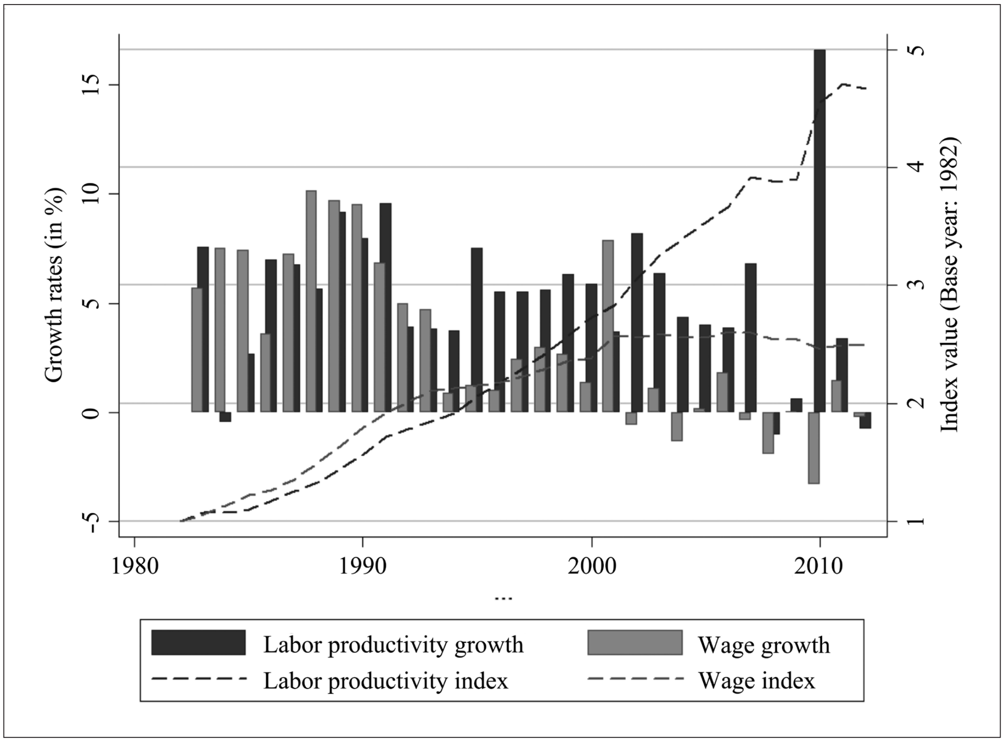

Figure 1: Development of Industrial Wages and Labor Productivity

Notes: Data retrieved from the Directorate-General of Accounting, Budget and Statistics. Indices and growth rates have been calculated at constant prices.

from average labor productivity, and how it has differed between periods characterized by rising wages and the more recent phase of stagnating wage growth. Our research methodology is based on both profit and output data, hence taking issue with the frequently voiced concern that even during a period of rising marginal product of labor, lack of company profitability may hinder company management from raising the level of staff compensation.

The two parts of our analysis build up on two types of estimation techniques in the literature on marginal productivity theory. The methodology with the longest tradition in the literature on marginal productivity estimation is based on the estimation of production functions. Work in this strand of research makes assumptions about the nature of production technology and estimates constant elasticity of substitution (CES) production functions. Most empirical papers assume a Cobb-Douglas production function (a special case of the CES function) or make use of the transcendental logarithmic (translog) approximation of the CES function. Hellerstein and Neumark (1999) and Hellerstein et al. (1999) estimate Cobb-Douglas and translog production functions and find that relative wages largely reflect differences in productivity.[3] Dobbelaere and Mairesse (2013) classify different labor market regimes and find that labor is paid more than its marginal product for firms in the dominant labor market bargaining regime based on Cobb-Douglas production function estimations for French firms. The evident weakness of this approach is that parametric assumptions need to be made in order to model the production technology.

More recently, a second approach to estimating marginal productivity based on profit data has been proposed by Biewen and Weiser (2014). This methodology does not impose the restrictive assumptions mentioned above. According to the logic of the methodology, residual company profits (or losses) contain information about whether each factor of production has been rewarded above or below its marginal product. Another practical advantage of the methodology is that the estimated coefficients conveniently allow for a direct analysis of the absolute deviation in remuneration from the level of remuneration in line with marginal productivity for each factor of production. In their empirical analysis, the authors find only moderate deviations from the predictions of marginal productivity theory for different factors of production in Chilean manufacturing plants.

The two estimation approaches based on company output and company profits therefore link up directly with the two potential causes put forward to explain the recent absence of wage growth in Taiwan and will be employed to uncover to what extent a potential slowdown in the marginal product of labor and developments in firm profitability can explain the recent developments in Taiwanese wages.

The rest of this paper is structured as follows. Section II outlines in detail the methodologies employed for the estimation of profit regressions and production functions. In section III we explain the content of our data set and provide descriptive statistics. Section IV presents our main findings, and section V analyses how different labor groups are affected with a particular focus on young workers. Section VI discusses our results and concludes the paper.

II. Methodology

A. Estimation Using Profit Data

In this subsection, we outline the methodology proposed in Biewen and Weiser

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3 While average firm wages have been found to be in line with marginal productivity, this does not exclude the possibility of dispersion around mean productivity at similar wage levels within a company from the most efficient to the least efficient workers. See the results in Frank (1984) for a restrictive sample of professions.

(2014) to obtain estimates of the gap between marginal productivity and factor compensation. Under the general assumption that the production function is homogeneous, residual profits reaped or losses incurred by companies contain information about whether each factor of production has been remunerated above or below its marginal product. The approach starts with the accounting identity that company profits π are equal to company revenues minus total costs c minus tax payments τ, i.e.:

$$\pi = p_Y Y - c - \tau \tag{1}$$

where Y and p_Y denote output and its per unit price, respectively. Total costs can be further subdivided into capital rents r_K, labor costs w_L and costs for intermediate inputs p_I, where r is the rental rate of capital, w is the compensation paid to labor and p denotes the price of intermediate goods. K, L and I are the levels of capital, labor and intermediate inputs employed in the production process, respectively. After replacing total costs with the sum of the different cost components, we obtain:

$$\pi = p_Y Y - rK - wL - p_I I - \tau \tag{2}$$

Due to Euler's theorem, a production function that is homogeneous of degree h can be written as:[4]

$$hY = f_K K + f_L L + f_I I \tag{3}$$

After substituting for Y, we thus obtain:

$$\frac{\pi + \tau}{p_Y} = \left(\frac{f_K}{h} - \frac{r}{p_Y}\right)K + \left(\frac{f_L}{h} - \frac{w}{p_Y}\right)L + \left(\frac{f_I}{h} - \frac{p_I}{p_Y}\right)I \tag{4}$$

This equation is the intuitive result that residual real profits before taxes can be decomposed into the weighted deviations of the compensation for each factor of production from its marginal product scaled by the degree of homogeneity of the production function.[5] In other words, all residual profits must be due to an underpayment of at least one factor of production or due to overpayment in case of

4 CES production functions such as the Cobb-Douglas function employed in the next sub-section are members of the more general class of linear homogeneous production functions.

5 A drawback of this methodology is the fact that productivity shocks that alter the productivity of the factors of production may lead to changes in input levels. Because some factors of production can be adjusted more quickly than others and compensation levels may also not be adjusted instantly, this may lead to some inaccuracy in the estimates. We will discuss the impact of productivity shocks in more detail in the next subsection.

company losses. The above equation will be the main vehicle for the empirical estimations in the first part of section IV. After rewriting real net profits before taxes as $\tilde{\pi}_{it}$ and using alphas to denote deviations from the marginal product for each factor of production, we denote our regression equation as:

$$\tilde{\pi}_{it}=\alpha_K K_{it}+\alpha_L L_{it}+\alpha_I I_{it}+\varepsilon_{it} \quad (5)$$

In the analysis of Biewen and Weiser (2014), the authors report problems in finding robust estimates for the coefficients in this regression due to the leptokurtic distribution of profit data. Robust regression methods are a solution to this problem since they provide reliable coefficient results even in the presence of a potentially large share of outliers. We briefly outline the robust regression methodology employed. Since the OLS approach minimizes the variance of the residuals $\tilde{\sigma}^2$, even a small fraction of outliers can have a large effect on the estimators obtained. Estimating the above equation using OLS may therefore not be able to yield robust estimates. In a situation when data are at best approximately normally distributed, a robust approach to statistical modelling has to be adopted to produce reliable parameter estimates (Maronna et al., 2006). The MM estimator proposed in Yohai (1987) is suitable since it is robust in face of outliers of both dependent and independent variables and transforms the residuals in a way that gives less weight to large residuals. Starting from equation 5 above, the OLS estimator solves:[6]

$$\hat{\alpha}_{OLS}=\arg\min_{\alpha}\sum_{t=1}^{n} r_t^2(\alpha) \quad (6)$$

where $r_i(\alpha)=\tilde{\pi}_i-\alpha_K K_i-\alpha_L L_i-\alpha_I I_i$ for $1\leqq i\leqq n$. As mentioned above, focusing on the variance of the residuals renders the estimator sensitive to outliers. The remedy is therefore to replace the square function by a function $\rho(\cdot)$ that puts less emphasis on outliers. The Tukey Biweight function is typically chosen in empirical work. The first step of the iterative estimation procedure is then to find a normalizing scale for a robust dispersion, which can be defined as $\hat{\sigma}^S(\alpha)$ and satisfies

$$\frac{1}{n}\sum_{t=1}^{n}\rho\left(\frac{r_t(\alpha)}{\hat{\sigma}^S}\right)=E(\rho(Z)) \text{ with } Z\sim N(0, 1) \quad (7)$$

This estimator from the general class of S-estimators possesses the property of high robustness in the presence of outliers (i.e. high breakdown point), but suffers from a low degree of Gaussian efficiency. A more efficient estimator can be obtained by

6 See Verardi and Croux (2009) for a more detailed discussion of S-estimation, M-estimation and the MM-estimator used in this study.

incorporating this estimate in a second step to obtain the MM-estimator Yohai (1987). After obtaining the normalizing scale, the final minimization problem of the MM estimator can be written as:

$$\hat{\alpha}_{MM} = \arg\min_{\alpha} \sum_{t=1}^{n} \rho\left(\frac{r_t(\alpha)}{\hat{\sigma}^S}\right) \tag{8}$$

This estimator is characterized by both a high breakdown-point and high efficiency and therefore suits the purposes of our empirical analysis.[7] Since our empirical implementation is analogous to the approach in Biewen and Weiser, the coefficients obtained will also be directly comparable to the ones from their study based on company data from Chile.

B. Estimation Using Output Data

While the methodology introduced in the previous subsection allows for an estimate of the deviation of factor compensation from the marginal product of each factor of production, a drawback of the methodology is that the actual development of the two variables is only treated implicitly. In this subsection, we therefore outline our methodology used to obtain estimates for the marginal product of labor and explicitly discuss its development. The estimation procedure is as follows. We follow the major part of the literature and start from a Cobb-Douglas production function which is given as:[8]

$$Y_{it} = F(A_{it}, K_{it}, L_{it}) = A_{it} K_{it}^{\beta_k} L_{it}^{\beta_l} \tag{9}$$

where Y_{it} is the value-added of company i in year t, while K_{it} and L_{it} are its capital stock and labor input in the same period. β_K is the elasticity of output with respect to a change in the capital stock and β_L is the output elasticity with respect to labor. A_{it} measures the efficiency level of the production in each company at each point in time. Since an increase in A_{it} implies an increase in the productivity of all factors of production, this has been termed total factor productivity (TFP). Under the assumption that the productivity term is Hicks-neutral and therefore additively

7 We follow Maronna et al. (2006), who recommend an implementation with a breakdown point of 50% and a Gaussian efficiency of 85% as the optimal way of dealing with the trade-off between robustness and efficiency.

8 Van Biesebroeck (2008) compares different methodologies to obtain productivity estimates and finds that the labor elasticity results of the semiparametric method implemented in this subsection are highly correlated with those based on other methods, such as data envelop analysis and stochastic frontier analysis.

separable from the production inputs, we can take natural logarithms and rewrite the production function as:

$$y_{it}=\beta_0+\beta_k k_{it}+\beta_l l_{it}+\varepsilon_{it} \tag{10}$$

where the lowercase letters are the natural logarithms of the notations in capital letters introduced above, and $ln(A_{it})$ has been decomposed into the mean efficiency of all firms in the data set β_0 and the deviation from this mean for each company in each year ε_{it}. By estimating this equation, an estimate for the elasticity of output with respect to labor β_l can be obtained and the marginal product of labor (MPL) can be calculated as follows:

$$\beta_l=\frac{\dfrac{\partial Y_{it}}{Y_{it}}}{\dfrac{\partial L_{it}}{L_{it}}}=\frac{\partial Y_{it}}{\partial L_{it}}\times\frac{L_{it}}{Y_{it}}=MPL_{it}\times\frac{1}{APL_{it}}\rightarrow MPL_{it}=\beta_l\times APL_{it} \tag{11}$$

where APL is the average product of labor, which can be directly calculated as value-added divided by the amount of labor employed. It is therefore straightforward to calculate our indicator of interest based on the coefficients obtained from a regression estimation of equation 10.

The next issue is how to obtain unbiased estimates of equation 10. Ordinary least squares (OLS) estimation would be the first candidate. However, as discussed extensively in the literature (Eberhardt and Helmers, 2010; Van Beveren, 2012), an OLS estimate of the equation would result in biased coefficient estimates. The major reason for this bias is the simultaneity between the level of inputs chosen and productivity shocks experienced by the firm which are unobserved by the researcher.[9] If management observes a productivity shock and alters its choice of input levels accordingly, the error term in the above equation is correlated with the regressors and the OLS assumption of zero conditional mean for the error term is violated. In order to obtain unbiased estimators, this simultaneity effect has to be incorporated in the regression model. The underlying idea of the proposed solutions is that the error term can be further decomposed into a productivity shock ψ_{it} which can be predicted and a random error term ζ_{ij} incorporating measurement errors and external events that cannot be anticipated by both the researcher and company

9 Other complications generally exist that render it difficult for the researcher to obtain unbiased estimates of equation (10). These include the lack of firm-level price data (De Loecker, 2011) and the effects of different production techniques for different products even within the same industry (Bernard et al., 2009). As in other similar investigations, these issues remain beyond the scope of our paper due to data limitations.

management.[10] Equation (10) can therefore be rewritten as:

$$y_{it}=\beta_0+\beta_k k_{it}+\beta_l l_{it}+\psi_{it}+\zeta_{it} \tag{12}$$

In the special case when ψ_{it} is time-invariant, estimation with firm-level fixed effects or the first-differenced version of the above equation will lead to unbiased estimates. However, productivity shocks generally differ over time even at the company level and empirical research shows that the fixed-effects estimators do not resolve the endogeneity problem (Ackerberg et al., 2006). Stochastic frontier models (henceforth: SF) interpret the productivity term as firm-specific inefficiency relative to an ideal production frontier (Aigner et al., 1977; Meeusen and van den Broeck, 1977). These models make distributional assumptions about the weakly negative inefficiency term which can hence be separated from the error term. Estimates for the model parameters and the inefficiency term can thereupon be obtained in a two-step procedure. The models proposed by Olley and Pakes (1996, henceforth: OP) and Levinsohn and Petrin (2003, henceforth: LP) assume that productivity shocks are idiosyncratic events and exploit the fact that company managers are to some extent able to observe the productivity shock that remains unobserved by the researcher. Proxy variables can thus be employed to measure the productivity shock for each company at each point in time. The former uses the level of investment as a proxy for the productivity shock, while the latter uses the level of material inputs. Because the proxies contain information about the size and the direction of the productivity shock, unbiased estimators for the model coefficients can be obtained via a multi-step procedure. We report annual coefficient results for β_l based on the different estimation methods in the appendix.[11] For our empirical analysis, we employ the coefficient results of the OP and LP methods, thus assuming that productivity shocks are to some extent idiosyncratic to the firm and managers possess some degree of knowledge of them.[12] Since

10 For simplicity, the productivity shock ψ_{it} contains productivity shocks experienced by all firms in a particular year, such as due to technological progress, and firm specific productivity shocks, such as an individual process innovation.

11 The five estimation methods reported are: OLS estimation without the productivity term, least-squares estimation in first-differences (DIF), a stochastic frontier (SF) model with an exponential distribution of the inefficiency term as proposed in Meeusen and van den Broeck (1977), and the OP (Olley and Pakes, 1996) and LP (Levinsohn and Petrin, 2003) methods.

12 Our qualitative results are not sensitive to the methodology adopted. Apart from the results of the first-differenced equation, the coefficient results from the other methods exhibit a similar time trend. The β_l-estimates obtained from the OP and LP methods are highly correlated and are the lowest amongst the different methods.

both semiparametric estimation methods solve the endogeneity problem of the company input choice and neither is generally to be preferred over the other, we implement both estimators and utilize the average result of both estimations in our empirical section.

III. Data Set and Descriptive Statistics

For our empirical analysis we make use of the Taiwan Economic Journal (TEJ) database, which contains information collected from the annual statements of companies listed at the Taiwan Stock Exchange (TSE).[13] These data allow for an annual analysis and include detailed information on company output, employment levels, capital stock, production inputs, investment expenditures and profits. In order to compare the development of the marginal product of labor as estimated from our output function estimations to the development of labor compensation, we calculate wages at the industry level from individual wage data obtained from the Manpower Utilization Survey, a representative survey of the Taiwanese workforce conducted annually by the national statistical authority. To account for different price levels for each year and industry, we deflate all data measured in monetary units by the most detailed deflators available from the Taiwanese statistical authorities.[14] After deleting incomplete observations, our unbalanced panel data set contains data from 1,742 companies covering 45 two-digit industries as defined by the Taiwanese statistical authorities. The lion's share of 1,600 companies belongs to the manufacturing sector with the 946 companies from the two sectors producing electronic parts or components and computers, electronic and optical products constituting the majority of manufacturing companies. The remaining companies are from the

13 Publicly listed companies admittedly constitute a particular subsample of Taiwanese companies. The only other potential data source is the Industry, Commerce and Service Census. Unfortunately, the census is only conducted at five-year intervals and a single year cannot be used to represent the whole period before and after the census. Due to the five-year gap between time periods, it would also be impossible to implement the algorithms controlling for productivity shocks for our output regressions. Furthermore, the census data do not contain company profit data, rendering it impossible to implement our profit regressions. For the case of Taiwan, it can be generally assumed that the trends in productivity of smaller companies largely follow those of medium- and large-scale businesses from the same industry contained in our sample.

14 Deflators for output and intermediate inputs are available at the two-digit (division) level, while deflators for the capital stock are available at the one-digit (section) level; see www.stat.gov.tw for details.

service sector (142).[15] The largest service sectors in our sample are real estate development (42), wholesale (22), and computer system design services (20). Since companies from the electronics sectors constitute about 59% of the manufacturing subset, we split the companies in our dataset into three groups: non-electronics manufacturing sector, electronics manufacturing sector and service sector.

Statistics of the key variables in our dataset for manufacturing and service sector companies across the three time periods are shown in Table 1. We briefly

Table 1: Key Statistics for the Three Time Periods

	1990–1993	1994–2002	2003–2012
Complete sample (1742 companies)			
Sales per worker	6334.05	6914.14	10633.60
Intermediate input per worker	3685.41	3684.86	4633.37
Value-added per worker	867.88	1255.55	1565.95
Capital-labor ratio	3330.21	4204.48	3281.54
Profits per worker	463.11	314.38	426.17
Non-electronics manufacturing sector (654 companies)			
Sales per worker	7564.21	9112.22	10820.48
Intermediate input per worker	4693.87	5262.19	5850.78
Value-added per worker	809.64	1072.11	1397.84
Capital-labor ratio	3663.45	4900.65	4207.12
Profits per worker	514.29	262.36	577.46
Electronics manufacturing sector (946 companies)			
Sales per worker	2156.05	4234.77	10131.55
Intermediate input per worker	1273.73	2311.61	4153.31
Value-added per worker	705.02	1286.65	1686.64
Capital-labor ratio	1663.62	3234.51	2560.57
Profits per worker	145.12	328.74	436.04
Service sector (142 companies)			
Sales per worker	10119.54	11838.12	14037.72
Intermediate input per worker	3607.92	3724.52	1503.29
Value-added per worker	1820.75	2068.74	1504.91
Capital-labor ratio	6034.41	6535.73	4130.11
Profits per worker	1073.08	509.76	−593.23

Notes: All values have been inflated to the price level in 2012. Unit: thousand NT$.

15 We drop a total of 28 companies from our dataset since these are scattered across other industrial sectors such as construction, utility supply, civil engineering and waste management.

discuss the trends in our variables of interest—profits per worker, output per worker and value-added per worker—and how their paths reflect the development of the other two production inputs per unit of labor input: material input per worker and capital stock per worker. The amount of output per worker has increased over time in all sectors. This can partly be explained by an increase in intermediate inputs per worker throughout all periods in the manufacturing sector. Intermediate input in the service sector has increased from the first to the second period, but has most recently decreased. Similar to the development of output, value-added per worker in the manufacturing sector has been rising over time, but service-sector value added has decreased in the past decade. An increase in capital labor-ratios has contributed positively to value-added from the first to the second period. In the final decade, however, the capital stock per worker has dropped in all sectors. Regarding the development of profit levels per worker, manufacturing sector profits exhibit no clear trend over time and were lowest in the first period for the non-electronics manufacturing sector and in the second period for the electronics manufacturing sector. Profits in the services sector, however, have continuously decreased, and have been negative on average during the past decade. Overall, the developments of profits generated per worker and value-added per worker differ markedly for all sectors over time, and our two estimation techniques therefore make use of different information from each dependent variable.

IV. Main Estimation Results

A. Annual Profit Function Estimation Results

In this subsection we apply the estimation procedure introduced in section II to our panel data set of Taiwanese companies. We first implement the profit regressions as outlined in equation (5) in section II. While our main purpose is to identify possible changes in the relationship between the marginal product of labor and labor remuneration over the three time periods identified in the introduction, the precise year when one period ends and another begins may be considered somewhat arbitrary. We therefore first provide the results from annual regression analysis before proceeding to the analysis pooling data by time period. For our profit function regressions, the first year included is 1990, while the final annual observations included are from the year 2012. Based on the following results, overpayment (or underpayment) for intermediate inputs can be directly inferred from a negative (positive) coefficient for this factor of production. For the other two factors of production we need to make adjustments since residual profits are allocated between workers and capital owners. In particular, workers receive bonus payments either in the form of cash or stocks. The amount of these bonus payments for the workforce of each company are disclosed on annual company statements and has been collected by TEJ in a separate data set. After obtaining the coefficient α_L, we therefore deduct the average real bonus payment per worker from the coefficient obtained in order to calculate the total productivity-compensation gap per unit of labor:

$$\tilde{\alpha}_L = \alpha_L - \frac{\frac{B}{p_Y}}{L} \tag{13}$$

For the degree of over-/underpayment for the factor capital, it should be noted that in addition to the reward paid to the factor of production, all residual profits (losses) after tax payments will also be reaped (incurred) by capital owners. We therefore subtract the amount of real profits after taxes per unit of capital from the coefficient obtained for the factor capital and calculate the total compensation per unit of capital $\tilde{\alpha}_K$ as:

$$\tilde{\alpha}_K = \alpha_K - \frac{\frac{\pi}{p_Y}}{K} \tag{14}$$

The annual coefficient results for $\tilde{\alpha}_L$, $\tilde{\alpha}_K$ and α_I for each company group are shown in Table 2 below.[16] The most striking insight from this part of the analysis is that capital is the only factor of production that has been consistently overpaid in almost all years, while the other two factors of production—material and labor—have been underpaid in most years included. The only time period when capital has been underpaid is during the global recession between 2008 and 2009. Yet, a closer inspection shows that the initial regression coefficients for the two periods were negative (implying overpayment) at −0.007 (in 2008) and −0.036 (in 2009) and the negative total compensation for capital owners is due to the large losses incurred during the period. The degree of underpayment for material inputs has

16 The robust R^2 reported for our profit function regressions has been calculated as

$$R_w^2 = \left(\frac{\sum_{i=1}^{n} w_i (y_i - \bar{y}_w)(\hat{y}_i - \bar{\hat{y}}_w)}{\sqrt{\sum_{i=1}^{n} w_i (y_i - \bar{y}_w)^2 \sum_{i=1}^{n} w_i (\hat{y}_i - \bar{\hat{y}}_w)^2}} \right)^2$$

where $\bar{y}_w = (1/\sum w_i)\sum w_i y_i$, $\bar{\hat{y}}_w = (1/\sum w_i)\sum w_i \hat{y}_i$ and w_i are the weights produced through Tukey's biweight function; see Renaud and Victoria-Feser (2010). We do not calculate an R^2 for our output function regressions in the following subsection, because the final step in those estimations is not a least-squares procedure.

Table 2: Annual Regression Results for Deviations of Factor Payments from Marginal Productivity

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Complete sample											
Labor	−12.384	12.957*	70.408*	100.733*	44.215*	43.974*	27.133*	162.047*	72.490*	151.523*	76.325*
Capital	−0.153*	−0.207	−0.095*	−0.189	−0.182*	−0.191	−0.145*	−0.244	−0.139*	−0.224*	−0.272*
Intermediates	0.044*	0.040*	0.048*	0.023*	0.043*	0.036*	0.027*	0.015*	0.036*	0.054*	0.052*
Observations	246	318	380	411	437	519	651	750	873	1016	1058
R^2	0.161	0.228	0.656	0.533	0.875	0.829	0.804	0.658	0.712	0.623	0.623
Non-electronics manufacturing sector											
Labor	−10.885	37.667*	99.949*	166.693*	55.374*	111.884*	211.944*	86.323*	254.093*	0.161*	30.088*
Capital	−0.163*	−0.181*	−0.103	−0.169	−0.180*	−0.120*	−0.135*	−0.151	0.017*	−0.067*	−0.147*
Intermediates	0.039*	0.039*	0.038*	0.022	0.041*	0.035*	0.013	0.021*	0.004	0.105*	0.077*
Observations	180	226	258	264	278	316	365	397	430	459	468
R^2	0.142	0.320	0.663	0.669	0.710	0.643	0.739	0.849	0.635	0.931	0.873
Electronics manufacturing sector											
Labor	−44.304*	13.085	4.818	93.986*	62.136*	27.135*	−10.540	143.200*	126.150*	21.029*	187.569*
Capital	−0.073*	−0.047*	0.018*	−0.121*	−0.230*	−0.248	−0.159	−0.238*	−0.224	−0.320*	−0.356*
Intermediates	0.081*	0.021*	0.027*	0.004*	0.013*	−0.009	0.031*	0.016*	0.046*	0.054*	0.024*
Observations	47	68	92	112	122	160	233	289	374	472	519
R^2	0.565	0.691	0.810	0.742	0.661	0.338	0.850	0.903	0.809	0.944	0.790
Service sector											
Labor	−230.433	162.103	62.103	−328.546*	28.018	69.133*	15.823	−47.203	157.680*	−39.857	−69.964*
Capital	−0.114	−0.886	−0.304*	−0.537*	−0.207	−0.320	−0.414*	−0.696*	−0.108*	−0.103	−0.322*
Intermediates	0.183*	−0.150*	0.157*	0.067*	0.141	0.159	0.087*	0.055*	0.017	0.012	0.003
Observations	19	24	30	35	37	43	53	64	69	85	71
R^2	0.701	0.268	0.478	0.300	0.748	0.549	0.736	0.556	0.449	0.065	0.885

Notes: Estimation results are based on equation 5. A positive (negative) coefficient indicates remuneration below (above) marginal productivity; see equation 4. Significance at least at the 10% level is denoted by the * symbol.

2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
53.855	70.310*	−71.313	10.796*	24.17	221.192*	193.408*	135.579*	191.244*	125.662*	317.293*	519.365*
−0.098*	−0.232*	−0.476*	−0.093*	−0.341*	−0.631*	−0.790*	0.582*	670.560	−0.848*	−3.470*	−27.815*
0.044*	0.074*	0.056*	0.065*	0.050*	0.017*	0.024*	0.052*	0.044*	0.071*	0.035*	0.007*
1103	1174	1231	1210	1196	1205	1208	1216	1247	1277	1286	1270
0.795	0.605	0.961	0.876	0.938	0.735	0.784	0.880	0.996	0.994	0.980	0.973
175.395*	133.049*	260.010*	291.838*	696.035*	328.763*	170.190	224.536*	93.378	492.415*	271.819*	335.466*
−0.007*	−0.036*	−0.199	−0.083*	−0.291*	0.010	−0.125*	1.098	−0.279*	−0.295*	−8.182	−63.953*
0.039*	0.051*	0.020*	0.058*	0.003	0.088*	0.034*	0.035	0.035*	0.019*	0.014*	−0.012*
469	482	493	489	489	488	490	495	507	522	540	542
0.802	0.537	0.792	0.895	0.646	0.926	0.298	0.920	0.704	0.803	0.475	0.864
−63.480	5.982*	−106.120*	23.581*	−17.209	178.082*	90.168*	84.645	116.394*	343.679	432.671*	540.891*
−0.220*	−0.376*	−0.771*	−0.611*	−0.749*	−1.182*	−1.596	−0.469	1224.658*	−1.298*	−0.110*	−1.294*
0.056*	0.076*	0.024*	0.019*	0.038*	0.028	0.055*	0.064*	0.052*	0.022*	0.029*	0.116*
567	628	671	663	649	659	662	670	693	701	696	677
0.633	0.570	0.667	0.900	0.798	0.843	0.958	0.997	0.854	0.982	0.754	0.600
266.553*	120.310*	342.672*	440.114	110.827*	562.903*	274.381*	−958.647*	274.044*	87.489*	58.569*	103.965*
0.199*	−0.196*	−0.268*	5.872*	3.205	0.072*	3.213	9.689*	0.670*	0.628*	−0.224*	−0.160*
−0.009	0.011	0.063*	−0.133*	−0.642	−0.019	−0.294*	0.348*	−0.185	0.118*	−0.084*	0.143*
67	64	67	58	58	58	56	51	47	54	50	51
0.580	0.562	0.782	0.724	0.620	0.715	0.909	0.912	0.895	0.886	0.968	0.924

been small and relatively stable over time with a coefficient in the range of 0.03 to 0.05 for most years of our analysis. The only factor of production for which large deviations from marginal productivity are identified is labor. Furthermore, the amount of underpayment for the factor labor is not only large in several years but also increasing towards the end of our analysis. Labor was paid close to its marginal product in the early years of our analysis, but has subsequently been underpaid in most years across all sectors and the degree of underpayment has been increasing, especially in the final decade. In the following subsection, we analyze whether these results are in line with a widening gap between the explicit estimation results of the marginal product of labor based on production function estimates and wage levels.

B. Annual Output Function Estimation Results

For our output data analysis, we structure our discussion in a similar manner as for the profit regression results above and first provide the results from our annual analysis before proceeding to the results from our pooled regressions by time period. The first step is the estimation of the β-coefficients of the production functions. In order to group companies most accurately by their production technology, we split our dataset into subgroups by industry similarity until each subgroup constitutes a sufficiently large sub-sample of at least thirty observations in each year of our analysis. At the end of this procedure, our companies are grouped into eight industry groups, for which we estimate production functions. The marginal product of labor is then calculated as shown in equation 11. Since the algorithm introduced by Levinsohn and Petrin (2003) requires two preceding periods for the production function estimation, the first year included in our annual output regression analysis is 1992. The results of our annual output regression analysis are shown in Table 3 below.

The main finding of this part of our analysis is that the growth in both marginal and average product of labor over time has been higher than the growth in wages in almost all years and sectors. Notably, worker wages during the early years of our analysis were higher than the marginal product of labor. Taking the production function estimates at face value, workers were therefore overpaid in the early years of our analysis. In 1995 the marginal product in the manufacturing sectors began to exceed the level of wages, and the same turning point was reached in the service sector in 1997. Growth in the marginal product of labor subsequently continued to outpace wage growth, and by 2006 the marginal contribution of labor to company value-added amounted to roughly twice as much as the wages paid. During the final decade, the decline in wages in the whole economy becomes evident. While wages peaked between 2001 and 2007 in the different sectors and subsequently began to fall, the marginal product of labor has continued to rise until the final year of our analysis. Our annual production function estimates demonstrate that the recent decline in wages began in spite of a sustained increase in the marginal product of labor.

C. Pooled Profit and Output Function Results

The results from both parts of our annual analysis already depict a clear time trend from the beginning of the 1990s until 2012. In this subsection, we divide our dataset into the three time periods identified in the introduction and pinpoint some of the differences that occur between the different periods. The results from our pooled profit and output regressions shown in Table 4 below are in line with the results from annual profit and output regressions, while presenting them in a more concise manner.

Our profit function estimates depict increasing underpayment for the factor labor over time. Our output data estimations confirm that this is due to sustained growth in the marginal product of labor that has outpaced wage growth across all sectors. Material inputs have been slightly underpaid at a roughly constant level during all periods in all sectors as was already evident from the annual analysis. On the contrary, capital is the only factor of production that has been slightly overpaid in all periods. Moreover, the degree of overpayment in the complete sample has been increasing most recently due to higher overpayment in the manufacturing sector, while capital has been slightly underpaid in the service sector.[17]

17 In order to deal with the effect of the large losses incurred during the global recession on our $\tilde{\alpha}_K$ adjustment shown in equation 14, we do not include the 2009 profit data in our calculation of average profits during the final period. The calculation of $\tilde{\alpha}_K$ is therefore based on profit data from the other nine years during the period.

Table 3: Labor Productivity Indicators and Wages over Time

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Complete sample										
APL	63288.9	75703.6	89855.1	95398.3	83867.7	92506.1	94522.9	97170.9	105731.5	88818.2
growth (%)		19.6	18.7	6.2	−12.1	10.3	2.2	2.8	8.8	−16.0
MPL	18806.8	26129.3	29060.9	36347.6	34296.0	38151.4	40614.9	44975.1	50256.6	46344.1
growth (%)		38.9	11.2	25.1	−5.6	11.2	6.5	10.7	11.7	−7.8
Wage	30938.9	32640.3	32857.2	33010.3	33158.2	34173.3	34755.3	36084.8	36936.2	37553.5
growth (%)		5.5	0.7	0.5	0.4	3.1	1.7	3.8	2.4	1.7
Observations	354	388	412	528	662	763	887	1031	1071	1116
Non-electronics manufacturing sector										
APL	71030.8	74291.3	87914.7	88530.2	78877.9	88115.7	86978.6	89759.5	87635.6	79639
growth (%)		4.6	18.3	0.7	−10.9	11.7	−1.3	3.2	−2.4	−9.1
MPL	25058.6	30064.7	32174.4	34335.1	30149.9	35100.4	35939.3	38954.5	41604.3	41470.6
growth (%)		20.0	7.0	6.7	−12.2	16.4	2.4	8.4	6.8	−0.3
Wage	31996.9	32367.0	32559.3	32779.1	32822.8	33741.7	34199.0	35263.1	35637.1	36004.1
growth (%)		1.2	0.6	0.7	0.1	2.8	1.4	3.1	1.1	1.0
Observations	228	236	246	316	365	397	430	459	468	469
Electronics manufacturing sector										
APL	48667.3	66041.8	76746.5	88461.5	81718.3	86933.7	94381.8	97513.3	103564.1	94603.8
growth (%)		35.7	16.2	15.3	−7.6	6.4	8.6	3.3	6.2	−8.7
MPL	5812.8	16214.3	25156.3	35339.3	37912.1	40602.5	43206.0	47774.3	49541.5	46600.9
growth (%)		178.9	55.1	40.5	7.3	7.1	6.4	10.6	3.7	−5.9
Wage	28604.5	30263.7	31199.5	31688.5	32272.7	33614.0	34531.3	36077	37416.7	38252.7
growth (%)		5.8	3.1	1.6	1.8	4.2	2.7	4.5	3.7	2.2
Observations	92	112	122	160	233	289	374	472	519	567
Service sector										
APL	67345.1	87360.4	82647.9	90364.4	94147.6	91021.2	106581.5	95396.7	119923.4	109611.5
growth (%)		29.7	−5.4	9.3	4.2	−3.3	17.1	−10.5	25.7	−8.6
MPL	37069.1	28907.8	22233.0	37736.4	39008.7	44028.4	42253.1	43453.5	66700.5	71188.7
growth (%)		−21.6	−23.1	69.7	3.4	12.9	−4.0	2.8	53.5	6.7
Wage	42365.9	42365.9	40511.3	39785.4	40007.7	40118.6	40217.3	41302.1	42223.6	42598.4
growth (%)		1.6	−4.4	−1.8	0.6	0.3	0.2	2.7	2.2	0.9
Observations	34	40	44	52	64	77	83	100	84	80

Notes: Marginal product of labor has been calculated as average of the results from the Olley and Pakes (1996) and Levinsohn and Petrin (2003) methods.

2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
107582.3	120002.8	131759.1	124548.0	140343.5	140982.1	119659.5	117801.6	138872.8	118519.3	115919.2
21.1	11.5	9.8	−5.5	12.7	0.5	−15.1	−1.6	17.9	−14.7	−2.2
56469.9	68289.0	71533.7	73842.0	84119.0	90470.8	80666.4	82542.6	97447.8	85761.8	85063.9
21.8	20.9	4.8	3.2	13.9	7.6	−10.8	2.3	18.1	−12.0	−0.8
38099.5	38794.4	38637.4	38642.7	39220.2	39194.2	38020.4	36354.6	37112.4	37076.1	37014.1
1.5	1.8	−0.4	0.0	1.5	−0.1	−3.0	−4.4	2.1	−0.1	−0.2
1190	1248	1226	1213	1221	1221	1229	1260	1290	1299	1284
96622.8	98626.5	112897.6	102153.8	111172.2	112052.2	99095.8	100075.2	114529.8	102884.5	99040.5
21.3	2.1	14.5	−9.5	8.8	0.8	−11.6	1.0	14.4	−10.2	−3.7
52915.3	57285.4	62335.8	59400.8	63501.9	66880.9	61351.7	61679.6	70854.5	62672.3	69182.3
27.6	8.3	8.8	−4.7	6.9	5.3	−8.3	0.5	14.9	−11.5	10.4
36098.8	36553.3	36542.4	36004.7	36262.3	35901.1	34634.7	33644.0	33973.5	33839.3	33665.1
0.3	1.3	0.0	−1.5	0.7	−1.0	−3.5	−2.9	1.0	−0.4	−0.5
482	493	489	489	488	490	495	507	522	540	542
112635.0	122388.3	130191.2	126396.7	139067.3	138084.8	124481.8	113890.2	137650.5	115921.1	117483.9
19.1	8.7	6.4	−2.9	10.0	−0.7	−9.9	−8.5	20.9	−15.8	1.3
53849.6	65720.6	66482.4	70979	81248.4	84761.5	79456.5	79812.1	94049.6	83149.6	87183.8
15.6	22.0	1.2	6.8	14.5	4.3	−6.3	0.4	17.8	−11.6	4.9
39201.0	40100.4	39931.5	40445.8	41318.3	41592.9	40381.6	38095	39255	39380.2	39468.3
2.5	2.3	−0.4	1.3	2.2	0.7	−2.9	−5.7	3	0.3	0.2
628	671	663	649	659	662	670	693	701	696	677
124434.6	115872.6	119681.6	111917.0	118644.1	119475.5	111231.5	128001.8	142448.1	140704.8	139969.5
13.5	−6.9	3.3	−6.5	6.0	0.7	−6.9	15.1	11.3	−1.2	−0.5
87054.8	84702.2	77659.2	80325.0	83744.3	88610.8	80818.5	86895.8	86685.8	100422.8	110310.6
22.3	−2.7	−8.3	3.4	4.3	5.8	−8.8	7.5	−0.2	15.8	9.8
42492.8	42355.5	41647.3	40668.4	40350.3	40016.2	40042.0	40311.3	39688.2	39518.3	39737.8
−0.2	−0.3	−1.7	−2.4	−0.8	−0.8	0.1	0.7	−1.5	−0.4	0.6
80	84	74	75	74	69	64	60	67	63	65

Table 4: Indicators Based on Pooled Regression Results

	1990–1993	1994–2002	2003–2012
Complete sample			
Labor underpayment	57.15*	120.07*	246.70*
Capital underpayment	−0.18*	−0.20*	−3.53*
Intermediates underpayment	0.04*	0.05*	0.04*
Observations	1368	6502	13681
R^2	0.33	0.76	0.77
Average product of labor	73919.29	105814.99	134517.64
Marginal product of labor	24649.71	48628.43	91689.44
Wage	31753.39	35786.10	38058.69
Observations	1229	6181	12861
Non-electronics manufacturing sector			
Labor underpayment	77.30*	194.94*	285.75*
Capital underpayment	−0.18*	−0.10*	−7.76*
Intermediates underpayment	0.04*	0.03*	0.05*
Observations	928	3182	5537
R^2	0.50	0.68	0.90
Average product of labor	73083.64	92575.75	118017.14
Marginal product of labor	27908.15	41407.50	68015.49
Wage	31537.85	34447.86	34945.49
Observations	805	3059	5260
Electronics manufacturing sector			
Labor underpayment	−9.45*	39.65*	128.09*
Capital underpayment	−0.05	−0.25	−0.87*
Intermediates underpayment	0.02*	0.03*	0.01*
Observations	319.00	2736.00	7369.00
R^2	0.66	0.52	0.90
Average product of labor	59755.24	108193.11	145510.82
Marginal product of labor	14911.13	49172.50	106828.40
Wage	29021.79	36066.66	39890.28
Observations	312	2568	6859
Service sector			
Labor underpayment	−62.65	77.89*	89.95*
Capital underpayment	−0.45	−0.22	1.87
Intermediates underpayment	0.08*	0.04	0.04*
Observations	108.00	489.00	614.00
R^2	0.11	0.33	0.52
Average product of labor	126451.51	163765.77	135313.97
Marginal product of labor	33284.37	84870.52	99766.58
Wage	41966.31	41385.51	40532.86
Observations	112	554	742

Notes: Under-/Overpayment estimates based on profit data; see equation (5). Significance at least at the 10% level is denoted by the * symbol. Marginal product estimates are based on output data; see equations (10) and (11). Wages have been calculated from industry-level data.

V. Results for Different Labor Groups

A. Results for Worker Groups by Educational Attainment

Low wages and stagnating wage growth for young workers have become an important labor market issue in recent years. We therefore further analyze to what extent different labor groups are affected by the incidence of underpayment as found above. For this part of our analysis, we make use of a supplementary staff composition data set that has also been collected by TEJ from annual company statements and is available only for the final decade of our study period. This supplementary data set contains information on the number of workers at different levels of educational attainment in the workforce of each company. The relevant information has been reported by most companies during the final decade of our analysis.[18]

In order to divide the staff into meaningful and sizeable subgroups, we split the workforce of each company into employees who have completed university education and those without university degree. It should be noted that university-educated workers are mostly from younger cohorts as a result of the recent expansion of higher education across the Taiwanese population, while the vast majority of workers without university education are from older cohorts.[19] In the following analysis, we refer to the group of workers who have completed university education as the high-education group and to workers whose highest degree is high school or less as the low-education group. For our profit function estimation we then estimate the following equation, which is analogous to equation 5:

$$\pi_{it}=\alpha_K K_{it}+\alpha_U U_{it}+\alpha_N N_{it}+\alpha_I I_{it}+\varepsilon_{it} \tag{15}$$

where U_{it} ("university degree") and N_{it} ("no university degree") are the number of workers from the high and low education group and α_U and α_N are the respective underpayment coefficients. We proceed to explain the details of our production function methodology for the final decade before jointly discussing both the profit

18 The educational attainment data are unavailable for 246 companies, hence reducing our dataset for the final decade to 1430 company observations.

19 Based on data from the most recent (2012) manpower utilization survey, 53.8% of workers with completed university education are 45 years of age or younger. 76.1% of workers without university education are from cohorts above 45 years of age. In our dataset, a 10% increase in the staff share with university education corresponds to a decrease in average staff age of 0.27 years at the company level.

and production data results.

In addition to our estimates of the difference between factor productivity and factor compensation obtained from an estimation of the equation above, we explicitly estimate the marginal product of labor and provide the sectoral development of total labor compensation as a unit of comparison. Since we focus on the final decade, we also pay attention to another issue which has gained importance in the most recent years: the rise of government mandated non-wage forms of worker compensation. During the past decade, the Taiwan government has introduced several reforms that have increased the level of pension premiums and labor insurance premiums paid by employees. Recent research on the pension system reform shows that such reforms can affect wages negatively via compensating wage differentials (Yang and Luoh, 2009). In addition to the wage levels calculated from the manpower utilization survey, we therefore also report the total level of labor compensation by adding payments of non-wage labor compensation paid by employers. We infer the level of non-wage labor compensation from the Employee Movement Survey available on the website of the national statistical authority.[20] For our production function estimation, we estimate the following regression, which is analogous to equation 12:

$$y_{it}=\beta_0+\beta_k k_{it}+\beta_u u_{it}+\beta_n n_{it}+\psi_{it}+\zeta_{it} \tag{16}$$

where u_{it} and n_{it} are the logarithm of the number of workers with and without university degree, respectively. The coefficients β_u and β_n are the respective output elasticities with respect to the two labor types.

The results of our profit and output regressions for different labor groups are as follows. According to the results of our profit regressions shown in Table 5, only university graduates have been consistently underpaid, while other workers have been mostly overpaid. In particular, workers with completed university education have been significantly underpaid in the most recent nine years included in our analysis. The coefficient for workers without university degree is negative in eight of the ten years and they have been significantly overpaid in two of these. This part of the analysis shows that workers with a university degree who are mostly from young cohorts are affected more severely by the incidence of underpayment.

Based on output regression results with different labor inputs displayed in Table 6, we confirm a large gap between the productivity of workers with university

20 The statistics for each year are available on the website of the Directorate-General of Budget, Accounting and Statistics, Executive Yuan, R.O.C. (Taiwan) (2014) at http://www.stat.gov.tw/np.asp?ctNode=1845.

Table 5: Final Decade: Annual Regression Results for Deviation of Factor Payments from Marginal Productivity

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Complete sample										
Labor (high educ.)	62.729	25.723*	433.608*	483.388*	625.585*	358.046*	435.280*	786.897*	601.165*	826.530*
Labor (low educ.)	−64.280	16.13*	−157.132	118.903	−125.394*	−153.266*	−58.243	−122.601	−61.673	−103.111
Capital	−0.444*	−0.258*	−0.504*	−0.563	−0.786*	0.546	−1.105*	−1.276*	−0.170*	0.441*
Intermediates	0.048*	0.057*	0.028*	0.026*	0.020*	0.062*	0.042*	0.018*	0.021*	0.045*
Observations	971	1038	1055	1086	1119	1117	1130	1167	1182	1169
R^2	0.657	0.846	0.819	0.837	0.996	0.872	0.703	0.973	0.980	0.892
Non-electronics manufacturing sector										
Labor (high educ.)	678.006*	551.294*	1329.819*	1122.614*	503.803*	751.642*	390.360*	592.167*	560.701	499.415*
Labor (low educ.)	−36.439	229.314	61.827	−203.031	59.454	−95.453	11.429	54.715	−70.526	259.802
Capital	−0.247	−0.378*	−0.392*	0.038	−0.121*	1.138	−0.326*	−0.329	−0.313	1.847*
Intermediates	0.052*	0.057*	0.038*	0.030*	0.033*	0.051*	0.043*	0.024*	0.016	0.015*
Observations	417	436	437	447	452	460	468	477	496	501
R^2	0.859	0.899	0.697	0.588	0.330	0.930	0.694	0.772	0.616	0.894
Electronics manufacturing sector										
Labor (high educ.)	−64.624*	86.696*	505.083*	339.231*	642.711*	715.721*	441.935*	854.410*	852.263*	630.486*
Labor (low educ.)	10.392	−194.068*	−66.506	83.017*	−167.525*	66.018	−401.741*	−391.126*	229.143*	225.951
Capital	−0.574*	−0.675*	−0.886*	−1.120*	−1.519*	−0.597	−1.813*	−2.077*	−0.024*	−0.714*
Intermediates	0.043*	0.029*	0.038*	0.034*	0.063*	0.014*	0.079*	0.036*	0.044*	0.000
Observations	504	550	568	586	614	611	622	648	642	622
R^2	0.745	0.705	0.664	0.881	0.913	0.800	0.971	0.946	0.980	0.985
Service sector										
Labor (high educ.)	400.904*	558.271*	549.220*	396.884*	813.130*	249.714	591.116*	1084.886*	42.266*	80.008*
Labor (low educ.)	270.760*	119.233	212.138*	52.344	55.183*	−392.539	−86.966	−206.414	227.537*	−101.777
Capital	−0.407*	5.955	3.741*	1.528*	3.228*	10.749*	0.762*	1.117*	−0.214*	−0.025*
Intermediates	0.063*	−0.249*	−0.455	−0.244	−0.178*	0.261	−0.383	0.544*	0.148*	−0.072
Observations	50	52	50	53	53	46	40	42	44	46
R^2	0.866	0.794	0.510	0.817	0.904	0.931	0.944	0.891	0.964	0.971

Notes: Estimation results are based on equation 15. The symbol * denotes significance at least at the 10% level.

Table 6: Final Decade: Productivity and Wages by Labor Type

	2004	2005	2006	2007	2008	2009	2010	2011	2012
Complete sample									
Workers with university degree									
APL	249721.5	217174.4	225027.2	219575.2	189481.6	192510.8	221791.5	190735.4	184453.3
MPL	138762.0	112081.9	126587.0	131409.0	113251.0	108583.8	131886.6	108783.7	108970.1
Wage	46260.4	44681.3	44356.4	42629.3	42500.6	41606.8	41983.7	41560.4	39735.6
Total compensation	52531.4	51076.3	51687.7	49332.2	49755.1	49345.4	48902.0	48627.2	45921.9
Workers without university degree									
APL	569619.8	639827.4	815512.0	915231.8	935837.2	1106696.0	1282702.0	1004795.0	1231984.0
MPL	32642.2	30195.4	41631.5	36795.3	39715.1	52352.3	42157.9	40716.8	54750.8
Wage	32691.9	32634.8	31688.8	31515.8	31076.1	30659.6	30196.8	29878.4	29164.7
Total compensation	37116.8	37301.9	36917.4	36461.3	36373.5	36356.8	35169.4	34953.4	33703.2
Observations	1033	1055	1086	1119	1117	1130	1167	1182	1169
Non-electronics manufacturing sector									
Workers with university degree									
APL	386405.7	300888.1	313988.0	300469.6	212204.8	235571.3	276323.3	237077.4	205816.2
MPL	158896.8	133611.3	148246.3	149878.8	106310.6	108115.8	123088.0	102743.8	85541.2
Wage	45673.1	45309.4	43955.3	42523.3	41381.6	40640.7	41386.3	40994.5	37799.0
Total compensation	51936.7	51841.4	51289.7	49273.8	48513.1	48266.9	48235.8	48002.9	43698.3
Workers without university degree									
APL	456847.9	419306.9	435554.3	485334.3	457358.3	567990.9	780423.4	805626.6	1061589.0
MPL	43000.2	33671.6	40456.8	35777.0	26211.1	21608.7	20631.2	24974.1	18445.6
Wage	36089.8	36784.3	34829.5	33731.0	33320.4	32667.7	31701.7	31889.7	30529.7
Total compensation	41039.1	42087.3	40641.1	39085.8	39062.6	38797.8	36948.3	37341.6	35294.5
Observations	435	437	447	452	460	468	477	496	501

Table 6: Final Decade: Productivity and Wages by Labor Type (continued)

	2004	2005	2006	2007	2008	2009	2010	2011	2012
Electronics manufacturing sector									
Workers with university degree									
APL	171620.7	166417.4	173726.0	180636.3	154411.3	157083.3	197679.9	150177.3	160133.9
MPL	108874.4	92644.0	100542.5	109727.6	100540.7	93988.6	118279.3	97096.9	108397.0
Wage	47031.6	44527.9	45105.4	42361.5	43291.7	42502.6	42472.9	42137.1	41445.9
Total compensation	53481.5	50947.2	52631.7	49086.3	50752.2	50478.2	49502.2	49340.8	47914.4
Workers without university degree									
APL	1492257.0	1762958.4	2011628.6	2136690.3	2383698.3	2938036.8	3023479.3	2444467.0	2673174.0
MPL	21486.3	26226.4	38870.1	34945.2	38752.6	37397.9	31962.4	31740.3	43989.0
Wage	29833.4	29390.6	29200.4	29015.3	28999.1	29080.4	28837.0	28069.9	27827.4
Total compensation	33924.7	33627.7	34072.8	33621.5	33996.6	34537.3	33609.6	32868.7	32170.4
Observations	548	568	586	614	611	622	648	642	622
Service sector									
Workers with university degree									
APL	236570.1	215435.9	229360.4	207596.0	185110.4	206358.5	245462.8	209876.8	201412.9
MPL	149238.7	118206.7	134615.7	149628.0	141637.8	160514.5	178355.8	171833.4	177028.8
Wage	42940.4	40875.1	39384.3	46777.4	43317.3	38891.5	41228.9	39426.3	37423.2
Total compensation	47317.3	45772.8	44502.0	52796.2	49056.9	44144.8	47172.7	45110.2	42867.4
Workers without university degree									
APL	1281589.1	941688.8	2420386.8	2638595.3	1831800.4	1941403.3	2644793.8	2575812.0	2519360.0
MPL	42206.3	42988.4	35750.9	41807.8	33633.4	55094.1	91143.1	47259.6	63162.8
Wage	34323.1	33205.8	33012.4	41840.4	36049.8	31671.9	34166.0	33851.7	32630.9
Total compensation	37821.6	37184.5	37302.2	47223.9	40826.5	35950.0	39091.5	38731.9	37377.9
Observations	50	50	53	53	46	40	42	44	46

Notes: Marginal product of labor has been calculated as average of the results from the Olley and Levinsohn methods. Total compensation refers to the sum of wages and social security contributions paid by employers. Our output regression variables have been winsorized at the outlying 2%.

degree and workers whose highest educational attainment is high school.[21] Moreover, the differences in productivity between the two labor groups exceed the wage differential between the two types of workers. The low education group has been overpaid twice and has been underpaid to a lesser extent than the high education group in all other years.

B. Results by Staff Age and Tenure Length

In the final part of this analysis, we investigate the degree of the deviation of labor compensation from the marginal product of labor by staff structure. To this end, we make use of information about the average age and the average tenure length of a company's workforce, which is also included in the staff composition data set employed in this section. For both of these variables, we compare the results for companies located between the 1st and the 25th percentile to those located between the 75th and the 99th percentile of the annual distribution for company level average staff age and average tenure length.[22] For the average age, this corresponds to company level average ages between 27.0 and 32.8 years in the young group compared to 38.1 and 48.0 in the old group. The respective ranges for short tenure and long tenure are between 0.8 and 3.3 compared to 7.3 and 18.4 years.

The results for our productivity gap estimations by staff structure are displayed in Table 7. Several insights can be gained from this part of the analysis. The first is that the degree of labor underpayment is higher in companies with a young workforce, and the lowest underpayment occurs for the company group with an old workforce and long average tenure. The short and long tenure groups are similar in terms of the size of total labor underpayment. The effect of tenure largely works towards the difference between the remuneration-productivity gap between high-skilled and low-skilled workers. In particular, low-skilled workers are paid above their marginal product of labor in companies with an older workforce and long tenure structure. The overpayment is highest in companies that possess both of these characteristics. This finding is similar to Huang (2011), who finds that work

21 For some of the annual regressions in this section, we initially found negative marginal products of labor for the low education group in some firms. When this was the case, we resorted to alternative estimation methods. For example, if the results of the LP method were negative, we calculated marginal products based on the OP method. If the OP method returned negative coefficients, we employed the SF method, and if these were negative we resorted to the first-differenced estimation results.

22 We exclude the extreme percentiles at both ends in order to avoid the effects of idiosyncratic outliers.

Table 7: Productivity Gaps for Each Factor of Production by Staff Structure

	Young staff	Old staff	Short tenure	Long tenure	Young staff & short tenure	Old staff & long tenure
Factor underpayments						
Labor	266.583*	137.469*	211.021*	236.867*	208.527*	125.890*
High educ.	583.230*	406.850*	408.492*	606.093*	351.455*	567.009*
Low educ.	−17.257*	−12.847	57.160	−43.079	108.572*	−164.543
Capital	−0.844*	0.224	−0.549*	0.442	−0.949*	0.886
Intermediates	0.010*	0.043*	0.098*	0.046*	0.016*	0.047*
Observations	2721	2496	2388	2719	1390	1747
R^2	0.806	0.614	0.904	0.668	0.595	0.604
Marginal products by labor group						
Labor	1105.272	1029.338	1254.534	951.973	1137.296	960.749
High educ.	1665.148	2026.794	1756.037	1964.039	1673.965	2042.298
Low educ.	653.182	365.173	838.630	332.610	874.837	352.126
Observations	2691	2482	2701	2365	1381	1735

Notes: The symbol * denotes significance at the 1% level. Our output regression variables have been winsorized at the outlying 2%.

experience is an important determinant of wages for low-skilled workers in Taiwan. Regarding the two other factors of production, capital owners are more able to divert rents in companies with a young workforce and short tenure structure, while the age effect is the larger one of the two. As in other parts of our analysis, the productivity-remuneration gap for intermediate inputs is small and similar across the different company groups.

VI. Conclusions and Discussion

In this paper, we analyze whether the recent decline in Taiwanese wage growth coincides with a drop in the marginal product of labor and changes in the distribution of rents between labor and capital over time. We first identify three distinct periods of wage growth: (1) rapid growth before 1994, (2) moderate growth between 1994 and 2001, and (3) stagnating wage growth since 2002. We then estimate profit regressions and production functions for Taiwanese publicly listed companies beginning from the early 1990s until 2012 in order to identify changes in the relationship between the marginal product of labor and labor compensation over time. Based on both methodologies, we find an increasing gap between the marginal product of labor and wages, implying that Taiwanese workers are increasingly underpaid. This is in contrast to the results in recent work by Biewen and Weiser (2014), who were the first to propose the profit function methodology employed in this study and applied it to the liberal market economy of Chile for the time span from 2001 until 2006. In their study, the authors find modest and often insignificant deviations of labor compensation from the marginal product of labor. Small and significant overpayment of the factor capital and small and significant underpayment of material inputs found in the current study, however, are similar to their previous results.

The most striking difference between the two economies lies in the results for the production factor labor. We therefore discuss some of the possible causes for the increasing wedge that has emerged between the productivity and compensation levels of Taiwanese workers. The results of our analysis are generally compatible with models of a monopsonistic labor market in which the wage elasticity of the labor supply curve faced by an employer is less than perfectly elastic. In this case, the employer can exert market power over workers and reap rents by pricing above marginal cost. Some of the reasons for the existence of employer monopsony power discussed in the literature include efficiency wages, moving costs and heterogeneous worker preferences (Boal and Ransom, 1997; Bhaskar et al., 2002; Manning, 2003). Since the discrepancy between worker remuneration and marginal productivity has emerged during the past two decades, an increase in employer monopsony power over time is a feasible explanation for this trend. The classification system for different product and labor market regimes proposed by Dobbelaere and Mairesse (2013) may serve as a framework to uncover the link between monopsony power and labor underpayment in Taiwan. Another potential cause of the increasing gap between productivity and compensation levels are changes in the institutional environment during the past decades, such as due to the introduction of the Labor Standards Law in combination with the Labor Inspection Law from 1993. Previous work on these regulations has found a negative effect on wages for affected groups of workers in Taiwan (Lai and Masters, 2005; Lin, 2013).

As we have seen in the final chapter of our analysis, university graduates are the main staff group affected by the gap between compensation and marginal productivity, while the gap is often insignificant or even positive for workers from predominantly older cohorts whose highest educational attainment is a high-school degree. In addition, our results for different labor groups by company staff structure also indicate that labor underpayment is higher in companies with a young workforce and that it is easier for capital owners to divert rents in these companies. Employers thus appear to be able to exert higher monopsony power towards certain labor groups. Future research should aim to analyze the conditions under which employers can exert monopsony power towards different labor groups in Taiwan in order to identify other factors behind the trends uncovered in this study.

Appendix

Table A: Comparison of β_l-coefficients for Different Estimation Methods

Year	OLS	DIF	SF	OP	LP
1992	0.552	0.939	0.459	0.257	0.315
1993	0.518	0.615	0.490	0.282	0.374
1994	0.549	0.634	0.490	0.285	0.369
1995	0.551	0.811	0.494	0.351	0.394
1996	0.677	0.902	0.625	0.355	0.418
1997	0.669	0.881	0.589	0.367	0.418
1998	0.828	0.937	0.678	0.401	0.425
1999	0.828	1.013	0.645	0.432	0.447
2000	0.825	1.184	0.641	0.455	0.452
2001	0.926	0.757	0.787	0.481	0.498
2002	0.914	1.056	0.754	0.504	0.528
2003	0.907	0.999	0.807	0.552	0.582
2004	0.892	1.004	0.795	0.553	0.558
2005	0.902	0.861	0.872	0.583	0.626
2006	0.964	0.891	0.893	0.596	0.659
2007	0.932	1.202	0.895	0.625	0.714
2008	0.987	0.821	0.928	0.657	0.717
2009	0.967	1.350	0.970	0.673	0.761
2010	0.949	0.977	0.933	0.682	0.754
2011	0.977	0.767	0.951	0.693	0.769
2012	0.954	0.831	0.963	0.680	0.759

Notes: Estimation results are based on equation 12. The column entitled OLS displays the results of an ordinary least squares estimation of the equation and the DIF-column displays the results of an ordinary least squares estimation of the first-differenced equation. The SF-column shows the results of a stochastic frontier model with firm-specific inefficiency, while OP refers to the Olley-Pakes method and LP refers to the Levinsohn-Petrin method.

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臺灣勞工是否處於低度回饋？基於企業面的勞動邊際產量估計之證據

侯杜比
北京大學國家發展研究院博士後研究員

辛炳隆
國立臺灣大學國家發展研究所副教授

摘　　要

爲研究臺灣勞工是否處於低度回饋狀況問題，本文運用臺灣上市櫃公司企業利潤與產值數據估計勞動邊際產量與勞動報酬之間的差距。本研究發現，無論是用利潤或產值數據進行分析，近幾年確實出現勞動邊際生產力與勞動報酬之間的落差，且三種生產要素中，惟有勞動持續處於報酬過低。相反地，資本的邊際產量與報酬之間的差異則爲負值，並隨著時間而增加，尤其是在近十年之製造業樣本中。此外，我們進一步發現勞動低度回饋情形在屬於較年輕世代之大學畢業生相對嚴重，其在員工結構比較年輕的企業中更大，且該子樣本中分配給資本之租金則較高。

關鍵字：勞動邊際生產力、工資、生產要素報酬、低度回饋

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